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Report of the Study Group on Risk Assessment and Management Advice (SGRAMA)

5–9 February 2007

Cape Town, South Africa

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The ICES Study Group on Risk Assessment and Management Advice (SGRAMA) met at University of Cape Town (UCT), South Africa from the 5–9 February 2007. This was the second meeting of the Study Group and the group started with the continuation of reviewing risk assessment frameworks and comparing these. Local participants presented the "Australian framework" for risk assessment (Fletcher, 2005) and also the local experience of using this framework for several risk assessments in an ecosystem approach setting (see Section 4.7.2. The work of the Study Group overlays to some extent with the EU project PRONE (see Section 8.2) and the progress of that project was summarized for the Study Group.

ICES fisheries advice has traditionally focused on single harmful event; recruitment failure or impaired recruitment. In a risk assessment context the scope of events will be broadened and given weight not only related to the probability or likelihood of such an event, but also the magnitude of the consequence. Measures of consequence can range from fairly simple ones as loss of yield (in tonnes) to socio-economic consequences where it is obvious that ICES will have to rely on expertise traditionally not included in ICES working groups. A broader range of issues within a risk assessment framework may take ICES advice further towards an ecosystem approach.

Risk assessments have the potential of replacing the current ICES framework to the precautionary approach. One aspect of this is the use of risk estimation within a Management Strategy Evaluation. The quality of such evaluations will rely on several judgements (e.g. a series of assumptions) with their justification, but will still represent simplifications and situations where not all sources of uncertainty are accounted for. A very interesting approach in that respect is the South African handling of "Exceptional Circumstances" within their Operational Management Procedure. This approach is basically comparing observations with their modelled counterparts (such as observed catch rates and predicted catch rates) and if the observation(s) fall outside a predefined confidence band they represent a situation not covered by the evaluation testing and some kind of action must be taken.

A risk assessment process offers one method to include elements of an Ecosystem Based Approach to fisheries management. A range of issues must be dealt with on a case-by-case basis and a way forward can only be found by trying and learning from the experience.

The Study Group is presenting a first suggestion for an ICES framework for risk assessment (se Figure 9.1). This framework is designed to handle a broad scope of issues and will then of course need broad participation from different fields of expertise including stakeholders. The process is described in 5 basic steps including "feedback" to earlier steps and formal reviews of elements of the process.

The Study Group is expected to link the results (the risk assessment framework) with the results from the Study Group on Management Strategies (SGMAS) and a short summary of the activity at the last SGMAS was presented. SGMAS had stakeholder participation on their last meeting and SGRAMA recognize the need to try out the suggested framework in a case study where stakeholder and manager participation will be essential for the outcome. Experiences from such a case study could then be used to finalize a set of guidelines for how to conduct an ICES risk assessment. A vital part of such a case study will be the gaining of experience in how to present the results to stakeholders and managers.

1 Opening of the meeting

The Chair opened the meeting at 10:00 on 5 February 2007. The list of participants and contact details are given in Annex 1. The venue was the meeting facilities in the Mathematics Building at University of Cape Town (UCT). The meeting facilities are well suited for such a meeting, but since there is a lack of access to a computer network in the rooms, meetings must be planned and conducted with that in mind.

1.1 Acknowledgements

SGRAMA gratefully acknowledges the contributions made by a number of individuals preparing and submitting their work to the group. Such presentations are essential to any scientific study group.

The group will also thank Doug Butterworth and his group at UCT for hosting the meeting. This enabled the meeting to run smoothly and helped us staying focused throughout the meeting.

2 Adoption of the agenda

There was no formal agenda for the meeting. The Study Group started the meeting with presentations of the different working documents submitted to the meeting. A short series of plenary discussions handling matters of a general interest was followed by work in three different subgroups. The topics handled by the subgroups (corresponding to section headings in this report) were:

- Risk assessment and management strategies
- Risk assessment as a tool for the ecosystem approach
- An ICES framework for risk assessment

The last day of the meeting started with a summary session where the work in the different subgroups was presented to the group and invited guests from Marine and Coastal Management and the University of Cape Town. The remaining part of the meeting was spent on the discussion and adoption of recommendations from the group. The recommendations can be found in Annex 3 of this report and are grouped into:

- General recommendations
- Risk assessment and Management Procedures
- Risk assessment and the Ecosystem Approach to Fisheries
- Recommendations for future meetings of the study group

3 Introduction

The Study Group chose to build the report around last year’s report. The purpose is to make the reading of the report easier (without referring to results in last year’s report). The first meeting of the Study Group attracted only a few participants while this meeting saw increased participation from ICES member states as well as local participation from Marine and Coastal Management (MCM), the University of Cape Town (UCT) and with two scientist from the National Marine Information and Research Centre (NATMIRC) in Namibia.

The most used definition of risk describes risk as the product of two components: The likelihood (or probability) of an (adverse) event or effect and the consequence or seriousness of the event.

ICES has traditionally only addressed the likelihood or probability component of risk which is quite challenging in itself. Our perception of the stochastic (or probabilistic) properties of estimates is based upon a series of assumptions (too often poorly justified) regarding the source of this uncertainty. And we are also facing situations where sources of uncertainty are not probabilistic in nature, but a severe source of bias. Such bias can be of a magnitude that makes estimates unsuited for decision making and represents “a lack of knowledge” situation with the frustrating implications for the advisory and decision-making processes.

The other component of risk is measures of the consequence or seriousness of an adverse effect or event. Such consequences are usually easily understood if given in monetary terms or other well known or familiar measures. Adverse effects on the ecosystem represent additional challenges. To put it a little bluntly: “At what level is the human (fishery) impact on the ecosystem damaging instead of a change?” Understanding and some kind of agreement or decision on the “seriousness” of consequences are needed if risk assessments shall form a basis for decision making.

Our review of different frameworks for risk assessment has revealed that most approaches emphasize the importance of participation from scientist, managers and stakeholders. And this relates both to the quality of the work as well as acceptance.

4 Reviews

This section consists of two well-differentiated parts. On the first part the main ideas about risk terminology and decision-making framework of some relevant works are summarized. This covers general books as Burgmann (2004) or reports from organizations like UKCIP (Willows and Connell, 2004), IPCC (2004) or EPA (1998) or published papers as (Lane and Stephenson, 1997; Francis and Shotton, 1997). In addition, different fields like climate change adaptation in (IPCC 2004; Willows and Connell, 2004), environmental management in Burgmann (2004) and EPA (1998) or fisheries management in Lane and Stephenson (1997) and Francis and Shotton (1997) are dealt with, providing a broad perspective throughout the applications in different fields. Due to participation from South African colleagues the review of the “Australian Approach” (Fletcher, 2005) was followed up with information from the experience of applying this framework. The second part studies the main similarities and discrepancies of the reviewed literature, with a special attention to uncertainty, risk terminology and decision making framework.

It is important to note that this section does not intend to be a complete revision of the available literature, but only a few examples of different ways for defining and dealing with risk related issues.

4.1 Review of IPCC Workshop on “Describing Scientific Uncertainties in Climate Change to Support Analysis of Risk and of Options” (IPCC, 2004)

The reviewed document from Intergovernmental Panel on Climate Change (IPCC, 2004) is a report from a workshop and presents risk and uncertainty from several angles. The main issue is uncertainty rather than risk: uncertainty related to science and socio-economic factors but also communication of uncertainty is emphasized. The workshop conclusions are more recommendations for future work within IPCC on uncertainty and risk so that it does not conclude on any framework for risk assessment or risk management. However there are some elements from this report that is worth noting. One is a presentation of the UKCIP approach, which is reviewed in Section 4.4. We will thus concentrate on the workshop’s recommendations on how to handle uncertainty questions and some considerations on risk that are presented in different parts of the report.

