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Executive summary

The Working Group on Fishery Systems [WGFS] meeting took place in three steps. First experts from outside of fisheries made presentations about handling uncertainty, ambiguity and complexity in the science policy interface. On the second day presentations were made by fisheries experts. The third day was a workshop in which the discussions from the two days were summarized with an emphasis on the two themes suggested by the ToRs.

Scientific advice under conditions of high stakes and high uncertainty is made more effective through a process of interaction that the workshop referred to most often as extended peer review (EPR) within an extended peer community (EPC). This EPR increases the factors of legitimacy, saliency and credibility that are important determinants of scientific influence on policy. ICES has for a long time more or less self-consciously operated within an EPC made up of scientifically literate clients who request advice and provide feedback. The EPC that centres on ICES is changing and this requires greater and more intentional awareness of these processes in order to maintain scientific credibility in the fact of these changes. These changes include, *inter alia*, new demands for "transparency" from clients and others, increased media interest in fisheries and marine issues, and the advent of the Regional Advisory Councils with their current somewhat ambiguous role in the production of management advice.

The WGFS meeting focused on what research has demonstrated about the institutions, processes and methods for effective EPR. These processes can only proceed with support from decision makers. Procedurally, it is valuable to orchestrate a careful marriage of process and analysis, share information widely rather strategically, and solicit broad, cross-disciplinary review. It is important to differentiate stage-specific functions of stakeholder and public involvement for a meaningful and efficient EPC. The process should be appropriately designed to address both levels of both scientific uncertainty and the socio-political ambiguity.

Under some circumstances the general public plays a critical role. Expert voices can be critical for maintaining also employed in expressing social cohesion, social identity and shared beliefs in addressing an uncertainties and risks. All societies, both traditional and modern, face choices and decisions about how to confront uncertainty. The associated risk has been a pervading issue throughout history. Attempts to understand, regulate and manage risk have only been only partly successful. The number of and complexity of risk issues will increase so long as populations continue to expand in size, density and technological dependence. There is a role here for social scientists to improve risk communication between stakeholders in order to improve the resilience of both industry and environmental concerns. Understanding the cultural context of the stakeholder roles and perceptions of risk among these groups is a key to achieving this.

The WGFS produced a number of methodological recommendations for engaging an extended peer community. An ideal extended peer review (EPR) would be an iterative process beginning with goal setting followed by a step by step process of clarifying assumptions and their implications. This would require from the scientists involved that along with specific findings for the advice they also prepare a detailed uncertainty assessment to prepare the groundwork for a pedigree matrix (Section 3.3.1) as well as a sensitivity analysis to evaluate how assumptions and model specifications affect the conclusions.

The EPR process should have a relatively broad analytical scope. It is more effective to develop the arguments inductively from data rather than deductively from theory. The present values components of the analysis need to be actively and intentionally managed. Technical insights need to be translated into interesting, generally relevant stories understandable by scientists from different disciplines, policy experts and, where relevant, the lay public.

Differentiating and grasping the characteristics of the actual uncertainty, the system complexity and the political ambiguities are critical. It can be helpful to "map" the uncertainty that exists in respect to a policy problem. One method for doing this first divides the uncertainty into three categories: *location, level and nature*. The uncertainty *location* refers to the sources of uncertainty and the resulting uncertainty in model outcomes. This may include the context the uncertainty is found in and the relevance of the uncertainty to the policy problem. Are we asking the right questions in relation to a certain policy problem? The second dimension is the level of uncertainty: is statistical uncertainty a sufficient representation, or does the uncertainty require scenario representation. And in some cases and situations there may be recognized ignorance or unpredictable human behaviour. The third dimension, the *nature* of uncertainty, is divided into *epistemic uncertainty* and *variability*. The intention of this category is to be aware of different nature of uncertainty regarding whether it reducible or irreducible. It is important to note that both categories can be associated with irreducible uncertainty.

Another uncertainty assessment tool is pedigree analysis. It can provide a graphical tool that can help scientists explain what processes have not been considered in the scientific analysis and provide a quick outlook of how much we know. Another important piece of information is the progress that has been done in terms of reducing uncertainty in each aspect of the system of interest. Maturity charts are often used in technology road-mapping to describe past, current, and future capabilities in terms of achieving a specific goal.

Managing uncertainty can also be linked to building the participatory capacity and scientific literacy of certain public groups, notably fishers. This is being done more and more widely through the joint creation of science / policy "boundary objects" such as the products of collaborative research projects and participatory scenario modelling with stakeholders and policy-makers. Through participation, fishermen are seen learning and gaining expertise about scientific concepts (sampling, standardization, data collection, consistency) and language. They gain scientific skills such as data recording, measurement, tagging, and data entry. This learning facilitates their meaningful participation in the EPC. Bayesian methods were also discussed widely in the WGFS meeting and the group felt that are a particularly promising approach to participatory modelling with an extended peer community in areas of high uncertainty.

In dealing with areas of high stakes and high uncertainty scientists need to be ready to play many roles, some less traditional than others. Scientists play multiple roles in society: professional, political, personal. So the ethical question is one of balancing and distinguishing which role one is playing at a given moment, and hence it is appropriate to reflect before acting. In cases of high uncertainty, scientists must make many assumptions in order to deliver "answers" to policymakers. Their work products should allow reviewers to view key assumptions, and should discuss the sensitivity of the findings to those assumptions. Some scientists should be actively involved in critiquing existing management systems to ensure that those systems evolve with our evolving knowledge.

The shifts required of ICES in respect to its changing EPC are not easy, particularly in light of the ecosystem approach and the greater number of clients and stakeholders who will be affected by advice. In an EPC the extension of the review process can be costly. Some of these costs are readily apparent, especially the transaction costs of more review demands when the current review system within ICES is strained. Other costs are less obvious. How to review innovative approaches in general is an issue in a complex management system. An extended review process will make this even more difficult because the questions of the policy saliency of the innovation are raised immediately, even prematurely.

Finally, unless we understand the extended peer community as part of an overall approach to management then the transaction costs will become overwhelming whereas the benefits of increased saliency and legitimacy will be lost. The WGFS suggests that the emerging (in fisheries at least) institutional process called "results based management" with a reversed burden of proof would be the appropriate institutional context for further developing the EPC around the ICES Advisory Programme.

1 Opening of the meeting

The meeting opened at 13:00 on 13 October, 2008 with a tour de table.

2 Adoption of the agenda

The agenda outlined in Annex Two was proposed and adopted.

3 Report of the 2008 Meeting

3.1 Terms of Reference

The ToRs for the 2008 WGFS meeting were as follows:

- engage with experts from outside of fisheries to review how uncertainty, complexity and ambiguity are addressed in related policy regimes. This review will inform tool development, the design of adequate participation procedures and comparative research on approaches being used in fisheries;
- assess forms of quality control and external accountability for participatory approaches to making decisions about the fisheries knowledge base in terms of both tools and practices. The objective of this is to begin to identify appropriate mechanisms and practices for facilitating extended peer review of the growing number of stakeholder driven scientific fora appearing in European fisheries using quantitative and qualitative assessments of uncertainties.

To meet these ToRs the meeting took place in three steps. First the experts from outside of fisheries made their presentations and these presentations were discussed by the whole group. On the second day presentations were made by fisheries experts and discussed by the group. The third day was a workshop in which the discussions from the two days were summarized with an emphasis on the two themes suggested by the ToRs: how uncertainty, complexity and ambiguity are best addressed in policy regimes; and, the forms of quality control and external accountability for participatory approaches to making decisions about the fisheries.

The following report follows these three steps. The first section is summaries of the presentations of experts working outside of fisheries. The second is summaries of the presentations of the fisheries experts. The third section reports on the results of the workshop.

3.2 Summaries of Presentations by Non-fisheries experts

3.2.1 Summary of Talk on Joint Fact-Finding

Clinton Andrews, Rutgers University, New Jersey, USA

Those who design decision processes have been busy in recent years. Management gurus have focused on the importance of team building, and companies worldwide have flattened their administrative structures and decentralized decision-making authority. The reigning metaphor is that of cooperative problem solving rather than rigid hierarchy. Policymakers have likewise developed more participatory, decentralized approaches for designing, implementing, and evaluating governmental programs. At the macro level this has appeared as "discursive democracy," featuring fireside chats, call-in talk shows, electronic town meetings, and frequent polls. At the micro level, planners have relied extensively on citizen advisory groups, regulators on public hearings, and evaluators on bottom-up input. Government officials now work hard to identify their stakeholders and satisfy their "customers".

These procedural innovations are placing new demands on technical analysts. Modellers no longer merely serve a single executive; instead they speak to decision-making teams and diverse stakeholder groups. Well-known, powerful analytical techniques like benefit-cost analysis and risk assessment run into credibility problems in this new context. The superstructure of assumptions supporting these techniques may not be broadly accepted or understood, the goals of the participants may conflict, and different perceptions of the problem being studied may coexist. It may even be necessary to overcome a residual of distrust based on previous unsatisfactory interactions. What should quantitative analysts do differently to succeed in this new context?

This presentation explored the practical challenges of working as a technical analyst in a highly communicative, joint fact-finding context. It used case studies to illustrate the challenges and the range of responses. A typology of contexts organized the cases-single or multiple decision-makers and elite or mixed participation in the analysis. The cases included advising a single executive (economic advice to the President), persuading multiple decision-makers (jury trial), producing non-partisan policy analysis (US Congressional Office of Technology Assessment), involving the public in priority-setting (state-level comparative environmental risk projects), and performing joint fact-finding with multiple decision-makers (regional electric power planning). Introductory and concluding sections linked the cases to broader conceptual debates about the social construction of knowledge in public settings.

Key practical lessons from the case studies include institutional, procedural, and methodological factors. The major institutional insight is that joint fact-finding can only proceed with support from decision makers. Procedurally, it is valuable to orchestrate a careful marriage of process and analysis, share information widely rather strategically, and solicit broad, cross-disciplinary review. Methodological recommendations are to pursue a relatively broad analytical scope, argue inductively from data rather than deductively from theory, actively manage the inevitably present values components of analysis, and translate technical insights into interesting, generally relevant stories understandable by a lay person.

3.2.2 Uncertainty in the Science-Policy Interface

Dr Jeroen P. van der Sluijs, Utrecht University, the Netherlands

The lecture started with introducing three fundamentally different understandings of uncertainty in knowledge in the science-society interface: the deficit view, the 'evidence evaluation view' and the 'complex systems / post-normal view'. Within the **deficit view**, uncertainty is considered to be a deficit of our knowledge. Uncertainty is seen as a temporary problem that will disappear if more objective research will be performed. In this view, management of uncertainty equals reduction of uncertainty and there is a strong belief that science is ultimately able to provide certainty. One tendency typically seen to achieve this is the production of ever more complex and detailed models, and calculation is seen as key to truth. The techniques applied include Monte Carlo, Bayesian belief networks and other quantification techniques. The pitfall of this paradigm is that a false certainty is created, because the numbers obtained from these models suggest more knowledge than there actually is.

The second view, **evidence evaluation view**, considers uncertainty to be a problematic lack of unequivocalness. When science speaks with multiple voices to policy, conflicting certainties may emerge. The solution proposed is a comparative evaluation of individual research results, focused on building scientific consensus. The focus shifts from establishing certainty to evaluation of evidence to establish gradations of certainty. Multidisciplinary expert panels such as the Intergovernmental Panel on Climate Change (IPCC) have been established for this purpose. This approach focuses on generating robust conclusions and widely shared interpretations of the available limited knowledge. The pitfall of this paradigm is that matters on which no consensus can be reached continue to receive too little attention, whereas, in fact, this dissension is often highly policy-relevant. One example is that in the first assessment report of the IPCC very little attention was given to non linear climate risks such as a possible shut down of the ocean circulation or a collapse of the West Antarctic Ice Sheet. There were (and still are) only weak signals that such scenario's may occur but it was impossible to reach any consensus interpretation of these weak signals of early warning (see also Patt, 1999).