Workshop recommendations

One of the conclusions at the workshop was a list of recommendations on how to handle uncertainty questions. These were:

- Authors should consider how to deal with uncertainty early on in their planning.
- Key issues requiring careful treatment of uncertainties should be identified as soon as possible.
- Consistency across the report should be maintained by using techniques for communicating uncertainty from among a set of options summarized in the guidance notes.
- Authors should consider both structural and statistical sources of uncertainty
- Authors should note the difference between likelihood and level of confidence in the underlying science.
- Probability distributions should only be used where there is high confidence in the underlying science
- Traceable accounts should document the basis used for making expert judgment.

Risk

The goal of the workshop was not to agree on a risk framework, but frameworks are presented in papers at the workshop. The report shows that there is an agreement from 1998 on how to use the term “risk”: “the likelihood that some event will occur or its expected frequency of occurring and the magnitude of the consequences of that event”.

The report recognizes that there are a number of different approaches to assessing risk, from formal and quantitative to largely personal responses based on experience and perceptions. All these deal with uncertainty in one way or another and the qualitative and contextual aspects are always important. For example, asymmetry is often recognized in the sense that being wrong in one direction may have more serious consequences than being wrong in the other.

The report says that an aim is to enable users of the IPCC assessments to more easily relate effects of climate change to other risks, and to integrate decision on climate change with existing decision making frameworks for dealing with risks.

Further the report argues that it is important to distinguish between uncertainties in predicting the frequencies of events and the uncertainty in their consequences.

This is an example of how it links risk to uncertainty: “Probabilistic approaches can be applied to risk analysis when strict numeric probabilities can be defined, e.g. when long term statistics are available for stationary phenomena. Because of this, risk analysis is most easily linked to probabilistic approaches to uncertainty. However, risk analysis techniques are frequently adapted to deal with circumstances in which strict numeric probabilities cannot be defined. In either case, uncertainty analysis plays a key role in risk assessment.”

Uncertainty aspects (selected)

In the report it is highlighted that there is a difference between the level of uncertainty and the level of confidence. By the level of uncertainty they mean the quantified uncertainty while the level of confidence refers to the degree of belief or confidence in a science community that available models or analyses are accurate. The confidence is based on both evidence and the more subjective interpretation of results. The report argues that both the quantified uncertainty and the confidence should be stated.

It is expressed that rather than presenting the single most likely prediction, a range of possible outcomes should be presented.

It is recommended that a comprehensive view of all plausible sources of uncertainty should be presented.

The report suggests how to present the knowledge that climate assessments are based on to reflect uncertainty aspects:

- Known: summarize present knowledge;
- Unknown: describe research needed to improve that knowledge
- Unknowable: summarize what we are unlikely to be able to know before the changes actually occur.

The report presents an interesting view on the nature of uncertainty:

"The goal of making scientific understanding of climate change widely accessible raises particular challenges when it comes to dealing with uncertainty. Uncertainties are usually more difficult to quantify than the factors to which they apply; their treatment is more complex both conceptually and operationally; and the normal use of language to describe uncertainty is often ambiguous. In order to deal with uncertainty in a way that is coherent [...] and useful for decision making it is recommended that descriptions of uncertainty be designed in ways that will improve risk assessment. This approach recognizes that climate change will modify existing risks and in doing so introduce additional sources of uncertainty into risk assessment."

4.2 Review of "Guidelines for Ecological Risk Assessment" (EPA, 1998)

The document has 188 pages and has in addition to the sections related to risk assessment also a section on "response to science advisory board and public documents". This very brief review is looking into some of the terminology and how the assessment process is described (as a framework).

Terminology

The guidelines document has a separate appendix on "key terms" and 4 of those are shown below:

Assessment endpoint — An explicit expression of the environmental value that is to be protected, operationally defined by an ecological entity and its attributes. For example, salmon are valued ecological entities; reproduction and age class structure are some of their important attributes. Together "salmon reproduction and age class structure" form an assessment endpoint.

Conceptual model — A conceptual model in problem formulation is a written description and visual representation of predicted relationships between ecological entities and the stressors to which they may be exposed.

Ecological risk assessment — The process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors.

Risk characterization — A phase of ecological risk assessment that integrates the exposure and stressor response profiles to evaluate the likelihood of adverse ecological effects associated with exposure to a stressor. Lines of evidence and the adversity of effects are discussed.

The guidelines contain no clear definition of risk as such. And since the guidelines are intended as internal guidance for EPA (U.S. Environmental Protection Agency) they are written with a specific set of problems in mind and much of the terminology is likely to exist as a part of an "agency culture".

Framework

The guidelines describe the risk assessment process as three phases: Problem formulation, analysis and risk characterization.

1) The purpose of the problem formulation phase is to articulate the problems (risks?) assessed and to plan how to do the next two phases (analysis and characterization). Initial work includes the “integration” of available information used to produce “assessment endpoints” and “conceptual models”.
2) The “assessment endpoints” and “conceptual models” are used to direct the analysis (second phase). The analysis is focused on “characterization of exposure” and “characterization of ecological effects” (cause and effect).
3) The risk characterization phase is divided into “risk estimation” and “risk description”. The risk estimation part gives fairly practical advice on how to estimate risk including the use of professional judgment or other qualitative evaluation.

The guidelines include some considerations related to risk management, risk managers and “interested parties”. The guidelines state that the planning of a risk assessment should include dialogue with risk managers and “interested parties”. “Communicating results to the risk manager” is mentioned as a separate step after risk assessment. “The ecological risk assessment framework” is visualised in Figure 4.2.1 (from EPA 1998)