The third view is the 'complex systems view / post-normal view'. It sees uncertainty as intrinsic to complex systems and as a fact of life. It further emphasizes that uncertainty also results from the very way by which knowledge is produced. For instance, the use of computer simulation models, scenario's and extrapolations all critically depend on the validity of the assumptions that unavoidably need to be made. Most of such assumptions can in principle not be validated. The post normal view acknowledges that not all uncertainties can be quantified and that in most complex issues unquantifiable uncertainties are more relevant and salient than the little bit where we have enough knowledge to quantify uncertainty in a reliable way. It calls for an approach that openly deals with deeper dimensions of uncertainty, such as those stemming from problem framing, choice of system boundaries, indeterminacy, ignorance, assumptions, value loadings, underdetermination (the same data allow for several interpretations and conclusions), and even institutional dimensions. This corresponds to a more qualitative and reflective approach to uncertainty. Techniques that are applied to deal with this are Knowledge Quality Assessment and risk management (including production of knowledge) as a deliberative (participative) social process. The pitfall of this paradigm is that uncertainty is highlighted to such an extent that we may forget how much we actually do know about the risk concerned and on which aspects there is, in fact, consensus.

Next, the phenomenon of uncertainty was explored using a **"monster" metaphor** (van der Sluijs, 2005), borrowed from Dr Martijntje Smits, to explore the way in which the scientific community responds to the monstrous uncertainties that they face in the production of the knowledgebase of complex environmental problems. The idea is that we are accustomed to order the world in terms of binary categories such as humans vs. animals, organisms vs. machines. Such categories shape a symbolical reconstruction of worldly phenomena. A special case of confusion appears when at the same moment a phenomenon fits into two categories that were considered to be mutually excluding. Such ambiguous phenomena are experienced as a monster.

When we apply the monster concept to the production of a knowledgebase for policy-making on complex environmental problems we can make a number of interesting observations. The categories that we thought to be mutually exclusive and that now tends to get increasingly mixed up to create monsters in the science-policy interface include: knowledge vs. ignorance, objective vs. subjective, facts vs. values, prediction vs. speculation, and science vs. policy. Smits distinguishes four styles of 'monster-treatment' with different degrees of tolerance towards the abnormal. These styles are: monster-exorcism, monster-adaptation, monster-embracement and finally monster-assimilation.

Monster-Exorcists want to expel the monster. Uncertainty causes discomfort and does not fit within symbolical order where science is seen as the producer of authoritative objective knowledge. They call for more objective research that should aim at "reducing uncertainties". There is a strong believe in "objective science": the puzzle can be solved. This view can be found in for instance the first scientific assessment of climate change by the IPCC: "We are confident that the uncertainties can be reduced by further research" (Houghton *et al.*, 1990). The borders between facts and values, knowledge and ignorance, science and policy are seen as real and inflexible and often the categories are also seen as norms (as in the notion that is a good thing to keep science and policy, facts and values, objective and subjective separated). Yet monster-theory predicts these attempts will prove to be vain in the long run: for each head of the uncertainty monster that science chops off, several new monster heads tend to pop up as a result of unforeseen complexities. It is interesting to see that for that reason, the IGBP (International Geosphere Biosphere Programme), one of the largest international research programmes on global change, concluded during their third Scientific Advisory Council Meeting in January 1993, that it might not be feasible to reduce uncertainties (Williamson, 1994). Williamson also notes that the increasing complexity of global models inevitably decreases the precision of their products and "full predictability of the earth system is almost certainly unattainable." He makes a case for the replacement of the research objective to reduce uncertainties by a pragmatic research goal to "provide reliable estimates of probability within defined limits, so that risks can be assessed and appropriate actions taken, rather than single value 'predictions' with spurious exactitude."

The **Monster Adaptation** style attempts to fit the uncertainty monster back in the categories, a process that can be characterized as purification. In terms of taming the uncertainty monster this can be seen as attempts to quantify uncertainties. Monster adapters feel uncomfortable with anything that does not fit in a spreadsheet. They need numbers, for otherwise they cannot do their calculations that they deem to be the basis of rational decision support. Where there is no objective ground for quantification, monster adapters tend to use subjective probability and Bayesian approaches to quantify uncertainties in terms of the degrees of belief that experts assign to their knowledge claims. By normalizing the post normal along these lines, the classic paradigms of Decision Support striving for optimization of expected utility as rational risk management strategy can be maintained. Monster adaptation by purification is further evident in the tendency to build system models based on "objective science" and then to externalise the subjective parts and uncertainties into ranges of scenario's – grouped into story-lines representing different value orientations – that are used to feed these "objective" models. The model is then seen as grounded in science and belongs to the domain of the scientists. Policymakers and stakeholders are welcome to contribute their insights, but in the scenario's that feed into the models, not in the science of the models itself. The limitations of the purification, or monster adaptation approaches are obvious in the many critiques of the models. The IPCC Special Report on Emission Scenarios clearly shows that different models fed with the same scenarios produce very different results. This reflects the significance of model structure uncertainties. Further, several authors have displayed that current models are not as objective as they claim to be: they contain many value-laden assumptions and stem from value laden problem framings (see for overviews for instance Van der Sluijs, 1997, 2002).

The third response, **Monster Embracement** welcomes the uncertainty and can perhaps be associated with fascination about the unfathomable complexity of our living planet Gaia. It creates the possibility to be filled with wonder and respect, something that was taken away by the engineering worldview in which science is able to understand and control nature, reflected in notions seeing the biosphere as something that can be managed. The schools of thought of Holism and attempts to integrate science and spirituality in Inclusive Science (Ken Wilber) can also be considered as embracing uncertainty, because it emphasizes the limits of the positivist reductionist schools of thought for which they provide alternatives.

Another type of response to monstrous uncertainty that can be seen as monster embracement is denial of the reality of environmental risks by pointing to all those uncertainties. A variety of techniques is used to deliberately raise doubts about the realness of environmental risks, such as distortion and magnification of uncertainties (making mountains out of molehills), and even acts "at variance with good scientific practise" (as recently the Danish Committee on Scientific Dishonesty qualified some of the things Lomborg did in his book The sceptical environmentalist). The unpleasant way in which such games are played and the mixture of valid and ungrounded criticisms that it produces is the price that has to be paid for the identification of weak spots in the knowledge base by those who have a strong incentive and drive to find these weak spots.

The fourth strategy, **Monster Assimilation** refers to not only adapting the monster, but also changing the cultural categories by which it is judged. In contrast to the other styles monster-assimilation makes use of the insight that cultural categories are flexible and constructible. In other styles, the uncertainty monster is somehow judged in terms of existing cultural categories and these cultural categories are in turn considered more or less as facts. Rethinking the categories that got mixed up in the monsters is at the core of the monster assimilation strategy. Post-normal science and other forms of reflexive science are clear instances of attempts to assimilate the uncertainty monster and give it a central and explicit place in a deliberative management of environmental risks. Because scientific consensus about the truth of complex environmental risks is unlikely to be achieved given the post-normal situation (facts uncertain, values in dispute, high decision stakes), we will have to drop our demand for a single certain truth and strive instead for transparency of the various positions and learn to live with ambiguity and pluralism in risk assessment.

Each of the four styles can be observed in the historical learning process and current practise of coping with the uncertainty monster in the science policy interface on complex environmental problems. We might see this ongoing process of learning to cope with complex systems as a dialectic process where one strategy tends to dominate the field until it fails followed by a rise of one of the other strategies. As evident in UPEM, we now seem to find ourselves in a phase with a growing focus on monster assimilation.

Finally the lecture briefly reviewed various tools for Knowledge Quality Assessment, (KQA), including the MNP guidance for uncertainty assessment and communication (Van der Sluijs *et al.*, 2008), the NUSAP system (Van der Sluijs *et al.*, 2005), the model quality checklist (Risbey *et al.*, 2005), and good practise for uncertainty communication (Wardekker *et al.*, 2008; Kloprogge *et al.*, 2007).

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3.2.3 Expertise in media

Lars Kjerulf Petersen, National Environmental Research Institute, Denmark

There can be different strategies to deal with uncertainty in science-policy interactions. One strategy is to make scientific findings – and not just science based advice and recommendations but also the scientific studies that such advice is founded upon – the subject of *extended* reviewing involving scientists from other disciplines, consultants, stakeholders and laypersons from outside science.

In some ways that kind of extended reviewing already takes place in and through the media; voices of expertise are disseminated in the public through various broadcast media, and this is one of the ways in which science becomes involved in policy-making.

The role of expertise in media goes beyond the mere dissemination of knowledge and information. Communication of expertise also works at a cultural level, where collective sentiments, social cohesion and cultural dissension are maintained and developed. (And this is probably also the case when science is communicated in closed forum).

There is a “control” aspect of communicating scientific expertise. In dealing with environmental risks, communication of expertise can in this sense be seen as a matter of publicly establishing the existence or non-existence of dangers, defining them and distributing information about their importance and gravity and how to deal with them. Experts serve as authorities endorsing the correctness of observations and may even add information about how to deal with challenges or danger, for instance in public campaigns seeking to advance or prevent certain forms of behaviour. And expert voices can also be involved in agenda-setting seeking to frame social issues in public media, defining what issues should attract attention and forming the perceptions of issues.

But there is also a ritual dimension of science communication (in media and in closed forum). Expert voices are also employed in expressing social cohesion, social identity and shared beliefs. The function of expert commentary and advice in media is not so much a contribution to specific policy-making as a representation and confirmation of social orders and basic world views. For instance when experts warn about a danger, it is not only the danger that is defined, but also the community that shares this danger.

It is important to note that social orders also consist of dissension and conflict. One of the social orders that might be communicated through media dissemination of expert voices might be the division between economical and environmental concern, or might even be that the world is an uncertain place.

Public performances of experts are invested in societal struggles. The category of uncertainty and the category of "ordinary people" are equally invested in such struggles and are no less ideologically charged and no less affiliated with dominant societal actors than the category of expertise.

3.2.4 Dealing with Risk and Uncertainty: An outsiders perspective to fisheries

Edward P. Borodzicz, Professor of Risk and Crisis Management, Portsmouth University

The paper reports on recent and historical developments in risk, reflecting on the authors perceptions of risk management from being trained as an anthropologist and psychologist.

All societies, both traditional and modern, face choices and decisions about how to confront risk. Although the way we perceive and attempt to manage risk may be new, the problem is not. The management of risk is probably among the oldest of recorded human activities. Anthropological studies of both ancient and traditional societies appear to suggest that risk has been a pervading issue throughout time. For many traditional and historical societies, this choice can represent fundamental survival strategies, from methods of farming and a choice of crops or hunting to early systems of kinship and social ordering. These types of choices and their associated risks can also be perceived, at least among traditional societies, as fundamental to survival against the elements.

Ancient societies have also left behind them a legacy of fascinating oracles. One of the oldest such oracles is the ancient Chinese text The I Ching. This text was used by ancient sages to help emperors and warlords, effectively, to manage the risks and uncertainty associated with power. In more recent times, Chairman Mao Tse Tong, was reported by his personal doctor to have used this device to inform his key decision-making. Western translations of the original text are widely available today in most bookstores.

Risk can be traced back to the early philosophers of both East and West; evidence of this can also be found among the early civilisations of the West. As Aristotle put it:

> *'It must be expected that something unexpected will happen' Aristotle (384–322BC)*

Despite intense social, economic and political interest in risk over recent years, our ability to both identify and manage risk is still questionable. Attempts to understand, regulate and manage risk have only been only partly successful. Some current theories even suggest that there is a homeostatic relationship between risk and humans making attempts to eradicate risk almost impossible (Wilde, 1976, 1994, Adams, 1995, 1999). Other theorists point to the systemic quality of risk when viewed within an organizational perspective. Certainly the number of and complexity of risk issues will increase so long as populations continue to expand in size, density and technological dependence. Recent events such as the Tsunami, terrorist outrages and catastrophic system failures force us to reappraise the whole approach to risk. Although it would be fair to say that there is now a substantial literature based on risk identification and prevention, there is little evidence to suggest that we are any better at either preventing or dealing with complex failures events.

In this context, understanding the risks pertinent to natural resources, such as fish, will pose equal dilemmas for theorist, practitioners and legislators. Without being able to accurately predict stocks of fish, issues such as the credibility of science will be seriously questioned and challenged when political questions are addressed.