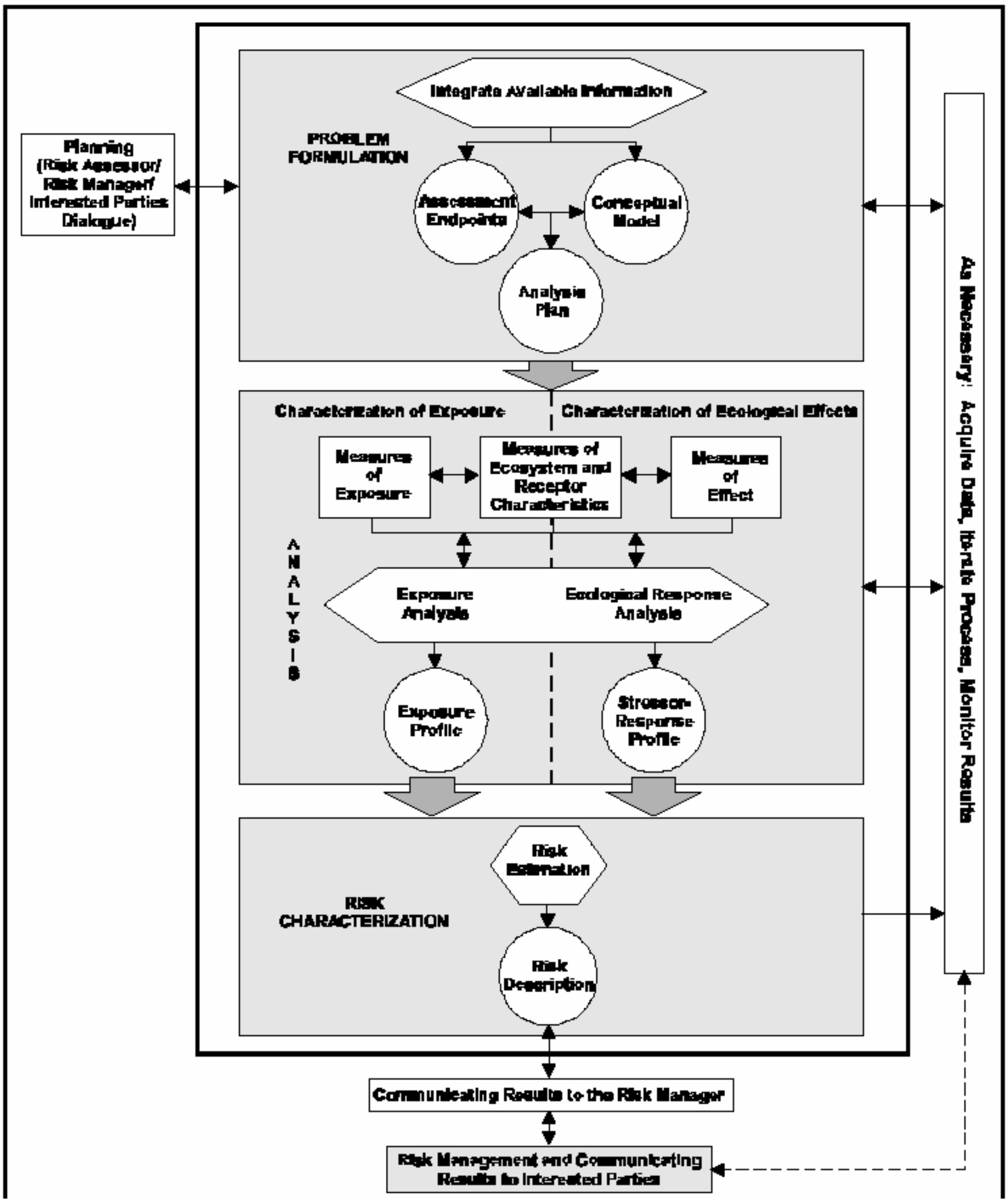

Figure 4.2.1. The ecological risk assessment framework (from EPA, 1998).

4.3 Review of the book "Risks and Decisions for Conservation and Environmental Management" (Burgmann, 2004)

This review is limited to aspects of risk assessment and/or risk management frameworks (relevant chapters are 3, 5 and 12).

Overview and overall impression

This book outlines how to conduct a complete environmental risk assessment. The first part documents the psychology and philosophy of risk perception and assessment, introducing a taxonomy of uncertainty and the importance of context; it provides a critical examination of the use and abuse of expert judgement and goes on to outline approaches to hazard identification and subjective ranking that account for uncertainty and context.

The second part of the book describes technical tools that can help risk assessments to be transparent and internally consistent; these include interval arithmetic, ecotoxicological methods, logic trees and Monte Carlo simulation. These methods have an established place in risk assessments in many disciplines and their strengths and weaknesses are explored. The last part of the book outlines some new approaches, including p-bounds and information-gap theory, and describes how quantitative and subjective assessments can be used to make transparent decisions.

The book thus covers a broad field of aspects regarding risk assessment and management for the decision making process in conservation biology. This is also reflected in the table of contents given below:

1) Values, history and perception
2) Kinds of uncertainty
3) Conventions and risk management cycle
4) Experts, stakeholders and elicitation
5) Conceptual models and hazard assessment
6) Risk ranking
7) Ecotoxicology
8) Logic trees and decisions
9) Interval arithmetic
10) Monte Carlo
11) Inference, decisions, monitoring and updating
12) Decisions and risk management

From this it can be seen that only part of the chapters are directly related to assessment and management procedures/algorithms and thus may have some potential for setting up a template of a risk assessment and/or management framework. The chapters directly touching these three aspects are 3, 5, and 12. Because of their introductory nature also chapters 1 and 2 will be part of the review.

In general, as the table of contents shows this book is quite complete in spanning a broad range of aspects in environmental risk assessment and management. It thus gives a lot of definitions of all-important elements of risk assessment and management. Unfortunately it is predominately descriptive and thus dominated by phrasing definitions and procedures and less by comprehensively formulating these in some formal way using a statistical or mathematical language where it would be necessary. But as outlined in the preface of the book this was also not the intention of it. It further lacks detailed examples where equations are given to a somewhat sufficient extent; the only chapter where some examples with equations are given is chapter 10 (“Monte Carlo”). Anyhow, a strength of the book is that (also in chapter 10) sensitivity analysis is outlined here as a powerful tool to check underlying model assumptions by examining uncertainties (parameter uncertainty, structural uncertainty, shape uncertainty, dependency uncertainty). A weakness of the book is that the author jumps between the various fields in a non-structured way.

In summary, it is a good book for giving a complete descriptive overview of the topic. Anyway, for practically installing and implementing a risk based assessment and management approach within ICES we need clearer and more explicit definitions and formulations in order to make a step forward compared to the current status quo. The book has more the character of a bulky philosophical encyclopaedia and less of a systematically structured manual how to proceed. In practice it lacks the instructional ability necessary for creating a risk assessment and management framework. Nevertheless, to some degree it can be a good source for looking up specific things (e.g. definitions, concepts) and clarifying these.

Chapters 1 and 2: Introduction and basic definitions

Risk is described here, as “the chance, within a time frame, of an adverse event with specific consequences”. The term “hazard” is used as a part of the detailed risk definition where hazard itself is defined as an intrinsic potential of harm.

Risk analysis is defined as “evaluation and communication of the nature and extent of uncertainty”.

Risk assessment is understood as the “completion of all stages of the risk management cycle, a marriage of risk analysis, adaptive management, decision tools, monitoring and validation”.

What is good here is that it outlines the duality of probability by distinguishing between chance and belief; the one dimension of probability is seen here as a statistical (or relative) frequency (objective probability, chance), the second dimension as the degree of belief warranted by evidence (subjective probability). It then presents a variety of probability definitions in this context that could effect risk measurement and stresses the fact that the concepts of probability and of defining consequence play a major role in risk definition and estimation.

It also makes the connection between probability and statistical inference and consequently outlines the link to uncertainty; in an own chapter (chapter 2) it thus describes the various types of sources influencing uncertainty (epistemic uncertainty: variability, measurement error, systematic error, natural variation, model uncertainty, subjective judgement; linguistic uncertainty: vagueness, context dependence, ambiguity, underspecification, indeterminacy).

Chapter 3: Conventions and the Risk Management Cycle

This chapter focuses on defining some essential conventions (hazard, stressors, environmental aspects, environmental effects) and on giving a rough overview of various disciplines (in terms of selected examples which illustrates aspects of risk assessment procedures) and some risk definitions (probability interpretation, frequency interpretation, subjective ranking) related to these such as

- ecology (fisheries, conservation biology)
- engineering (nuclear power, petroleum geology)
- ecotoxicology (for instance, US, EPA)
- public health (physician’s judgements, epidemiology, US, UK)
- economics (stock market mechanisms).

It sets up a common context for environmental risk assessment by defining:

- management goals (that embody broad objectives)
- assessment endpoints (that translate management goals into a conceptual model)
- measurement endpoints (things that can be actually measured)

and by touching the following two aspects:

- selecting endpoints (difficult to do due to complexity of systems, definition of general characteristics, tools to test whether objectives are reached)
- targeting risk assessments
    - sampling ecosystem attributes, indicators
    - definition of the level of impact (populations, single/multiple species, communities, ecological processes, natural resources)
    - measures of impact (changes in genetic variability within/between populations, relative abundance of stage/of a species, numbers of species and their relative abundances, the abundances of functionally different kinds

of organisms, species turnover from place to place in the landscape within a community, the value or magnitude of ecosystem services, species turnover among communities, the number/size/spatial distribution of communities).

Other aspects touched are practicalities for the choice of measure such as expense and time, experience in labs, problems with the definition of endpoints, complexity of systems, the need of calibration/standardization/standards (baseline conditions) and of setting up protocols, visualisation tools, etc.

It then discusses the risk management cycle, which involves the steps

- initial learning
- problem formulation
- hazard identification
- risk analysis
- sensitivity analysis
- decision-making
- monitoring
- communicating
- updating
- plus from-time-to-time validation, revision, reinforcement, adaptive improvement

Chapter 5: Conceptual Models and Hazard Measurement

Here conceptual models of hazard assessment are discussed with focus on schematically structuring and framing it. The simplest and most illustrative one is considered to be an influence diagram which is basically a visual representation of the functional components and dependencies in the system with different types of shapes (ellipses, rectangles) representing variables, data, and parameters. Arrows link the elements to specify causal relationships and dependencies.

It is further stated that – "to make things clearer and to foster a feasibility/operability study - proposals should be separated into phases (time frame) and should include a benefit-cost (investment) analysis." This chapter then discusses how to set up checklists, carrying out (structured) brainstorming (expert brainstorming, hazard operability analysis (HAZOP)), and formulating a hazard matrix as a matrix of interactions linking hazards to activities and components of the environment that may be affected by the actions.

It also touches FMEA, which is the failure modes (categories of failure) and effect analysis. It involves calculating a risk priority number (RPN) for each hazard as the product of the three quantities severity (assessment of the seriousness of the effect of failure), occurrence (assessment of the likelihood that a particular cause will lead to a failure mode during a specific time frame) and detection (assessment of the likelihood that the current controls will detect the cause of failure mode or the failure mode itself). The RPN is used to set priorities for action on hazards and to identify elements that require additional planning and to set critical thresholds.

Then another method is discussed which is the hierarchical holographic modelling (HHM). Hierarchical holographic models recognize that more than one conceptual (or mathematical) model is possible for any system. They try to capture intuition and perspectives embodied in different conceptual (or mathematical) models/sub models (i.e. individual assumptions, biases, etc. of some specific modeller). Each sub model is then seen to be a complete view of the system from a single perspective.

Chapter 12: Decisions and Risk Management

It is firstly stated here that risk management makes use of the results and insights from risk assessment to manage the environment. Chapter 12 touches following aspects

- the link between policy and risk (comparative risks, real and perceived risks, definition of acceptable risks);
- the philosophy of strategic decisions (decision criteria, risk regulation, procedures of deciding under uncertainty);
- the philosophy of stochastic analyses and decisions (stochastic dominance, benefit-cost analysis, stochastic dynamic programming);
- what to do with info-gaps (measures of performance, models for uncertainty);
- how to evaluate attitudes to decisions (scenario analyses, multi-criteria decision analyses, multi-criteria mapping);
- how to communicate risks (communicating probabilities/comparative risks, selection of the target audience and adaptation to it, determination of the purpose of communication, meeting legal requirements or policies limiting the design of risk communication);
- the philosophy of adaptive management, precaution and stakeholder involvement.

4.4 Review of the UKCIP Technical Report on "Climate adaptation: risk, uncertainty and decision making" (Willows and Connell, 2003)

The technical report of the United Kingdom Climate Impacts Programme (UKCIP) (Willows and Connell, 2003) aims at providing guidance that helps decision and policy makers to take into account the risk and uncertainty associated with climate variability and future climate change and to identify and evaluate measures to mitigate the impact or exploit the opportunities presented by future climate. The report is structured in two parts. The first part presents a decision-making framework. The second part provides supporting material on risk assessment in general and risk-based climate change impact assessments in particular, including an overview of concepts related to risk and uncertainty.

Terminology

The basic definitions related to risk and uncertainties that are given in the report are as follows:

Hazard: Situation or event with the potential to cause harm.

Risk: Product of the probability or likelihood of an event occurring and the magnitude of the impact or consequence associated to that event. The reports remarks that in some cases in might be more useful to retain and communicate the likelihood and impact components of risk separately, as this will allow the decision-maker to decide policy and ethical issues. For example, if the decision-maker may wish to implement a policy of risk-aversion.

Uncertainty: Lack of knowledge. Thus, concerning risk uncertainty may result when the probabilities of the hazards and/or the magnitudes of their associated consequences are uncertain. However, even when there is a precise knowledge of these components there is still uncertainty because outcomes are determined probabilistically.

Three types of uncertainty are distinguished:

a) Natural variability

b) Data uncertainty arising from measurement error, incomplete or insufficient data or extrapolated data.

c) Knowledge uncertainty referring to lack of knowledge about the processes or future outcomes. Model uncertainty is a particular case of knowledge uncertainty and includes uncertainty on model choice and structure; model input values, model parameters and model output variables.

Risk analysis: Process, by which knowledge concerning the probabilities, uncertainties and magnitude of future events is brought together, analysed and organised by the decision-maker. Risk analysis includes risk assessment, risk evaluation, and the identification and assessment of risk management alternatives.

Risk identification: Process by which hazards are recognized and characterized.

Risk assessment: Process by which hazards and consequences are identified, characterized as to their probability and magnitude, and their significance assessed. Risk assessment may involve either quantitative or qualitative techniques. Qualitative techniques are particularly useful in circumstances where we lack knowledge of the probabilities.

Risk evaluation: Component of risk assessment in which judgments are made about the significance and acceptability of risk.

Risk estimation: Rigorous determination of the characteristics of risks, usually progressing from qualitative to more quantitative approaches. These characteristics include the magnitude, spatial scale, duration and intensity of adverse consequences and their associated probabilities as well as a description of the cause and effect link.

Risk screening: Following initial identification of hazards and risks, risk screening is the process by which it is determined which risks should be investigated in more detail. Risk screening is usually based on ranking or scoring methods

Risk assessment endpoints: Explicit expression of the attributes, associated with a receptor that is to be protected or achieved. Risk assessment endpoints may represent an intrinsic threshold or an agreed, policy-defined threshold, at which decisions to manage the risk will be required. A measurement endpoint may be defined for the attribute in terms of the probability that a certain level of performance will be achieved over a defined period of time, and with a specified level of confidence.

Risk management: Any action or portfolio of actions that aim to reduce the probability and magnitude of unwanted consequences or manage the consequences of realized risks.

Tolerable risk: The willingness to live with a particular level of risk, in return for certain benefits, based upon a certain confidence that the risk is being properly controlled or managed.

Decision making framework

The decision-making framework is illustrated in Figure 4.4.1.

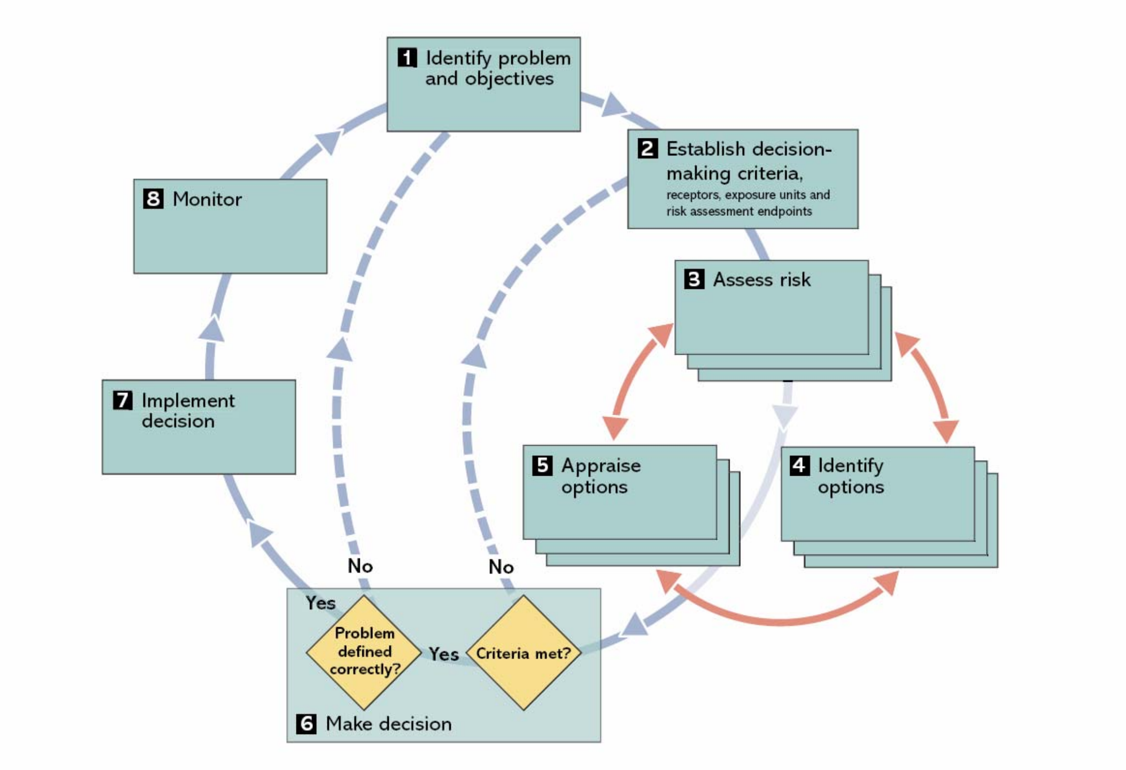

Figure 4.4.1. Decision making framework taken from the UKCIP report (Willows and Connell 2003).