There is a role here for social scientists to improve risk communication between stakeholders in order to improve the resilience of both industry and environmental concerns. Understanding the cultural context of the stakeholder roles and perceptions of risk among these groups is the key to achieving this.

3.2.5 Precautionary and inclusive governance: Some insights on major challenges from the food safety field

Dr Marion Dreyer, DIALOGIK, Stuttgart, Germany

Presentation at the meeting of ICES Working Group on Fisheries Systems: Uncertainty and Policy, ICES, 13 October 2008

The presentation shall provide empirical insights (gained in subproject 5 of the EU-funded Integrated Project SAFE FOODS[1]) into issues that have evolved from a revised food safety policy (at EU-level and in several Member States as well) that endorses the Precautionary Principle, devotes more attention to scientific uncertainties, and increases opportunities for stakeholder consultation in the governance of food risks. Although the cases of food safety and fisheries are clearly different in terms of issue-nature (with food safety being not a natural and common-pool resource with associated collective action problems), the general critical issues that will be highlighted seem to have relevance also for the fisheries management field.

The revised European food safety governance system is an *evolving* system with many specifications of the recent reforms still developing and the challenges of putting the reforms into practise becoming increasingly visible. It will be argued that in order to further implement the principles of food safety governance enshrined in the

[1] For a detailed presentation of the research results see Dreyer, M., Renn, O., Ely, A., Stirling, A., Vos, E., Wendler, F. (2008). *A General Framework for the Precautionary and Inclusive Governance of Food Safety in Europe*, Final Report of subproject 5 of the EU Integrated Project SAFE FOODS (30 June 2008), Stuttgart, DIALOGIK; a refined version of this report will be published in the book: Dreyer, M. & Renn, O., (February, 2009), *Integrating Science, Precaution and Public Involvement in Food Safety Governance*, Springer, in press.

2002 General Food Law (GFL) and the agenda on governance in the European Union, *precaution* and *participation* are among those aspects that deserve more attention and need further improvement. Both the issues and the recent reforms that have an impact on them continue being subjects of debate and controversy.

Official representations in EU food safety regulation increasingly express commitment to a more systematic recognition, consideration and communication of the scientific uncertainties that may be involved in the assessment of risk. At the centre of a more systematic approach to dealing with the challenge of scientific uncertainty lies the application of the precautionary principle, formally established by the GFL as a general principle of food law. However, there are a number of questions for its application in food safety governance which are subject to fierce debates. In particular, there is the question over whether precaution is applicable to assessment at all, or whether it is simply an approach to risk management. Alternatively, if precaution is applicable in the assessment stage, what is then the precise nature of the relationship between precautionary approaches to assessment and established practises based on conventional risk assessment?

In the past four years there have been growing efforts to involve stakeholders in both management and assessment of food safety threats. Still, there is ongoing intense debate. In the centre of this debate is the question of how to feed the perspectives of a wide diversity of social groups and also of the wider public systematically into the regulatory process, without an overkill of participatory procedures that would abuse the scarce resources of both the responsible institutions and those 'involved'. Moreover, the consultation of stakeholders through the assessment authority, the European Food Safety Authority (EFSA), remains a disputed issue. At the core of this debate is the question of how to ensure that this does not compromise the safeguarding of assessment against 'inappropriate' non-scientific influences.

The presentation will provide three *suggestions* to address these issues:

- Consider the precautionary principle a general governance principle which is employed in framing the overall governance process (composed of the four major stages of framing, assessment, evaluation, and management) and therefore has implications for each governance stage.
- Differentiate between stage-specific functions of stakeholder (and public) involvement for a meaningful and resource-efficient use of the valuable input these actors can provide to the governance process (knowledge, values, and preferences).
- Match degree and design of involvement with levels of scientific uncertainty and socio-political ambiguity.

Through the following presumptions the relevance of the empirical insights for the field of *fisheries management* will be expressed:

- Concerns about procedural fairness and trust are more salient with uncertainty; non-acknowledgement of uncertainties can cause deficits in trust and legitimacy.
- 'Precautionary assessment' does not resolve pervasive uncertainties but may create more constructive conditions under which the collective gathering of useful knowledge (systematic, experiential, and practical) has a legitimate place.

- Together with openness about what is known and what is not known precautionary assessment could help to avoid endless/fruitless debates about adequacy of science (which may mask other issues) and allow the disputes to be addressed more directly.
- Stakeholder involvement should be 'governance stage-specific'; i.e. the purpose of involvement in ICES activities, for instance, should be expressly different from the purpose of involvement through the Regional Advisory Councils (RACs).
- Framing and Evaluation as explicit governance steps (with their own procedures and structures) could improve transparency on how (available) knowledge and (different, divergent) values were both acknowledged and combined in the governance process; responsibilities for these activities would need to be clarified; one could consider the relevance of creating an *interface* structure including ICES (and/or other key scientists), RACs, and political decision-makers with responsibility for dealing with these tasks (in an advisory function).

3.3 Summaries of Presentations by Fisheries experts

3.3.1 Uncertainty in scientific advice for fisheries management– a preliminary diagnosis and possible tools

Kjellrun Hiis Hauge, IMR, Norway

In this section we will outline some uncertainties associated with advice for fisheries management and briefly discuss tools for dealing with them. We start with presenting a range of purposes for addressing uncertainty. For discussions on uncertainty to be relevant, uncertainty must be seen in relation to management objectives and the management measures to achieve these. A brief overview is thus presented before discussing what tools are commonly used in ICES related to the source, level and nature of uncertainty. Finally we briefly discuss tools that are used in related research and advice areas.

The purpose of addressing uncertainty and developing uncertainty tools is diverse, and can be summarized as follows:

- Mapping uncertainty
- Communication of uncertainty
- Accounting for uncertainty in decision making and
- Reduction of uncertainty.

Mapping uncertainty can be done by checklists, for example the one developed by Walker *et al*. (2003). This can serve to increase awareness among scientists when developing models used in decision making to ensure that relevant aspects of uncertainty is addressed. In complex systems, as fisheries management systems, mapping of uncertainty together with an uncertainty assessment can help identifying what uncertainties should be communicated. Because uncertainty issues can be numerous, it may be necessary to reduce the number of issues to avoid an overload of information. On the other hand, it may not be obvious what the most relevant issues are for decision-making. A mapping exercise based on a checklist can solve this problem, but may necessitate a dialogue between all interested parties.

The quality and relevance of uncertainty assessments is crucial when deciding what uncertainties to be accounted for and how. Various ways of accounting for uncertainty may affect stakes and stakeholders differently, so a careful analysis of value implications is relevant. In some situations the aim of an uncertainty analysis may be to reduce uncertainty, either by conducting research or by introducing management measures, regulations or increasing surveillance.

Table 1 gives a coarse overview of management objectives or principles, management measures to meet the objectives and some uncertainty issues. It only includes issues linked to the natural science based advice, but yet illustrates that fisheries management is complex and that there are many general uncertainty issues. In addition comes uncertainty related to socio-economic factors and compliance.

Table 1.Underlying (biological) principles and management measures.

OBJECTIVES/PRINCIPLES	MET?	REGULATION	UNCERTAINTY ISSUES
Sufficient mature fish to spawn	Yes/No	Quotas based on limits on biomass and harvest rate. Effort limits	Hyper-precise advice, Better to cut slice or layer? Link between species, Uncertainty in thresholds, Can stocks be rebuilt? Effect of global warming, Genetic changes in stocks.
Don't fish the small fish	No	Closed areas, Mesh size, Gear restrictions, Discarding required	Are mesh size restrictions effective? Discard levels? Effect of discards on assessment? On future stock abundance?
Stock as a management unit	Yes/No	Agreed distribution	Effect of mixed fisheries, Does stock definition cause local depletions?
Optimize catches	No	Quotas based on limits on biomass and harvest rate.	Are there meaningful measures? What does it mean in a multispecies context?
Avoid destruction of bottom habitat	Yes/No	Closed areas, Gear restrictions	Does bottom trawling destroy sandy seafloors?

Some of the uncertainty issues in fisheries management are taken into account, some are implemented in scientific advice, and some are discussed on a political level and some in academia whereas others get less attention. Uncertainty is easier to relate to when it is quantified, but some of the issues listed in Table 1 are connected to the relevance of regulations, or problem framing, and are thus less quantifiable. Walter *et al*. (2003) divide uncertainty in three categories: *location, level and nature*. Table 2 shows a simplified version of their three-dimensional uncertainty matrix. The uncertainty *location* refers to the sources of uncertainty and the resulting uncertainty in model outcomes. Note that *context* is related to the framing problem and its relevance i.e. are we asking the right questions in relation to a certain policy problem. The second dimension is the level of uncertainty: is statistical uncertainty a sufficient representation, or does the uncertainty require scenario representation. And in some cases and situations there may be recognized ignorance. Uncertainty is commonly assessed with statistical models in scientific approaches. Further, evaluation of harvest control rules implement various degrees of scenarios when taking uncertainty in underlying assumptions and conditions into account in simulation exercises. These assumptions can be related to different ecosystem conditions or human behaviour.

The third dimension, the *nature* of uncertainty, is divided into *epistemic uncertainty* and *variability*. The intention of this category is to be aware of different nature of uncertainty regarding whether it reducible or irreducible. It is important to note that both categories can be associated with irreducible uncertainty.

Table 2. Mapping uncertainties (Walker *et al*., 2003).

Location	Level			Nature	
	Statistical uncertainty	*Scenario uncertainty*	*Recognized ignorance*	*Epistemic uncertainty*	*Variability uncertainty*
Context					
Model					
Inputs					
Parameters					
Model outcomes					

In relation to, for example, uncertainty in scientific advice on quotas, statistical and scenario tools are developed to reflect uncertainty related to location. However there has been little focus on developing tools for uncertainty related to context and to non-quantifiable uncertainty. Funtowicz and Ravetz (1990) developed the idea of including pedigree matrixes as part of the presentation of scientific results for use in multidisciplinary projects or in decision-making to permit the users to evaluate the reliability of the presented number or advice. Table 3 is an example of a pedigree matrix, which Craye *et al*. (2005) developed for a policy problem related to a controversy on contamination. The table presents four categories for each of the five defined science and problem framing qualities.

Scientific advice for fisheries management is obviously associated with uncertainty of various kinds and forms. Better or additional tools to assess, communicate and account for uncertainty can be helpful in decision-making. This section indicates some areas of improvement and presents two tools with great potential. Further development of such tools for scientific advice for fisheries management is recommended.

Table 3. Pedigree scheme (Craye *et al.*, 2005).

	Problem framing	Data–definitions	Data-collection	Analysis	Review
4	Negotiations	Negotiation	Task Force	Established	Extended
3	Scientific	Science	Direct	Discussion	External
2	Compromise	Pragmatic	Bureaucratic	Competition	Independent
1	Inertia	Symbolic	Indirect	Embryonic	Internal
0	Controversy	Unknown	Fiat	No info	None

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3.3.2 The Paradox of Transparency: Scientific Institutions and the Ecosystem Approach to Fisheries Management in Europe

Doug Wilson, Innovative Fisheries Management – an Aalborg University Research Centre

Introduction

The institutions, knowledge and techniques needed for such the Ecosystem Approach to Fisheries Management are still very much in development. One can think of the problem as an essentially technical challenge where the ecosystem is seen as a big machine that needs to be properly maintained and so the first thing we need to do is to diagnose the problems then we can decide who needs to do what to fix them. The alternative is to start by seeing the problem as an essentially social dilemma. The question then becomes how people who see problems are able to initiate a decision making process to learn about and then effectively respond to those problems. The first approach is the initial response of most natural scientists, but when they begin to deal with the issue practically the social dilemmas quickly emerge. This presentation, based on a monograph of the same title from the University of Amsterdam Press, traces how these two paradigms have played themselves out within ICES.

ICES has gone through a reorganization driven to a large extent by the demands of the ecosystem approach. It has become more spatial, and to some degree more qualitative, rather than purely statistical in its basic approach to management. ICES has also self-consciously remade itself into a learning organization through broad institutional changes rather than simply a group that collates the knowledge of individual scientists. The lessons ICES has learned in this process are valuable for fisheries and other arenas of science-based policy.

Data and Methodology

The qualitative aspects of the case study research include the detailed observation of 16 scientific deliberations within the ICES system and five related meetings within other institutions. In addition, 35 formal interviews with fisheries scientists or close observers of the fisheries science process were held. A large number of documents were also reviewed. Notes from observations, informal interviews, and original documents were analysed using NUD*IST textual data analysis software. The quantitative methodology used in this case was a random sample survey of European marine fisheries scientists employed in the countries around the North Sea. In all 465 valid responses were received from a sample of 900.

Results and Discussion

Scientific advice is a critical element with marine management and many stakeholders have an interest in it. Hence scientists working to produce this advice are doing so in an environment that has many bureaucratic and political impacts on their activities. These include how scientific activities are funded, demands related to the ways the advice is formed and communicated, and several kinds of more or less direct political influences on the advice process. The norms of the larger scientific community also have an important influence on the advice formation process.

The working conditions of scientists are systematically affected by their relationship with the advice production system. Fisheries scientists on average scored their job satisfaction well above the mean of our survey's scale, scientists working directly with the assessment of fish stocks for scientific advice, while still scoring above the mean, scored significantly lower than other scientists. This greater dissatisfaction is linked to travel demands and frustrations about their chances to produce peer reviewed publications. The high level of uncertainty they have to deal with also spills directly over into their working conditions because they are often have no objective way to know when their work is adequately completed.

Systematic pressure is on scientists to "inflate the science boundary" meaning to expand the range of issues that can be legitimately resolved through scientific findings. Fisheries scientists are increasingly being asked to deal with problems and concepts more directly suited to the social sciences. They have to expand their models to deal more explicitly with problems around the allocation of fish stocks in addition to simply assessing their biological condition. The scientists are resisting these pressures to inflate the boundary in various ways.

Perhaps the most serious pattern is a growing belief among scientists that the activities they are doing in support of the CFP are far from their understanding of what science is. Many scientists are experiencing a form of anomie arising from being asked to play a difficult role under sometimes trying conditions and then having the results of these efforts disembedded from the culture of their scientific community by the management system and changed into something they no longer see as science. Analysis of the survey data shows that this experience has a significant, negative impact on job satisfaction that is independent of the problems with working conditions mentioned above.

I trace the attempts to reform the ICES system to address these problems while moving the entire system toward an ecosystem approach to marine management. These attempts were very difficult because of both the natural science demands and the institutional requirements of creating effective scientific advice.

ICES made considerable progress because of the decentralized power dynamics within the ICES network, especially between the more purely scientific and the more advice oriented parts of the network. This decentralization has made possible the maintenance of the series of "creative tensions" meaning areas of ongoing disagreement over how to prioritize scientific values that no internal ICES agenda has the power to completely resolve. These creative tensions include: How to place the "science boundary" especially in terms of the appropriate forms of review; How ICES should make use of its scientific activities, especially in terms of the degree to which advice-driven terms of reference should determine working group activities; What "adequate advice" actually means, especially in the tension between the need for quantification and specific answers and the need for humility and "soft predictability"; and, finally, a tension over leadership roles, especially the degree to which ICES should be out front in pursuing a conservation agenda as opposed to responding mainly to client needs.

A central challenge emerged in the form of the "paradox of transparency", meaning that attempts to create transparency require the development of new codes, languages, procedures and constellations of participation, and these changes create new kinds of opaqueness for those who do not have the access or skills to participate in this new transparency.

Within ICES reorganization the paradox of transparency created constant challenges and ICES scientists responded by working out new mechanisms of quality control. Second only to the idea of scientific review, the use of the word "consistency" has strongly characterized these efforts. New languages were created to allow entirely new kinds of consistency of both data and concepts that were required for the various parts of the ICES network to effectively stabilize the "boundary" processes that allowed science to become scientific advice.

During this research at least six different meanings of the term consistency emerged in ICES discussions. They are ordered below along an intuitive continuum from technical to social consistency. Types A and B are almost entirely technical in nature while the last four are related directly to advice. Types C, D and E have to do with both the social and technical organization of advice, while type F is almost entirely social and, in fact, is an issue that arises for any large organization, scientific or not.

- Type A is consistency with the accepted standards of science and it responds to questions of credibility;
- Type B is consistency of methodology across time, space and scale that allow the integration of information and creation of new knowledge. It is related particularly to methods of data gathering. Again it responds to questions of scientific credibility;
- Type C is consistency with standards of advice and it responds to questions of legitimacy;
- Type D is consistency in advice in response to a single policy question that involves multiple scientific disciplines. It responds to questions of saliency;

- Type E is consistency in the way scientific methods and scientific advice are linked across time, space and species. It responds to questions of legitimacy;
- Type F is consistency of message from the various parts of ICES and it also responds to questions of legitimacy.

As almost purely technical concepts Type A and B are treated in a straightforward manner within ICES. **Type A** is primarily a question of peer review. **Type B** has immerged as important in an ecosystem concept in respect to the question of integrated as opposed to concatenated advice. Type B consistency makes integration possible.

One of the background agendas in the restructuring was to facilitate Council oversight of the Advisory Programme because of a concern in the Council about **Type C** consistency. In this case it is consistent adherence to advice practises that reflect international agreements. This has meant the precautionary approach in particular but interest in ensuring adherence to EAFM is beginning to be felt as well.

Type D consistency is raised by ICES leaders in respect to coherence of advice between fisheries, ecology, and environment now that they are being asked to tackle similar issues in a multidisciplinary framework. One hypothetical example of this kind of consistency offered me by one of the Delegates I interviewed was that if ICES is giving advice about the exploitation of a fish stock, the former ACFM might advise one level of exploitation based on sustainable harvesting and the former ACE might advise another based on the needs of seabirds. ACOM in this case would presumably choose one of these two levels as the "ICES advice". This would require either an ICES judgement about which was more appropriate, or more likely a dialogue with clients about which one they really wanted.

Type E consistency is the most sociologically interesting form of consistency. The question is one of "similar judgements" about "similar issues". The question often seem to be couched as questions about methodology and failure to meet this kind of consistency is often referred to as an "error" that should be caught by review. However, this way of framing the question turns out to be mistaken on closer analysis.

For example, there were two debates about two similar questions: whether the deep water redfish (*Sebastes mentella*) and the black scabbardfish (*Aphanopus carbo*) should be treated as one or several populations across their range. The current evidence is uncertain for both. ICES decided to treat the deep water redfish as two stocks and to divide the black scabbardfish into a number of separate stocks. A client then wanted to know why one fish was treated one way and one fish was treated the other way. The client was asking for Type E consistency.

It is Type E consistency that most solidly straddles the science boundary. The question the client asked about deep-water redfish and black scabbardfish is not really a scientific question. Science asks about the factual evidence about how many stocks of deep-water redfish or black scabbardfish are in the area. The client's question does not address the evidence about how many stocks of deep-water redfish there are, nor does it address the evidence about how many stocks of scabbardfish there are. Rather it is asking a question about ICES as an institution. Did two different groups of scientists looking at a similar question about two different stocks approach the question in the same way?

The source of the question is not, in fact, in science at all. But to say it is not a question sourced in science is not the same thing as saying it is not an important question. The source of the question is the notions of fairness about the equal treatment of black scabbardfish fishers and deep-water redfish fishers transmitted through politicians, ministers and/or DG MARE. These groups are looking for science to provide the same transparency of argument to each advisory issue, indeed Type E consistency is about increasing transparency by making the scientific methodologies involved more tractable and accessible to those outside the process.

Type F consistency is very much a concern of the ICES leadership because ICES is such a public body acting on the public stage. This is often certainly the primary way the Council as the intergovernmental overseers imagine ICES. From this perspective ICES must not only be consistent, it must speak with a single voice.

Conclusion

The problems ICES is facing with doing the kind of science that scientists can comfortably own are found in many areas of science for policy support. The way in which power within the ICES network is distributed in complex ways is a source of great frustration from time to time for both ICES leaders and clients. But this same distributed power has made possible the maintenance of creative tensions that have allowed ICES to be a more responsive learning institution. The various kinds of consistency are an interesting example of the kinds of complex languages that are required to stabilize the creation of effective advice at the science policy boundary.

3.3.3 The Communication of Scientific Advice in Data Poor Cases

Panayiota Apostolaki, Cefas, UK

Simulation of systems on which limited research has been carried out is often characterized by low level of realism and high degree of uncertainty in model predictions. However, the low level of realism might also fail to capture the uncertainty in each process that is part of the system we try to describe. In that case the level of uncertainty in scientific predictions might be low and can increase as new research facilitates the description of more system processes in quantitative terms. There are a number of tools that can be used to describe the uncertainty in the results of simulation modelling. This includes quantitative tools such as CVs and confidence intervals, figures (e.g. pdf graphs), and matrices (e.g. traffic light approach). Those tools help us communicate the effects of uncertainty in the knowledge of processes that were captured in the calculations. But what about those system processes that were not even captured in the analysis? Scientists are aware of that lack of knowledge and often can suggest which of the omitted processes might lead to considerable changes in the results in they are included in the analysis. But do scientists communicate this type of uncertainty to the users of scientific results? Furthermore, do the information we give to managers, stakeholders and policy-makers about uncertainty is enough for them to develop a clear understanding of the influence of uncertainty in the results of the analysis?

A potentially useful approach to communicating the process, through which scientific advice was formed, especially in cases in which information that was not included in the analysis directly has contributed to shaping scientific advice, is to provide information on the level of maturity of research (or quality of knowledge) as part of scientific advice. There are tools that are used in other scientific areas to communicate this information and which could be of help to fishery scientists. Pedigree analysis that is used for uncertainty assessment (Funtowicz and Ravetz 1990, van der Sluijs 2008) could provide a graphical tool that can help scientists explain what processes have not been considered in the scientific analysis and provide a quick outlook of how much we know. Such information can also facilitate and increase participation to discussions (among decision makers or decision makers and interested groups, etc) because it ensures that all participants understand the different factors that could shape scientific advice (i.e. understand the limits of scientific advice; use same knowledge base, etc.).

Another important piece of information that could be of use to policy-makers is about progress that has been done in terms of reducing uncertainty in each aspect of the system of interest. Maturity charts are often used in technology road-mapping to describe past, current, and future capabilities in terms of achieving a specific goal. This idea can be added to graphics produced from pedigree analysis to provide a more complete picture of the maturity of science, its evolvement over time and whether room for considerable improvements in the understanding of key system process still exists. Policy makers might be reluctant to base policies on scientific results which are characterized by high uncertainty. Information on accumulation of knowledge and potential future improvements could be of use to decision makers in at least three ways; a) it helps them understand why scientific advise might change from year to year, b) provides a simple way to communicate that uncertainty can be reduced up to a point but in most cases cannot be eliminated and to indicate when we are approaching that upper limit and c) helps illustrate the changing nature of the system we deal with and highlight the need to develop management advise that can adapt to a changing environment.

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3.3.4 Uncertainty Explained

Robert Aps, Estonian Marine Institute, Tallinn and Hans Lassen, ICES

Manifestation of uncertainty in fisheries system is exemplified by the case of setting the TACs for the Baltic internationally regulated fishery resources. In historical perspective (1977–2004) IBSFC Contracting Parties, as maximizers of economic value, often set the TAC by unit stock in excess of what is considered sustainable. Little has been changed since then. TACs set in excess of sustainable levels of exploitation (decision-overfishing) reflect the relative importance attributed by negotiating parties to the interests of multiple groups participating in the fishing industry, and is increasing the decision process associated uncertainty. Uncertainty is generated also by poor catch and landing data, insufficient fisheries economic data, and overcapacity driven argumentation and behaviour. European Commission’s statement that the Community fleet is capable of catching between two and three times the maximum sustainable yield is explaining a great deal of the uncertainty surrounding the Baltic fishery. Fishing fleet overcapacity, being clearly conducive to overfishing and economic underperformance, is believed to be an important negotiation context element in striking the balance between divergent short-term interests, environmental on the one hand, and socio-economic on the other, often authorizing catch quantities that are higher than those recommended by the scientists, in order to protect the immediate social and economic interests of those employed in the industry. Furthermore, overcapacity detracts from the profitability of the fishing industry and in a context of decreasing authorized catches is an incitement to non-compliance with these restrictions.