The decision-making framework has eight stages:

1) Identify problem and objectives: Before starting the decision making process it is important to understand the reasons for the decision being made and the decision-maker's broad objectives.
2) Establish decision-making criteria: In this stage the broad objectives of the decision-maker of the previous stage need to be translated into operational criteria that can be used in a formal risk assessment, and against which the performance of different options and the subsequent decision can be evaluated. This includes an agreement on preliminary risk assessment endpoints that relate to the decision criteria.
3) Assess risk. The objectives of this stage are to characterise the nature of the risk, to provide qualitative or quantitative estimates of the risk, to assess the consequences of uncertainty for decision options and to compare sources of risk. One of the key issues of this framework is that the risk assessment will be undertaken at different levels depending on the level of decision and the level of understanding. See Figure 4.4.2.

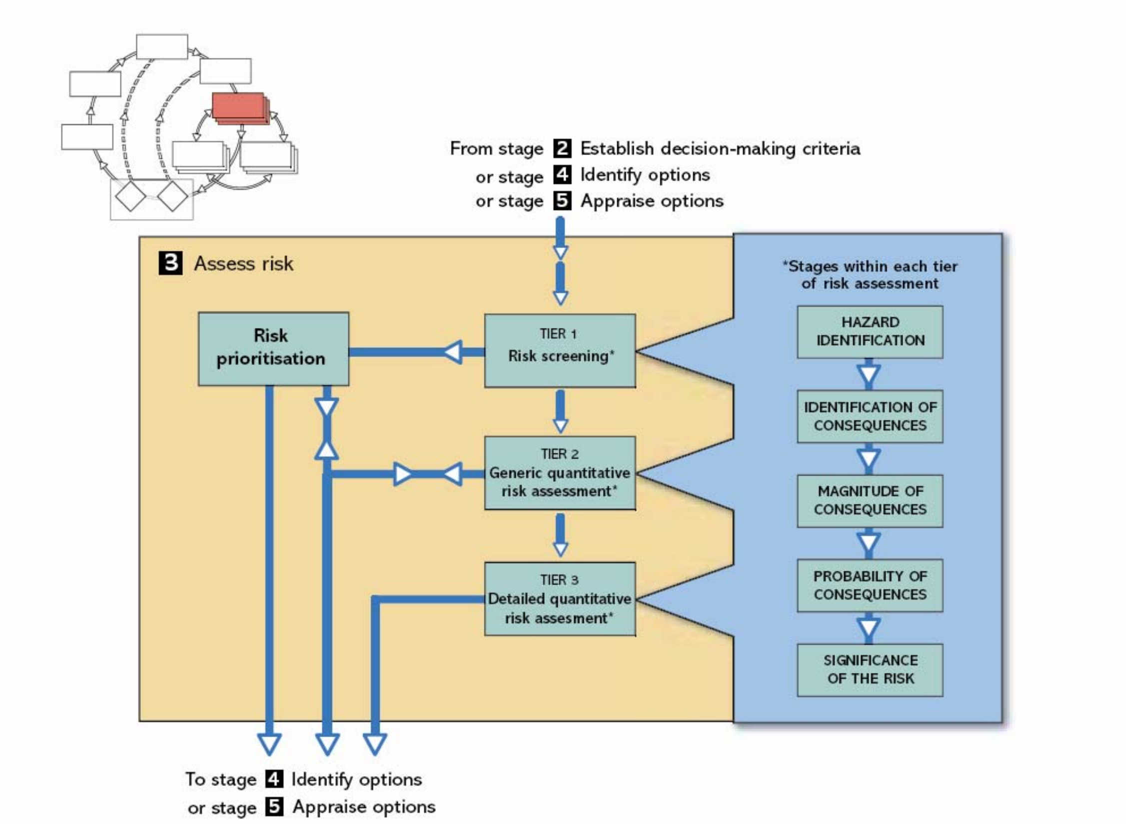

Figure 4.4.2. Stages within risk assessment (Willows and Connell, 2003).

4) Identify options: At this stage it is important to consider a wide range of potential options and to avoid the premature rejection of viable options.
5) Appraise options: This stage comprises the evaluation of the options against the criteria established in stage 2.
6) Make decision: This stage consists on bringing the information together and evaluating it against the objectives and defined decision criteria. It includes the effective communication of the analysis.
7) Implement decision.
8) Monitor, evaluate and review.

In general, the three important aspects of this framework are that: (i) it is circular, allowing the performance to be reviewed and decisions revisited through time, (ii) it is iterative, allowing refinement as a result of previous analyses and (iii) certain stages are tiered, allowing screening, evaluation and prioritisation of risks. It is important to remark that this decision process should involve all stakeholders.

4.5 Review of the paper "A framework for risk analysis in fisheries decision-making" (Lane and Stephenson, 1998)

This paper examines the form and content of an analysis for decision-making that specifically incorporates risk analysis – risk assessment as well as risk management.

Terminology

The main definitions related to risk that are given in Lane and Stephenson (1998) is as follows:

Risk analysis: Overall process that comprises risk assessment and risk management

Risk assessment: Process that evaluates possible outcomes or consequences and estimates their likelihood of occurrence as a function of a decision taken and the probabilistic realization of the uncontrollable state dynamics of the system.

Risk management: Process whereby decision makers use information from risk assessment to evaluate and compare decision alternatives.

Framework

The authors state that in the traditional framework for fisheries advice (Figure 4.5.1) the scientific resource evaluation function, is restricted to biological considerations, and it is separated from other economical or social issues. However, afterwards these other factors will lead to modification of advice by external pressures (kinked lines).

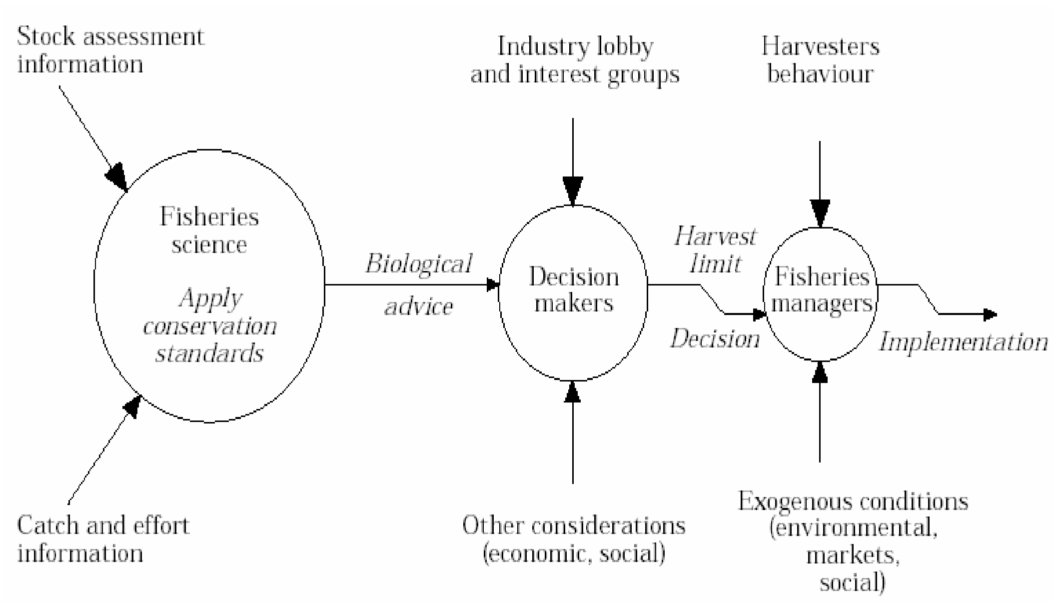

Figure 4.5.1. Conceptual view of the traditional framework for fisheries advice and management (Lane and Stephenson, 1995a).