3.3.5 Managing uncertainty and building capacity: Cooperative research in the Northeast US

Teresa R. Johnson, School of Marine Sciences, University of Maine

This presentation reports on the experiences and lessons learned from cooperative research in the Northeast US for managing complexity and uncertainty. Fisheries management in this region involves a participatory process that includes industry and other stakeholders in regional fishery management councils that develop fishery management plans. In this region, cooperative research emerged from conflict and distrust between fishers and scientists over the science used in policy-making, particularly the government resource survey data and the stock assessments based on this survey. The conflicting views of fishers and scientists about the state of the resource represent a source of uncertainty that cooperative research aims to address.

Cooperative research projects include study fleets of fishermen voluntarily collecting fishery-dependent data, industry-based surveys to supplement the government's large-scale, fishery-independent survey, tagging studies to investigate migration patterns of fish stocks, and gear technology research to reduce discards and bycatch of weak fish stocks. Many of these projects aim to improve the government's resource survey and stock assessments, in part by reconciling the differential views of scientists and fishermen. Broad goals of cooperative research include improving the quality and quantity of data for management, utilizing fishermen's knowledge, building buy-in and trust in science and management through shared understanding, and reducing conflict between stakeholders. Unlike previous cooperative efforts, these efforts involve industry participation throughout the process of scientific research, including problem or hypothesis generation, research design, data collection, and dissemination of research results. Stakeholder participation also occurs through reviews of proposals and final reports that have been reviewed through traditional technical review processes. In addition to scientists gaining insights from fishermen throughout the research process, fishermen are also gaining knowledge, expertise, and skills from scientists.

Cooperative research aims to reduce uncertainty by improving the knowledge base of management (i.e. improving the quality and quantity of data, including data collected at multiple scales). It is thought can improve the quality of knowledge production by directing scientists towards relevant research questions that managers need addressed. On the other hand, cooperative research allows for managing uncertainty and reducing conflict by developing a shared understanding and trust or buy-in to science and management. This occurs as communication between fishermen and stakeholders increases and the scientific process becomes more transparent. Moreover, capacity building occurs as fishermen and scientists interact and learn from each other. Indeed 2-way knowledge flow can be seen in many cooperative efforts. Through participation, fishermen are seen learning and gaining expertise about scientific concepts (sampling, standardization, data collection, consistency) and language. They gain scientific skills such as data recording, measurement, tagging, and data entry. This learning facilitates their meaningful participation in science and management. Capacity building also involves the development of social networks of fishermen and scientists that are able to identify and respond to environmental change and emergent problems. However, communication and transparency must be assured throughout the effort in order to maintain any trust and buy-in that develops.

3.3.6 The Co-Production of Science and Policy in Environmental Regimes. A Theoretical Framework to study the Role of Science in Fisheries Governance (Baltic Sea)

Sebastian Linke, Section for Science and Technology Studies, University of Gothenburg

This study focuses on the *Role of Science* in international environmental regimes aiming for sustainable governance in fisheries management. It poses a theoretical framework to investigate the role of scientific knowledge in such regimes using different approaches from the social sciences and from Science and Technology Studies (STS) in particular.

The background for this study is the problem existing now for decades in environmental politics: how to develop sustainable fisheries management in international seas, focussing here on the Baltic. Scholars in STS investigate the interface between science and other parts of society like the public or the political arena by emphasizing the social context. Fisheries management offers an outstanding case where science/ scientific knowledge is contrasted with other knowledge cultures from fisherman or NGOs as well as with the policy concerns of EC.

This presentation explores the fisheries management system of the Baltic Sea with approaches about the *role of science* from regime theory and international relations and contrasts these with some approaches about the co-production of science and policy from STS. In the literature on international relations one can find two significantly different approaches about role of science in environmental governance regimes.

According to the first one, the interest-oriented perspective (institutionalism), the international political community consists of rational acting nation states, bargaining and trying to achieve their own interests. The *role of science* in this model is playing only a minor role as an external 'input' tot the policy process: it well defines ecological vulnerably and gives advice and recommendations, but the negotiating process itself is formed by self-interested actors (e.g. nation states) that operate according to pure cost-benefit calculations. The factual evidence, provided by science, does not affect the attitudes or interests of the actors, only their evaluation of the environmental issue at stake. Institutionalists have therefore limited expectations about environmental cooperation because they "expect to find negotiated regimes whose substance merely reflect the measures tolerable to the least enthusiastic party" (Haas 1997), formulated as the "law of the least ambitious program" (Underdal 1982).

The interest-oriented approach has been contrasted with the concept of *Epistemic Communities* by Peter Haas, emphasizing the importance of policy-relevant and consensual knowledge in *shaping* regimes. The role of science is not only to change the external environment for a state or any other actor but works as a 'learning facilitator' and 'role definer'. Environmental regimes are not only driven by state power, but by the application of (a common) scientific understanding about ecological systems to the management of environmental policy. Haas proposes the concept of epistemic communities as an 'elite' analytical tool to investigate the role of science in the formation and development of regimes because 'consensual knowledge' can be applied directly to the policy process, while from the perspective of the institutional model it first has to be negotiated by political parties in order to reach compromises.

The two approaches leave us with a controversial view about *role of science* in environmental regimes. The crux is whether scientific knowledge is able to shape regimes or if it is only one factor among a number of others that provide input to the work of regimes. From an STS perspective both models can be criticized to misunderstand and simplifying the role of science in environmental regimes by applying an uncritical or even positivistic view about science itself. They both frame science as separated from the policy context, as something produced externally to the political forces and then applied to the negotiation and decision-making processes. Also Haas' model, emphasizing the importance of science, can be criticized for prescribing the role of science rather than explaining it. STS aims to overcome this simplification by making visible and explaining the social and material contexts, which have been created in order to move science in society (e.g. in policy-making). It views the scientific expert as one player embedded in a system where knowledge is produced, distributed & maintained through social networks.

The *'Idiom' of Coproduction* (Jasanoff) proposes a mutual understanding of scientific knowledge and political order. This approach implies the claim that policy always influences the production and stabilization of knowledge while this knowledge simultaneously supports and justifies policy. The production of knowledge is also the production of policy and vice versa: People accept specific knowledge-claims because they support their policy strategy while they reject others. The key of *co-production* is that both science and policy are part of the same culture, cooperating in the domain of policy-relevant research. Hence co-production means that uncertain or contested science can grow stronger if the policy context is 'right' while on the other hand, a weak policy context can grow stronger with the support of (the 'right') science.

The study presented here uses STS concepts like *co-production* and *boundary work* (Gieryn) to explore the role of science in the governance regimes for fisheries management. Cases like the Baltic Sea decision-making process for TACs, involving the negotiation of scientific advice from ICES and STECF, the input from other stakeholders e.g. via the Baltic Sea RAC and the policy concerns of the European Commission make the case to study the interplays in more detail – both between science and society in general, and between scientific advice for fisheries management and its policymaking in particular. The presentation given here explains different approaches about the role of science from regime theory and international relations and contrasts these with more sophisticated understandings from STS.

3.3.7 Measuring uncertainty: Bayesian approach to stock assessment

Samu Mäntyniemi, University of Helsinki

Types of uncertainty to be and not to be measured

The Bayesian approach is designed to quantify and integrate aleatory and epistemic uncertainty. Aleatory uncertainty means uncertainty as a result of inherent randomness in the system dynamics and data collection procedures. This type of uncertainty can be thought to have one true value, which is typically unknown. As an inherent property of the system, the aleatory uncertainty can not be reduced by obtaining more information. Uncertainty about the aleatory uncertainty needs to be addressed through the concept of epistemic uncertainty.

Epistemic uncertainty describes the lack of knowledge i.e. degree of belief. That type of uncertainty is essentially a state of mind, which varies among persons based on the information that they possess. Such a personal lack of knowledge can be reduced by obtaining more information. Unlike aleatory uncertainty, the epistemic uncertainty does not have one objectively true value to be found, but the true value varies between persons. The personal probability can be found out by interviewing the person whose beliefs are of interest.

Converting the true beliefs of an expert to probability statements includes uncertainty, which can not be quantified by the Bayesian approach. The effect of this variation on management advice can be evaluated by conducting a sensitivity analysis, where small deviations from the expert's probabilities are evaluated.

Naturally, the uncertainty about unidentified hypotheses can not be quantified prior to their potential identification, which might arise as a result of new research.

Basic principles

The Bayesian inference is based on two simple principles, from which other properties follow

- Express the current knowledge (prior to seeing data to be analysed) about the state of nature and potential observations as a joint probability distribution.
- Process that information by using probability theory: integrate different sources of knowledge and update the knowledge if new observations become available.

Bayesian inference can be coupled to utility theory of decision making, which makes up the discipline of Bayesian decision analysis. Decision analysis allows ranking of decision alternatives regardless of the amount of uncertainty.

Application to stock assessment

The purpose of the Bayesian stock assessment is to *formalize and structure the thinking of the stock assessment expert group*. As a result, the expertise of the working group can be represented as a probability distribution that factorises to two parts: prior knowledge from other sources of information than the data available to the group (e.g. literature, knowledge of similar stocks), and interpretation of the observed data. More specifically, the following steps should be taken in the working group:

1) Specify existing knowledge
   - Model structures: use theory of ecology, behavioural research
   - Priors for model parameters: "basic" research (e.g. fecundity of fish)
   - Data collecting process: commercial data, survey programmes.

2) Add observations, if they exist
   - Use probability calculus to update
   - Use posterior distribution as a starting point in the next assessment.

Complexity

Earlier presentations by WGFS participants raised the point that obtaining more data would lead to more complex models and that way to also higher uncertainty. This phenomenon takes place when the model structures are judged primarily by the size of the dataset rather than by considerations of the biological uncertainty about the population dynamics and sampling procedures. It was argued here that when following the principles of the Bayesian approach the contrary will happen: complexity and uncertainty are highest when the dataset is smallest because there is little evidence of any particular model structure and parameter combination. This means that all plausible model structures need to be taken into account yielding a highly complex meta-model. The uncertainty will slowly decrease when more observations accumulate and are used to update the knowledge.

Quality assessment

Because the result of the Bayesian stock assessment is a description of the knowledge of a particular group of experts, the review should concentrate on the transparency of the process of compiling that knowledge rather than questioning the knowledge itself. Questioning the knowledge would imply mistrust to the expertise and that the composition of the expert group should be changed. The process could be evaluated using pre-agreed scoring rules, and the result of scoring could be potentially displayed graphically for a quick outlook. For example, an assumption (prior distribution) about natural mortality could be given a low quality score if it is based on technical requirement of the modelling technique or based on a quick guess done under the tight schedule of the working group meeting. High score would be granted to an assumption (prior distribution) that is based on biological reasoning from premises presented in multitude of peer reviewed papers and/or is based on hierarchical meta-analysis of similar populations. To aid the review, working group could rate the assumptions themselves using a pre-agreed scoring system that should be used by all working groups.

Discussion

After the presentation the issue of usefulness of high uncertainty was brought up arguing that using complex models with small amount of data could lead to a situation where the result of the assessment is too uncertain to be useful. Use of simplified models was proposed instead in order to gain higher certainty about the model parameters. As a response to this question it was pointed out that the results of a simplified model would be overly precise compared to actual uncertainty of the experts and therefore of low reliability in terms of representation of uncertainty. The Bayesian theory maintains that uncertainty is what is, and it should not be artificially decreased under the fear of the result not being useful. According to Bayesian theory the amount of uncertainty does not carry any intrinsic value in terms of usefulness: the decision analysis can be used to rank the alternative decisions regardless of the amount of uncertainty. Therefore each level of uncertainty is equally useful.

3.3.8 Risk, uncertainty, and monster management in fisheries—thoughts from the US

Bonnie McCay, Rutgers University, New Jersey, USA

Much of the discussion at this meeting has focused on conditions of "post-normal science", which I see also as a contrast between the "modern" form of natural resource management, which emanates from the 19th Century development of that discipline during the so-called Progressive Era and the newer "post-modern" or "post-normal" enterprise, which is increasingly referred to in "ecosystem" terms and poses new challenges in terms of the complexity and dynamics of the systems involved (slides 1 and 2).

For this meeting I recently completed a review of literature on risk perception, risk communication, and risk management for lessons that may apply to issues in this new era of ecosystem-based fisheries management (McCay 2008). From that literature some general lessons emerge very clearly (slide 3), including the importance of respecting and inquiring deeply into causes of seemingly irrational responses of people to risky situations, the need to broaden participation in the otherwise technical work of characterizing and appraising risks, especially in data-poor, highly contested, and very worrisome situations; and in that regard, ensuring effective participatory processes.

In reviewing this literature, I was struck by the contrast between concerns about public underestimation of risks, which comes mainly from the public health perspective, and public overestimation of risks, which comes from some areas of environmental policy, namely situations in which risks that experts deem very small are perceived and responded to by some groups of people as significant enough to call for government action, which has led me to question which kind if either is applicable to fisheries risks (slides 4 and 5). The "overestimation" question may pertain in some ways to public responses to harvest of some charismatic megafauna such as whales and seals (slide 6), and it is increasingly likely to pertain to issues of climate change and acidification. Most fisheries risks, as framed within fisheries management, are likely to be of the "underestimation" kind, where the risk communication task, from the perspective of fisheries managers at least, is that of convincing people that there are significant risks requiring some action or sacrifice (slides 6–9). Related "underestimation" kinds of risk communication problems may exist for the dangers at sea faced

The second part of my talk focused on "creative tensions" in US fisheries management, namely between participatory governance and intensified science-based approaches to fisheries risk (slides 10–12). The US management system for federal waters is based upon regional fishery management councils that include state and federal representatives but also members of the public and besides that have numerous advisory and other mechanisms for stakeholder participation. In addition, the government's fisheries science system has opened up significantly to participation by academic and independent scientists and also industry and other stakeholders, and in the northeast region is increasingly dependent also on advice by a formally designated group of independent experts (the Council of Independent Experts). However, recent changes in the federal legislation have required a much stronger precautionary approach to establishing catch limits and other measures, and this approach, as developed recently, involves a much more central role of scientists (slide 13). It also suggests an approach that requires huge investments, bringing to mind Jeroen van der Sluijs's talk at this meeting on the "monsters" of new challenges and approaches, such as ecosystem-based management, and how they are being managed, this being a case of trying to manage by exorcizing it, trying to get more data at great cost (slide 14–15).

I then talked about a recent case that involved what I call "taming the monster," the case of critical review and revision of the stock assessment model and projections for summer flounder (*Paralichthys dentatus*), a popular commercial and recreational fish in the northeast US, particularly the Mid-Atlantic region, where it is managed through the Mid-Atlantic Regional Fishery Management Council (MAFMC) (slides 16–17; see also slide 10). Briefly (see slides 11–26), the VPA-based stock assessment, with a legal and administrative framework requiring rebuilding according to specific targets and reference points, led to a situation in which summer flounder population had increased (after quota-based and minimum-size management measures starting in 1993) to the point at which it not only was no longer declared “overfished,” but also was at its historically high level. Nonetheless, it was defined as in the state of “overfishing” continuing, and very, very far from the rebuilding target.

As the population seemed to increase, restrictions became much worse, leading even to the possibility of a complete closure of both recreational and commercial fisheries. This led to the kind of “outrage” noted in situations of great public “overestimation” of risks, large demonstrations, and great criticism of the science community. Then, in 2008, the scientists changed the model, the target for rebuilding was much smaller, and the management council was able to recommend an increase in the quota, the first in several years. In the popular media this was denounced by representatives of recreational fishing interests as another instance of how incredulous science could be, but the true story was that, given openings for more participation in science, a genuine albeit still young “extended peer community” system, plus the capacity-building benefits of over a decade of cooperative research (see Johnson’s presentation), it turned out to be possible to use scientific findings—in this case about sex-ratios in the biology of summer flounder—to lead to major changes in the stock assessment model.

It is “taming the monster” in the sense that the outrage experienced by the user community was translated into productive engagement in actual stock assessment on the part of academic scientists, supported by the recreational and commercial fishers, who were able to take a “backseat” role in guiding the assessment (slide 27).

References

McCay, Bonnie J. 2008. “Risk Analysis, Decision-making, and Public Participation: Lessons for Fisheries.” First prepared for Keynote Address, Governmental Quality and Risk Management Theme Session, Annual Science Meeting, International Council for Exploration of the Seas, Halifax, Nova Scotia, Canada, 22–26 September 2008. Revised 12 October 2008, in preparation for ICES Working Group on Fishery Systems, Copenhagen, Denmark, 13–17 October 2008. On SharePoint site.

3.3.9 Stakeholder Perceptions of the Baltic Sea Regional Advisory Council (BS RAC)

Christian Stöhr, Gothenburg Centre for Public Learning and Understanding of Science

In this presentation I will discuss the results and a preliminary analysis from our project “Facilitating fisheries governance by improving communication among stakeholders.” The project aims to develop recommendations on strategies and methods to improve the process by which the BS RAC develops informed consensus among its members in order to contribute more effectively to the governance of the Baltic Sea fisheries.

The European Commission has recognized the need for significant stakeholder participation in providing advice to the Commission in support of a successful outcome of the Common Fisheries Policy (CFP). This led to the establishment of seven Regional Advisory Councils (RAC’s), which are charged with preparing and providing advice to the Commission on behalf of the fisheries sector and other interest groups in its region of oversight. The BS RAC members, two thirds representing the fishing industry and fishermen and one third representing other interested non-governmental organizations, including environmental groups, must consider scientific data on the status and prognosis for the fisheries in their deliberations. Out of their own experience and perspectives, coupled with the scientists' inputs, the RAC members should provide their advice to the European Commission in a consensus report, rather than disparate voices.

This presentation describes insights we have gained about stakeholder perceptions of the Baltic Sea Regional Advisory Council (BS RAC) and identifies some of the challenges for the BS RAC as a participatory instrument in fisheries governance. The RACs have only an advisory function, which raises the question to what extent and under which circumstances the BS RAC actually has an impact on decision making in fisheries governance. The two factors that are supposed to be of high relevance for the impact of the BS RAC advice are consistent and active participation of the significant stakeholders and the ability to reach consensus in important issues.

In the first part, I emphasize the importance of being aware of the different modes and motives for participation. Creating space for engagement alone does not ensure that stakeholders actually participate. In the BS RAC, attendance and activity of the individual members vary significantly, which can be explained by the differences in motives, as well as by the availability of resources. Consequently, some of the more active BS RAC members pointed out that more consistent attendance and participation of each organization's representatives in the meetings would help improve the collaborative dialogue process.

In the second part I discuss the consensus building process within the BS RAC. Our data show that there are different conceptions of the role of consensus within the BS RAC process. Although for many, consensus is crucial to the BS RAC's legitimacy and impact on EC proposals, others argue that consensus is unlikely to be reached in critical issues. Therefore it is preferable to present the entire spectrum of views to the European Commission. These divergent perceptions have an influence on the strategies of the BS RAC members, e.g. in terms of the flexibility of positions and the participation in working groups. Generally, distrust between the different stakeholders and differing levels of expertise and knowledge was frequently mentioned as hindering the consensus-building and collaborative process. However, many BS RAC members agree that the discussions in the BS RAC – often continued informally – have already had an impact on the development of trust and understanding among the different stakeholders.

The cooperation between the European Commission and the BS RAC has been described throughout as positive and constructive. The EC regularly presents their views in the RAC meetings. Some members would prefer an even greater degree of interaction. Serious concerns were expressed regarding the use of the BS RAC advice in the EC proposals to the Council of Ministers. Although there are positive examples, several RAC members would like to see the advice produced by the BS RAC given more consideration by the Commission. For some members, consideration of BS RAC input by the Commission is crucial as a reason for their participation in the BS RAC, because there are other ways of influencing the fisheries policy – particularly through national ministries and communication with the public.

Finally I discuss the relation between the stakeholders and scientists, including the matter of scientific advice. There is a fundamental dichotomy in the understanding of how the advice should be interpreted. It is seen as one or the other of the two views below:

- Scientific advice is an objective criterion in fishery governance, because the conclusions are based on the best available data.

- Scientific advice is a point of departure for discussion. Since the interpretation of data is subject to considerable uncertainty, fishermen's experiences and socio-economic considerations should be taken into account.

Misinterpretation and misunderstanding of "scientific advice" was an important subject of comments and the issue was addressed by all stakeholders and interested groups. There is consensus among the BS RAC members that the stronger inclusion of fishermen and fishing industry in the scientific data collection process is the most promising way to gain better and more reliable fish stock assessments. Although this process has started, our study indicates several issues of poor communication and mutual distrust between scientists and environmental NGOs on the one side and fishermen on the other as a significant barrier to a productive dialogue.

In this presentation I show that the "natural" difference of interests among the stakeholders is not the only – maybe not even the dominant – barrier to conducting productive dialogues. Further efforts to increase trust, improve communication and understanding of science may have a significant positive impact on the consensus building process among the stakeholders within the BS RAC.

3.3.10 Bayesian estimation of biological reference points

Laura Uusitalo, Samu Mäntyniemi, Sakari Kuikka, Heikki Peltonen and Jukka Pönni, University of Helsinki

Introduction

Biological reference points (BRPs) are widely used in fisheries management in order to define sustainable levels of exploitation and implement precautionary fisheries management. Two types of reference points are often defined: limit reference points (LRPs) that define the threshold values that should not be crossed and target reference points (TRPs) are those that are considered safe, but not sacrificing too much of the yields. These points are most often defined for spawning-stock biomass (SSB) and fishing mortality (F). Exact definitions, as well as names, of these points vary, however. For example, ICES uses two sets of biological reference points: limit values (B_{lim} and F_{lim}), which denote dangerously low spawning-stock biomass and dangerously high fishing mortality, and precautionary reference points (B_{pa} and F_{pa}), which account for the possibility of bias in the estimates of stock size and fishing mortality, and set a buffer between the limit and PA values.

In this work, limit and target reference points are examined in a Bayesian context, defining them according to Caddy and McGarvey (1996): Limit reference point is the safe maximum value for the fishery exploitation, and the target reference point is set so that it has a *small, preagreed-upon probability that LRP will be exceeded*. The approach is illustrated by estimating SSB and F reference points for the Baltic herring stock in the Bothnian Sea (ICES Subdivision 30).

Material and methods

A Bayesian age-structured stock assessment model was used to estimate the yearly SSBs, recruitments, and stock-recruitment curve parameters (Mäntyniemi *et al.*, *in prep.*). The limit reference points were chosen from literature: Mace (1994) suggested that the spawning-stock biomass (SSB) which produces 50% of the maximum recruitment (maximum of the stock-recruitment curve) could be used as the SSB limit reference point. Sissenwine and Shepherd (1987) pointed out that if the stock size is to remain constant over the years, the spawning potential of each recruiting year class over their life time needs to be equal to the spawning-stock biomass of their parents. If fishing mortality increases, the lifetime spawning potential decreases. Therefore, each fishing mortality can be associated with an average survival level that is required to maintain that F sustainably. Sissenwine and Shepherd suggested, therefore, that the fishing mortality corresponding to the average observed survival could be used as the limit reference point for F. These SSB and F reference points were computed for the Bothnian Sea herring. We used the same data ICES stock assessment working group uses.

Bayesian models include probability distributions for each variable and parameter in the model. These probability distributions describe our knowledge (and lack thereof) about the quantity in question. Therefore, we can also describe our knowledge and ignorance about the limit reference points as a probability distribution. This definition of the limit points lends itself directly to Caddy and McGarvey's definition of the reference points: target reference points will be set so that there is a *small, preagreed-upon probability that the LRP will be exceeded*. When the knowledge of LRP is expressed as a probability distribution, we can select the TRP directly according to our desired risk level (Figure 1).