Hence, the authors defend that effective decision-making in fisheries requires the provision of "fisheries management advice" (vs. strictly biological advice or economic advice, etc.) based on applying general principles of problem-solving including quantitative evaluation of alternatives and projection of their strategic implications on all aspects of the fishery system. The proposed decision framework is illustrated in Figure 4.5.2. The essential steps in this framework are summarized as follows:

1) Problem definition: definition of the problem includes quantification of objectives and constraints for the fishery system.

2) Deterministic modelling: this component includes scenario development, the projection of controllable and uncontrollable variables affecting the fishery system (e.g. market evolution, price and cost adjustments) and preliminary deterministic modelling of the multidimensional impacts of all management options.

3) Simulation modelling: the simulation results are organized to provide the likelihood of decision performance under stochastically varying conditions, e.g. variable stock recruitment and growth, varying economic conditions, etc.

4) Risk analysis part I (risk assessment): this component compiles the distribution of performance measures resulting from the simulation model and assigns probabilities to the multidimensional simulation outcomes for each decision alternative.

5) Risk analysis part II (risk management): this component is the application of decision-making criteria embodied in management utility functions that measure the

expected value of each decision alternative in terms of the multiple criteria and their trade-offs, and thereby evaluates and ranks alternative decisions for presentation to decision makers.

6) Implementation and monitoring: The final step in the problem-solving process is the implementation of the decision. These steps form an integrated and interdependent decision analysis framework with continual feedback as illustrated in the diagram of Figure 2. The circular process contrasts with the linear framework of Figure 1 and embodies the feedback loop of successive decisions made by the responsible political powers on the integrated advice developed from all relevant components of the fishery and implemented into fisheries operations. Risk assessment is an integral part of the advice development stage where multiple alternatives and their attributes are presented as part of the provision of advice. Risk management advice is provided to the decision-makers as the basis for their ultimate course of action.

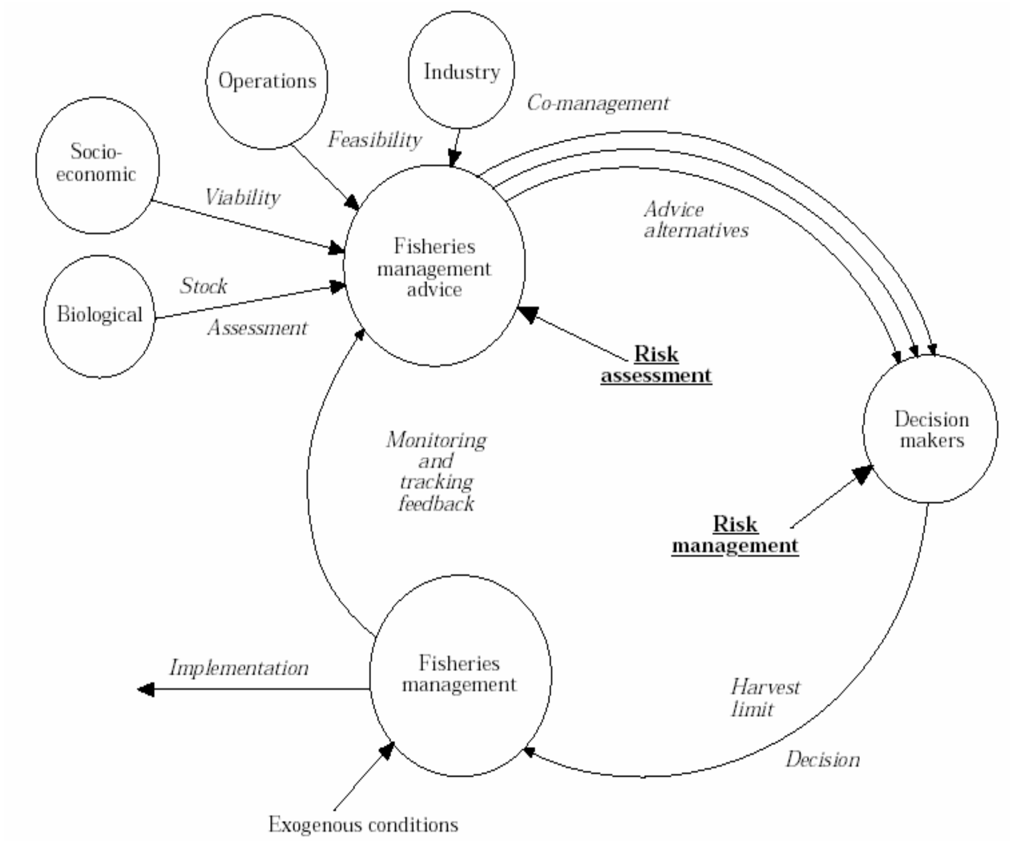

Figure 4.5.2. Conceptual view of the proposed decision analysis framework for fisheries management including risk assessment and risk management components (Lane and Stephenson, 1995a).

4.6 Review of the paper ""Risk" in fisheries management" (Francis and Shotton, 1997)

The paper by Francis and Shotton (1997) provides a complete review of both the terminology and the process of dealing with risk that includes risk assessment and risk management.

Terminology

Uncertainty

The paper uses the definition of uncertainty given by FAO (1995) "The incompleteness of knowledge about the state or processes (past, present, and future) of nature") and distinguishes six types of uncertainty: those associated with process, observation, model, estimation, implementation, and institutions.

Risk

The paper presents the two different ways of defining risk. The first one is as “the probability of something undesirable happening” and the second one as the probability of undesirable events and the magnitude of the associated consequences.

Risk assessment

Although in the review a variety of definitions that use different name conventions are presented, all of them agree on that risk assessment is “using information on the status and dynamics of the fishery to present fishery managers with probabilistic descriptions of the likely effects of alternative future management options.”

Risk management

Similarly to risk assessment, a large number of definitions have been given to risk management. However, the authors defend that “risk management entails a description of the decision criteria that is sufficiently complete and specific to define the quantities that should be calculated in the risk assessment and to make the decision”.

Framework

In this paper the framework for dealing with risk has two stages: risk assessment and risk management.

In the literature reviewed and summarised in the paper risk assessment has the following common components:

1) Inputs:
    a) Data on the fishery and the fish population (including estimates derived from such data);
    b) A model describing the dynamics of the fishery;
    c) Quantitative descriptions of uncertainty about the data and (or) the model;
    d) Several alternative future management options.
2) Method: Monte Carlo projection.
3) Outputs: One or more performance measures describing the future performance of the fishery under each of the alternative management options.

However, the major problems related to risk assessment are identified as:

1) The lack of a standard approach to present the advice. Two issues are to be decided on this respect: the performance measures to use and how complex should the presentation be for each performance measure.
2) True versus perceived states: This may involve having a single model and two sets of parameters or two different models. In either case, one model (or parameter set) is taken as describing the “true” state of the fishery, and the other, how it is perceived by scientists and managers.
3) The value of simple models. Recent works have shown that simpler models can support fishery management better than more realistic ones.
4) The risk of collapse. This is the most negative undesirable event. However, it is difficult to model this event.

There are few examples of risk management in the literature, but the main issues authors want to draw attention to on this respect are:

1) Objective or loss function. This function calculates the performance measure and is to be maximized or minimized accordingly for choosing the best management option.

2) Multiple objectives. When the management objectives are multiple, and possibly conflicting, the objective function has to combine all of them.

3) Eliciting objectives. The authors refer the lack of explicit objectives as the major barrier to effective management.

4.7 Review of the "Australian Approach"

4.7.1 The review

Briefly this method relies on a three step process:

1) Identification of risks/issues

2) Prioritization of issues

3) Development of Performance Reports

1) Identification of issues: The method utilizes generic component trees to help participants to "tease" out the main issues or risks that the fishery faces. The process starts off by breaking the fishery down into eight main components in three main categories; *Ecological Wellbeing*, *Human Wellbeing* and *Ability to Achieve*.

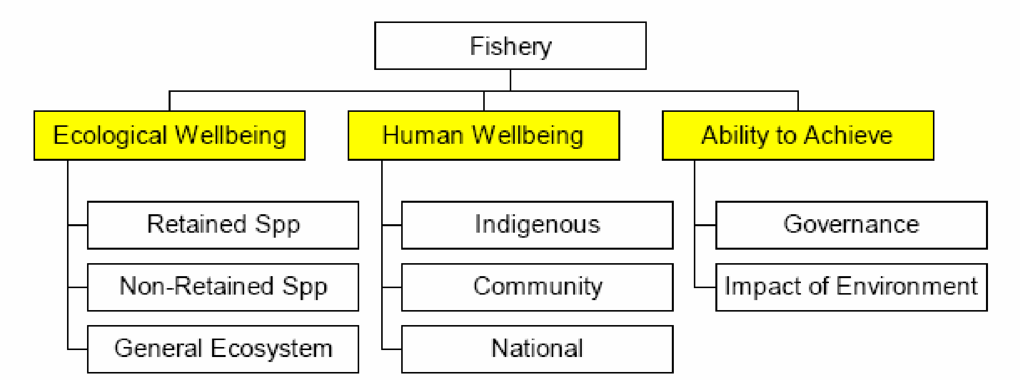

Figure 4.7.1.1. Diagrammatic representation of the eight major components of the risk assessment process.

Each of these eight components is then further deconstructed into more detailed sub-components for which ultimately operational objectives can be developed. The Australian framework provides guidance on common themes at increasing levels of detail to assist in the deconstruction.

The above outline was used in the South African Hake Risk Assessment for Sustainable Fisheries with the exception of the 'indigenous wellbeing' component which was considered to not be applicable to this fishery due the offshore nature of the fishery.

2) Prioritization of issues: Identified issues are then prioritized by scoring the consequence of the given risk actually occurring, and then the likelihood of it occurring. Again, the Australian framework provides guidelines for scoring consequences and likelihoods.

Likelihood level	*Descriptor*
Likely (6)	It is expected to occur
Occasional (5)	May occur sometimes
Possible (4)	Some evidence to suggest this is possible here
Unlikely (3)	Uncommon, but has been known to occur elsewhere
Rare (2)	May occur in exceptional circumstances
Remote (1)	Never heard of, but not impossible

Consequence level	*Descriptor*
Catastrophic (5)	Longterm recovery period to acceptable levels will be greater than decades or never, even if stopped
Major (4)	Recovery period measured in years to decades if stopped
Severe (3)	Recovery measured in years if stopped
Moderate (2)	Recovery probably measured in months – years if activity stopped
Minor (1)	Rapid recovery would occur if stopped – measured in months
Negligible (0)	No recovery time needed

A risk rating is then calculated as follows:

Risk = Consequence x Likelihood

3) Development of Draft Performance Reports: Issues are categorized as Negligible (0), Low (1–6), Moderate (7–12), High (13–18) and Extreme (>18) risk according to their overall risk score. Full draft Performance Reports are then developed for all issues of sufficient priority (i.e. greater than Moderate risk). Performance reports are developed according to the following template.

Performance Report Heading	Description
1. Rationale for inclusion	Summary outcome of Risk Assessment
2. Operational Objective (plus justification)	What are your trying to achieve and why?
3. Indicator	What are you going to use to measure performance?
4. Performance Measure/Limit plus (justification)	What levels define acceptable and unacceptable performance and why?
5. Data Requirements/Availability	What monitoring programs are needed?
6. Evaluation	What is the current performance of the fishery for this issue?
7. Robustness	How robust is the indicator and or the performance measure in assessing performance against the objective?
8. Fisheries Management Response	
- Current	What are the management actions currently being used to achieve acceptable performance?
- Future	What extra management is to be introduced?
- Actions if Performance Limit is exceeded	What will happen if the indicator suggests performance is not acceptable?
9. Comments and Action	Summarise what actions will happen in the coming years
10. External Drivers	What factors, outside of the fisheries control may affect performance against the objective?

4.7.2 The South African experience

South Africa has completed Risk Assessments for the Sustainable Fishing (RASF) of three major resources: demersal hake (*Merluccius capensis* and *M. paradoxus*), small pelagics (*Sardinops sagax* and *Engraulis encrasicolus*) and West Coast rock lobster (*Jasus llalandi*). These risk assessments were completed as part of the Benguela Current Large Marine Ecosystem (BCLME) Ecosystem Approach to Fisheries management (EAF) in the Benguela – A Feasibility Study.

The workshops used the Ecological Risk Assessment (ERA) method/approach developed under the National Ecologically Sustainable Development reporting framework for Australian Fisheries (Fletcher *et al.* 2002). There was general consensus at these workshops that ERA was misleading and agreed to use the term Risk Assessment for Sustainable Fishing (RASF) instead.

The ecosystem approach to fisheries requires a sound scientific basis to provide the means of assessing the ecosystem effects of fishing and the effectiveness of management options proposed in response to identified risks or effects. South Africa, by virtue of several decades of multidisciplinary studies and monitoring of the Benguela ecosystem, and a relatively flexible management approach which already involves some stakeholder participation, is well placed for a test case for EAF. Ecological risk assessment (Fletcher *et al.,* 2002; Fletcher, 2005) has been adopted as a means of identifying and prioritizing ecosystem issues (problems) in three main fisheries: hake, small pelagics and west coast rock lobster.

Importantly, all issues raised were considered issues and were subjected to risk analysis, irrespective of whether or not there was consensus on whether an issue was in fact relevant or important. The importance of each issue was brought out during the actual prioritization process itself, and this required general consensus and was usually attained after much discussion. It was recognized that there was a level of subjectivity as participants were predominantly of biological and commercial backgrounds, and lacked knowledge (expertise) in the social and economic disciplines. Further, not only is it very difficult to bridge the gap between biologists and socio-economists, but also between conservationists, managers and different sectors of the industry, as all have very different fundamental approaches, objectives and methodologies. However, the Australian Risk Assessment framework provided a structure that encouraged issues to be dealt with from all perspectives, and created an environment conducive to discussion and general buy-in across a range of stakeholders.

One example of a high priority issue is used per fishery to illustrate how South Africa is moving towards an EAF by identifying required biological research and/or monitoring, indicators and management actions required to address each issue. Indicators derived from biological or catch data facilitate the formal tracking of ecosystem changes and responses to management actions adopted to optimize economic and social objectives while ensuring the ecological sustainability of marine resources. Implementation of EAF is regarded as an ongoing process, comprised of the following main needs:

- Identification of the current status of the resource
- Examination of concerns regarding single-species, community or ecosystem based approaches (such as spatial issues or species interactions not currently accounted for in management) and expression of these as ecosystem objectives
- Identification of indicators to support ecosystem objectives
- Translation of ecosystem indicators into decision criteria (for example by defining limit reference points to be avoided)
- Identification of research and monitoring needs

- Development of appropriate management actions to be taken with stakeholder participation
- Development of evaluation criteria for adopted management measures

The outputs of the risk analyses for the three South African fisheries examined are available in full reports (Nel, 2005a, 2005b, 2005c) and have been expanded upon in Shannon *et al.* (2006). These results have been disseminated via EUROCEANS Fact Sheets (http://www.euroceans.eu/training_and_outreach/wp9/).