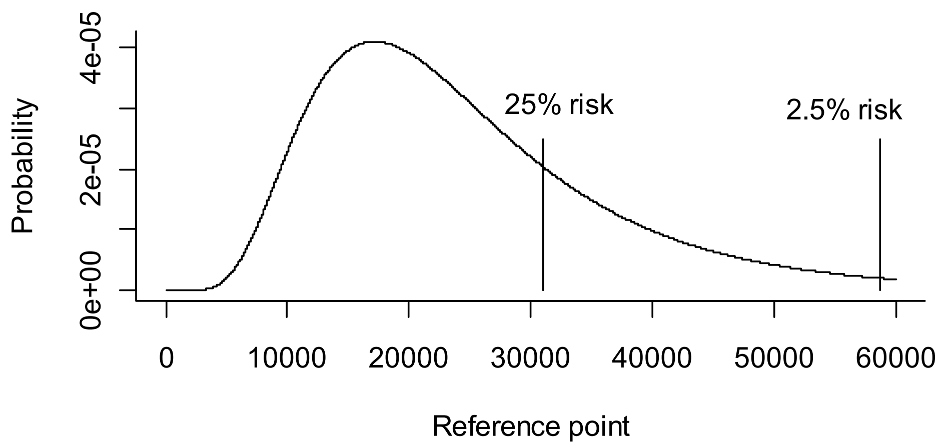

Figure 1. Example of setting the target reference point in Bayesian context.

The probability distribution function (the solid line) expresses our best available knowledge of the true value of the limit reference point (e.g. the SSB that produces 50% of maximum recruitment). The vertical lines represent the target reference points with 25% and 2.5% probability that the true, unknown LRP will be exceeded, if this TRP is chosen.

Results and Discussion

It is found that the uncertainty related to the real spawning stock sizes and yearly recruitment was very large (Figure 2). This also leads to high uncertainty about stock-recruitment curve parameters and therefore to very high uncertainty about the limit SSB. This directly leads to very high target SSB (Figure 3). Fishing mortality limit reference point, which is based on observed median survival rather than parameters of a fitted curve could be estimated with smaller uncertainty.

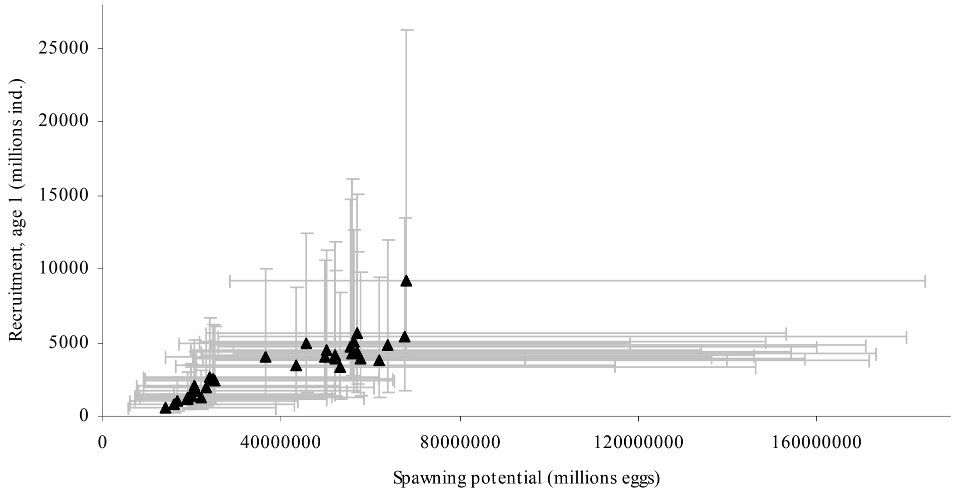

Figure 2. Estimates of spawning potential (expressed as the number of eggs produced by the spawning-stock biomass) and recruitment-at-age 1 with the 95% probability interval.

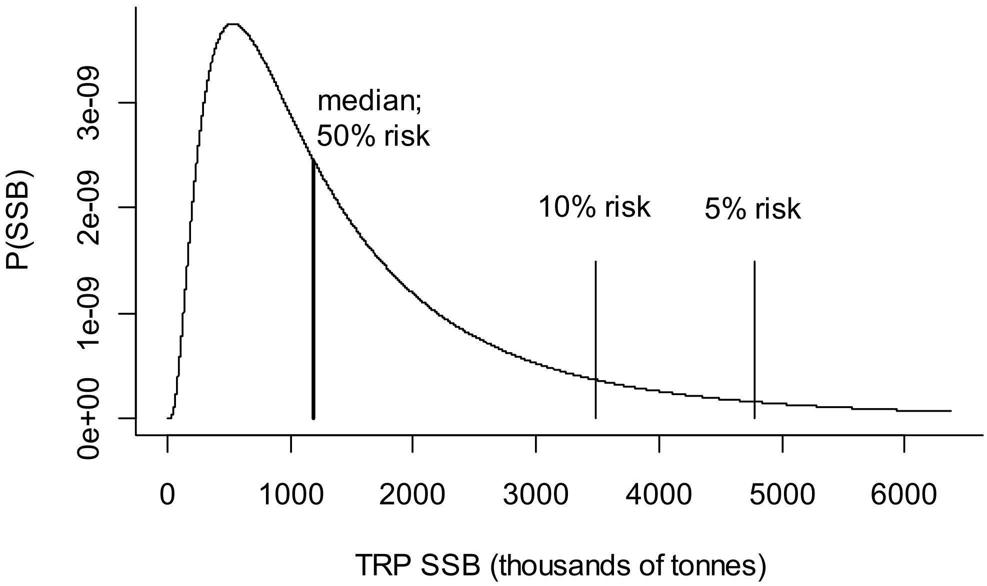

Figure 3. Estimate of the SSB limit reference point and exemplary target reference points with 10% and 5% risk level.

We suggest that computing TRPs based on the uncertainty about the true value of LRP will contribute to transparency of fisheries management. It also allows estimation of trade-offs between the risk taken and the allowed exploitation level. However, this approach doesn't directly address implementation uncertainty: if we aim fishing at TRP, what is the value we actually achieve? It is also suggested that, to the extent possible, management measures should e based on stock characteristics that can be estimated with a small uncertainty.

3.4 Results from the Synthesis Workshop on the Final Day

3.4.1 What are the Key General Lessons for Fisheries from other Areas of Science-based Policy?

Both knowledge judgements (what do we know about a given case/problem) and value judgements (protection goals, acceptable levels of impact, role/relevance of precautionary principle, sustainability, biodiversity, eco-system approach etc.) are highly significant as ingredients in fisheries management.

The group identified a set of factors from non-fisheries research which could be highly relevant. These were:

3.4.1.1 'Framing' as an explicit step involving experts, political decision makers and key stakeholders

Framing involves definition of the problem, the questions to be addressed, the boundaries of investigation, the conventions of scientific assessment to be applied etc. The value judgements implied in designing the scientific assessment process should be addressed and deliberated explicitly.

More intensive, systematic and targeted exchange between scientific experts and political decision-makers at this early stage of the fisheries management process and agreement on the way in which the scientific assessment process should be designed holds potential to facilitate communication of scientific advice – including communication of uncertainties – to political decision-makers. As both knowledge judgements and value judgements are highly significant at this stage it would be advisable to also include key stakeholders in the framing process.

3.4.1.2 Pro-active utilization of fisheries research

Results of a lot of fisheries research does not appear to be utilized in a proactive manner by decision-makers and resource users. This appears to be linked to the lack of a deliberate, systematic framing step. This appears to be a key area for future social science (science-policy interplay, governance, communication etc.) research.

3.4.1.3 Engagement through role play

Engagement through role play is a methodology which provides a 'blame-free' environment in which key stakeholders and scientists are able to exchange and understand each others point of view. Key stakeholders frequently perceive the world and its associated risks from very different and defined viewpoints. Understanding a variety of viewpoints can facilitate a wider understanding of the implications of their actions on a variety of diverse stakeholders including finance, political, social and environmental.

3.4.1.4 Effective communication requires both sending and receiving messages

Risk communication should not be seen as a one-way transmission of information. For risk communication to be effective it should be an interactive and iterative process which requires active engagement of all stakeholders involved. This requires constant feedback loops.

3.4.2 Does the acknowledgement of massive uncertainty change the role of scientists?

Uncertainty profoundly affects the roles of scientists in policymaking—as individuals, as a collective scientific enterprise, and in their relationships with decision makers.

3.4.2.1 Roles for individual scientists

All scientists play multiple roles in society: professional, political, personal. So the ethical question is one of balancing and distinguishing which role you are playing at a given moment, and hence it is appropriate to reflect before acting. Scientists have to be comfortable in performing such moral reasoning.

In their work, individual scientists make many choices that influence the quality and relevance of their products. In cases of high uncertainty, scientists must make many assumptions in order to deliver "answers" to policymakers. Their work products should allow reviewers to view key assumptions, and should discuss the sensitivity of the findings to those assumptions. Where the assumptions include major value judgments, decision makers should be queried.

Some scientists should be actively involved in critiquing existing management systems to ensure that those systems evolve with our evolving knowledge. They should be willing to offer balanced advice and speak in public.

3.4.2.2 Rethinking the role of the scientific enterprise

Science as an enterprise also filters its members' findings. The enterprise needs to avoid the orthodoxy trap of Kuhn's "normal" science, while preserving rigor and ensuring that only high quality work gains attention. In cases of high uncertainty, it is harder to perform quality control, achieve consensus, and deliver firm conclusions. Yet scientists have to learn how to acknowledge the presence of uncertainty without destroying the perceived value of scientific advice.

We suggest that it becomes more important to:

- reveal the process by which scientific conclusions emerged;
- identify robust rather than "optimal" policies/conclusions, so that scientists effectively take a Hippocratic oath to "above all do no harm";
- identify effective strategies for working with fishermen's' knowledge to ensure that it becomes scientifically valid and reliable;
- investigate the scientific demands of (and perhaps advocate for) alternative management regimes, e.g. a multispecies or ecosystem approach, or a protected-areas approach, rather than only continuing to accept the single-species approach;
- learn how to do effective participatory modelling and policy analysis;
- ensure that some scientists are performing "subversive" science aimed at trying find weaknesses in the current management regime and suggesting alternatives to it;
- identify areas of consensus and spokespeople to share those messages; and
- accept an obligation to open up the black box of scientific deliberation to reveal the extent of uncertainty, the major controversies, and the contingent nature of the result.

3.4.2.3 Helping decision makers better utilize what scientists offer

Policy decision makers expect clear and simple answers from scientists, which in cases of high uncertainty are more than scientists, can deliver. Scientists need to help policymakers (1) reframe what is asked (e.g. do not ask for a falsely precise total allowable catch number but instead ask for a broader dashboard of measures of mixed quality); (2) express objectives in a clear, quantitative and ranked manner; (3) design policies that are evaluate-able, and fund evaluations; (4) make it safe for scientists to offer meaningful advice without jeopardizing their careers; and (5) employ management strategies that accommodate the need to be more precautionary in cases where the knowledge base is weaker.

3.4.2.4 Key lessons

Working scientists should not limit themselves to being passive providers of information; they need to be active but thoughtful participants in management discussions, and help shape management regimes that make realistic use of what they know.

When there is great uncertainty, it becomes especially important to make the processes of scientific investigation and deliberation more transparent and open. Major controversies, negotiations, lack of data, variables etc. should be visible. Possibilities for non-scientists to participate in data collection and modelling should be encouraged.

The scientific community should clearly establish what it "knows" with wide agreement, and what factors underlie that consensus. The community should likewise distinguish what it does not know so well. It should help establish the pedigree of knowledge and identify the different degrees of uncertainty associated with that knowledge. The ways in which uncertainties are communicated have implications for how they are interpreted and acted upon. The scientific community should consider carefully which tools they use to communicate uncertainties to non-scientific audiences.

The scientific community should explicitly recommend how management strategies should accommodate different degrees of uncertainty. This requires development of a clear vocabulary for describing uncertainty, helping decision makers establish firm links to specific managerial alternatives, and advising managers in asking questions that can be answered by the scientific community.

3.4.3 How Should Scientists Relate to an Extended Peer Community?

More effective communication of scientists with others in extended peer community (EPC) and other contexts is particularly critical in a situation in which resource managers are confronted with great complexity and uncertainty for example when dealing with:

- Multi-species fisheries management;
- Ecosystem-based management;
- Increased numbers and types of social and economic interactions with marine ecosystems;
- Increased general public interest and concern;
- Developing the scientific requirements for the precautionary approach.

These are the conditions facing ICES and other groups tasked with providing science-based advice to fisheries management bodies.

The situation of great complexity, high levels of uncertainty, and demands for policy action is one that, as shown in many other domains, calls for what Funtowicz and Ravetz (1992) call "extended peer communities," broadening the scope of expertise to reflect other scientific specialists as well as lay members of society representing the groups most interested in and affected by the issues at hand (i.e. the stakeholders). Even more generally recommended, as shown in the literature on risk perception and communication (e.g. National Research Council [US] 1996, 2008), is an increase in the level and quality of wider participation in environmental decision-making. It is generally argued, especially where risks are substantial and there is high uncertainty, that participation be done much earlier, more frequently, and more effectively than is common. For example, participation is often relegated to the endpoint of a process of scientific assessment and policy-decision-making, where it becomes merely informative or educational, or at best an opportunity for stakeholders to react to highly developed proposals. Experience and research findings show that this is a poor way to proceed, and that having wider participation early in the process, perhaps even at the very beginning, can improve the substance, the credibility, legitimacy of science-based policy and compliance with its measures.

Therefore, follow general rule: MORE participation of interested and affected parties

- Earlier
- More often
- More truly interactive.

Fisheries management is moving in this direction in the EU, in North America, Australia, South Africa, and other countries, often under the rubrics of "co-management" or "participatory management," but thus far little attention has been given to the implications of this for scientific work, especially stock assessment and the advice that follows. We therefore propose that scientific work should be engaged with wider participation (i.e. extended peer communities) in an iterative process.

Scientists and "EPC" interact for these purposes:

- Broad scoping of issues, objectives
- Strong focus on overarching principles and management rules, with commitment to stick to them
- Identify expertise needed and ways to incorporate it (including socio-economic)
- Designing scenarios and selecting issues for models to test
- Creating trust and mutual understanding, social learning and capacity building.

Implementing this approach calls for rethinking of and reforms to existing systems of scientific stock assessment and its linkages to policy. This approach implies:

- Less focus on routine assessments; more on ones
- Openness to new evidence/Inputs coming from extended peer community as well as specialized science process
- Mechanisms for including economists, other social and/or policy scientists
- More willingness and encouragement to experiment with alternative and new approaches
- Both technical peer review and "extended peer review" with clarity about roles, criteria, rationales for models used

- Tailored to issues raised by EPC (scientists, fishers, policy-makers, greens, etc.).

This approach will be very demanding of all parties, and it will require high levels of commitment and rules of engagement. Some of the rules of engagement are:

- Agreement on criteria of science-based and evidence-based advice
- Explaining what the advice is and why it is made
- Commitment to the process (attendance, providing information, resources, etc.).

We conclude with a brief consideration of why the Extended Peer Community approach can be very helpful to the goal of improving marine fisheries management, not just a reflection of larger trends toward greater public participation. This approach can:

- Expand knowledge available for understanding and managing complex and dynamic systems
- Ensure transparency and accountability of the research/managing authorities
- Increase credibility of scientific advice and foster its use in decision-making.

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3.4.4 What are important Practical Questions about how ICES relates to its Extended Peer Community?

ICES has for a long time more or less self-consciously operated within an EPC. ICES has always faced high uncertainty giving advice that had important economic implications. It has had to relate to clients who were both scientifically literate people and people who had very specific requirements for ICES advice. So for ICES the concept of extended peer community is not new even if the term may be. Within this relatively narrow EPC the Advisory Programme has become very skilled at administering the flow of science and understanding how to carry out reviews and appropriately certify as "scientific" boundary objects in the form of official advice. The EPC that centres on ICES is changing and this requires greater and more intentional awareness of these processes in order to maintain scientific credibility in the fact of these changes. These changes include, *inter alia*, new demands for "transparency" from clients and others, increased media interest in fisheries and marine issues, and the advent of the Regional Advisory Councils with their current somewhat ambiguous role in the production of management advice.

These shifts are not easy. Through standard peer review, established scientific methods actually facilitate transparency because they allow the clearest explanation of how any particular piece of knowledge has been established. However, they also encounter what is called above (0) the "paradox of transparency" – that attempts to increase transparency create new opacity – because of the background and skills needed to carry out adequate peer review. The EPC increases the legitimacy of science and its saliency, or the degree to which it response effectively to the needs of policy. That is it purpose because scientific legitimacy and saliency, not credibility, are what uncertainty makes more difficult. Scientific credibility is established under uncertainty simply by acknowledging that a particular question cannot be answered at a particular time. It is the social requirements of science that are then called into question.

In an EPC the extension of the review process can be very costly. Some of these costs are quite apparent. More effort is needed to ensure adequate review at all levels. People resist being in an EPC because the transaction costs are so high. In an EPC interests are going to influence what facts are considered important, making review more time consuming. You can spend all your time reviewing instead of doing science. In ICES the current peer review system is very demanding and it is difficult to mobilize people. Many potential extended peer reviewers would prefer just to have an answer and let the scientists parse out the uncertainty; as long as they get the saliency they want and the results are legitimate in their own eyes. Other costs are less obvious. How do you review innovative approaches in general is an issue in a complex management system. An extended review process will make this even more difficult because the questions of the policy saliency of the innovation are raised immediately, even prematurely.

An ideal extended peer review (EPR) would be an iterative process beginning with goal setting followed by a step by step process of clarifying assumptions and their implications. When framing the policy problem, the EPR can contribute by mapping the values of interest. Further EPR can contribute in how these values and goals can best be translated to relevant management measures and relevant scientific problems. This would include a review of the justifications of choices of modelling approach, data and assumptions. This would require from the scientists involved that they carry out:

- A detailed uncertainty assessment to prepare the groundwork for the pedigree matrix discussed above (3.3.1)
- A sensitivity analysis to evaluate how assumptions and model specifications affect the conclusions.

Finally, unless we understand the extended peer community as part of an overall approach to management then the transaction costs will become overwhelming while the benefits of increased saliency and legitimacy will be lost. We suggest that the institutional form now being referred to as "results based management" with a reversed burden of proof would be the appropriate institutional context for an EPC within science for fisheries management. Results based management consists of:

- Formulating the objectives and setting the corresponding limits to measure progress towards each objective
- Making a management plan in response to those limits, including a plan for the monitoring of performance
- Auditing adherence to the plan i.e. for purposes of accountability, learning and future decision-making.

Under results based management the actual form of the EPC depends on the scientific and policy expertise required at any particular stage of the process. Step One requires a broad EPC in which many stakeholders with interest in the marine environment would have an interest in the scientific results. So an EPC for the science used for setting limits would involve the legal management authorities, the civil society, local government, environmental groups as well as economic interests. Step Two, however, no longer requires a broad EPC because the limits are already set and the burden of proof is on the economic interest to develop a plan for their activities that stays within the limits, including how they will demonstrate that they have stayed within the limits, set in Step One. Scientific advice is still required here, but the EPC does not have to extend beyond the particular economic interest that wants to be licensed to carry out an economic activity. In Step Three the scientific role is smaller as the mechanisms for accountability are part of the plan developed in Step Two. Some scientific input may still be needed and the EPC would then involve the monitoring authorities and the economic interests.

This is only an outline of an institutional goal that is a long way from being translated into a management system. The demands on ICES for developing scientific advice in a high stakes, high uncertainty environment continue and grow. The complexity grows greater as we approach an ecosystem approach to marine management. How we related to the extended peer community that we find ourselves in will require our continued attention.

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Annex 2: Agenda

The Working Group on Fisheries Systems / JAKFISH / CEVIS: Workshop on Uncertainty and Policy – Fisheries in Dialogue with Other Sectors				
Monday 13 October		Tuesday 14 October		Wednesday 15 October
9:00		9:00 9:30 10:00	Laurence Kell Kjellrun Hiis Hauge Doug Wilson (PKFM/SAFMAMS/JAKFISH)	Workshop led by Edward Borodzicz
10:45		11:00 11:30	Panayiota Apostolaki Robert Aps	Workshop continued
3:00 13:15 14:00	Welcome Tour de Table: Doug Wilson Clinton Andrews Jeroen van der Sluijs	13:30 14:00 14:30 15:00	Teresa Johnson Sebastian Linke Samu Mantyniemi Bonnie McCay	Workshop continued
15:00 15:45 16:30 17:15 17:30	Marion Dryer Lars Kjerulf Petersen Edward Borodzicz Reflection on day: Doug Wilson Close	16:00 16:30 17:00 17:30	Olga Stepanova Laura Uusitalo Doug Wilson (CEVIS) Close	Any required assignments for completing report Terms of Reference for 2009 Election of new chair Closing

Annex 3: WGFS terms of reference for the next meeting

The **Working Group on Fishery Systems** (Chair: Kjellrun Hiis Hauge*, Norway) will meet at ICES Headquarters in Copenhagen from 12–16 October 2009 to:

a) review and generate recommendations about the future structure of risk evaluation and management strategy research within ICES toward greater inclusiveness across the fisheries system and greater usefulness in policy advice. This includes re-evaluating the role of WGFS in light of several other ICES groups involved in risk evaluation and management strategy;

b) catalogue successes, problems and approaches in participatory, bio-economic modelling of management scenarios as a stakeholder involvement tool in fisheries management? This includes an evaluation the links and synergies between participatory modelling and collaborative research;

c) evaluate the past contribution of WGFS activities on ICES as a way to inform future directions.

WGFS will report by 1 December 2009 to the attention of the Resource Management Committee.

Supporting Information

Priority:	The main focus of WGFS is the fishery system and the role of scientific advice within that system. The system-based approach relates directly to priorities such as developing an ecosystem-based approach to management and the effective implementation of the precautionary approach. Consequently, these activities have a very high priority. The work of the Group is also essential if ICES is to advance the development of realistic projections of fisheries development that account for the reaction of other parts of the overall fisheries system.
Scientific Justification and Relation to Action Plan:	The Group met in 2000, 2001, 2003, and 2004 to develop a framework for case study analysis and has identified European (North Sea cod) and North American (Georges Bank mixed fisheries) case studies. Funding for the European case study had been granted from 2003 under the EU Framework V Programme; funding for the North American study was granted from 2004. This effort resulted in 7 papers that were published in the special issue of the ICES JMS based on the Symposium on Management Strategies held in Galway in 2006. The key role for the WGFS is to integrate across disciplines to develop analytical and investigative methods/approaches for studying fishery management systems. The main but not exclusive focus of these investigations of the overall fisheries system is to improve the effectiveness of scientific advice. The Group met in 2005 in conjunction with the PKFM, FEMS and EASE projects all of which dealt with organizational and institutional aspects of the production of scientific advice. The 2006 meeting placed a strong emphasis on the ecosystem-based approach and particularly the issue of spatial planning. The 2007 meeting also considered and provided specific recommendations in relation to ICES current reorganization of the advice system, especially in respect to the European Marine Strategy and the role of the Regional Advisory Council. The 2008 meeting invited experts from policy arenas outside of fisheries to discuss the ways they handle uncertainty in making scientific advice.
Resource Requirements:	Secretariat support for meeting.
Participants:	These include scientists working with fisheries management, both from an economic, social and biological perspective. Participation is from ICES countries and scientists both from disciplines and scientific circles not traditionally represented at ICES.

Secretariat Facilities:	No additional software/hardware is anticipated beyond that which is currently available.
Financial:	None
Linkages to Advisory Committees:	The goal for this Working Group is to better understand fishery management systems which is a central element of the work of ACOM.
Linkages to other Committees or Groups:	Close links to SGMAS and SGRAMA who address the technical aspects of management strategies.
Linkages to other Organisations	ICES will continue to seek to widen participation for this group, including contact with relevant academic and inter-governmental organizations
Secretariat Cost Share	ICES: 100%