4.7.3 Summary of discussion

(On the South African experience regarding risk assessment following the Australian framework)

The discussion centered around the scales used to evaluate the likelihoods and consequences of issues identified during risk assessment workshops conducted for the South African hake, small pelagic and west coast rock lobster fisheries. The concern was that the scales were qualitative and may not have been interpreted identically by all participants of the workshops. It was also of concern that the outcome of the workshop was dependent on the participants (i.e. the final results obtained from one group of participants would likely differ from those of a different set of participants). A further criticism levelled at the process was the multiplication of the likelihoods and the consequences to obtain a measure of risk – it was suggested that perhaps these should rather have been additive as at least some people tend to interpret the likelihood and consequence levels as logarithmic.

In response to the concerns raised above, it was pointed out that the aim of the workshops was to identify ALL issues related to the respective fisheries and to rank them. The workshop aimed to inform stakeholders of, and obtain buy-in from stakeholders to the EAF process, to raise awareness of and EAF and ecosystem related issues in three of South Africa's most important fisheries, and to identify and prioritize these issues. Further, the workshops aimed to expand from here by identifying research, indicators and management actions required to address the priority issues.

It was felt that the aims of the workshops were well met and that there was buy-in from the stakeholders. The process provided a framework for discussion among stake-holders, succeeded in exposing stakeholders to the perspectives of other stakeholders, serves as a supporting basis from which ecosystem concerns can be addressed in the respective fisheries, and it provides a reference for newly appointed fisheries managers at MCM. Hence, given the aims of the workshop, the manner of determining the risk was appropriate and served its purposes well.

It was cautioned that if this process of risk assessment was to be taken further, focusing on the top issues only, then the methodology adopted would have to be revised because the use of qualitative indicators would become problematic. In addition, the confidence of the estimates would require evaluation. However, the nature of the second phase of the workshops should be noted, where qualitative costs and benefits were sought and management actions were identified which addressed priority issues and simultaneously often also several issues considered less important.

4.8 Review of Uncertainty Categories

Handling uncertainty is an essential part of a risk assessment and in particular in the risk estimation part of the assessment. The ideal situation is where the total uncertainty can be quantified, but unfortunately this is seldom the case when dealing with human impacts on ecosystems. Although statistical models handle uncertainty, there is yet remaining uncertainty due to model assumptions of various kinds. Sensitivity analysis can resolve parts of this. This section is a review of how a small selection of papers has characterized uncertainty and the role of qualitative uncertainty in risk assessment.

To clarify the uncertainty aspects, uncertainty is often separated into *uncertainty categories*. The literature shows that uncertainty has been divided in several ways. In fisheries science there is a tradition of dividing uncertainties by *their sources*. Francis and Shotton (1997) is an example of this. They divide uncertainty (and based on a review of fisheries science literature) into its following sources: *process, observation, model, estimation, implementation and institutions*. The UKCIP report from 2003 (see Section 4.4) operates with *natural variability, data uncertainty* and *knowledge uncertainty*.

Other parts of the literature divide uncertainties in qualitative characteristics. Wynne (1992) uses 4 types of uncertainties: *risk, uncertainty, ignorance and indeterminacy*. *Risk* is when the system is well known and the probability distribution for different outcomes is known. *Uncertainty* is recognized as when you know the important system parameters, but not the probability distributions. *Ignorance* is uncertainty that is not recognized, and Wynne stresses that ignorance increases with the commitments based on the knowledge that includes uncertainty. *Indeterminacy* is an open-ended kind of uncertainty. For example uncertainty from assumptions in science or assumptions on human behaviour where we cannot evaluate their validity is denoted as indeterminacy. Indeterminacy is a question whether the body of knowledge has been changed to fit the problem or whether the problem has been redefined to fit science.

Funtowicz and Ravetz (1990) divide uncertainty into *inexactness, unreliability* and *ignorance (*or *border of ignorance).* They combine the degree of uncertainty with decision stakes to characterize knowledge production: applied science, professional consultancy and post-normal science. Post-normal science is a concept they have developed that denotes the science needed for policy decisions where decision stakes are high and uncertainty level is high.

Although the papers by Wynne and by Funtowicz and Ravetz are on uncertainty, they are closely linked to risk because both papers are uncertainty in a policy context where stakes are high. While Funtowicz and Ravetz separate uncertainties and stakes, Wynne claims that uncertainty and stake are not independent; indicating that his way of understanding uncertainty is more related to risk. Both Wynne and Funtowicz and Ravetz argue that traditional science (curiosity driven science) is not suitable for the emerging policy problems where stakes are high.

The IPCC workshop (2004) divides uncertainty into 2: uncertainty (quantitative) and confidence (qualitative) and stresses that both are important in assessing the uncertainty.

Klinke and Renn (2006) introduce the concept of *systemic risks*: "Systemic risks are a product of profound and rapid technological, economic and social changes that the modern world experiences every day. They are characterised by high complexity, uncertainty, ambiguity, and ripple effects. Due to these characters systemic risks are overextending established risk management and creating new, unsolved challenges for policy making in risk governance. Their negative effects are often pervasive, primary areas of harm."

They explain the four major properties the following way (quoted):

- *Complexity* refers to the difficulty of identifying and quantifying causal links between a multitude of potential candidates and specific adverse effects. The nature of this difficulty may be traced back to interactive effects among these candidates (synergisms and antagonisms), positive and negative feedback loops, long delay periods between cause and effect, inter-individual variation, intervening variables, and others. It is precisely these complexities that make sophisticated scientific investigations necessary since the dose-effect relationship is neither obvious nor directly observable. Nonlinear response functions may also result from feedback loops that constitute a complex web of intervening variables.

- *Uncertainty* comprises different and distinct components such as statistical variation, measurement errors, ignorance and indeterminacy […], which all have one feature in common: uncertainty reduces the strength of confidence in the estimated cause and effect chain. If complexity cannot be resolved by scientific methods, uncertainty increases. But even simple relationships may be associated with high uncertainty if either the knowledge base is missing or the effect is stochastic by its own nature.

- *Ambiguity* denotes the variability of (legitimate) interpretations based on identical observations or data assessments. Most of the scientific disputes in risk analysis do not refer to differences in methodology, measurements or dose-response functions, but to the question of what all this means for human health and environmental protection. Emission data is hardly disputed. Most experts debate, however, whether an emission of x constitutes a serious threat to the environment or to human health. Ambiguity may come from differences in interpreting factual statements about the world or from differences in applying normative rules to evaluate a state of the world. In both cases, ambiguity exists on the ground of differences in criteria or norms to interpret or judge a given situation. An example for such ambiguity is pesticide residues in food where most analysts agree that the risk to human health is extremely low yet many demand strict regulatory actions. High complexity and uncertainty favour the emergence of ambiguity, but there are also quite a few simple and almost certain risks that can cause controversy and thus ambiguity.

- *Ripple effects* indicate the secondary and tertiary consequences regarding time and space, i.e. functional and territorial dimensions of political, social and economic spheres. The cross-border impact of systemic risks exceeds the scope of domestic regulations and state-driven policies. To handle systemic risks interdisciplinary mechanisms in international governance are required.

The authors argue that a holistic and systemic concept of risks cannot reduce the scope of risk assessment to the two classic components: extent of damage and probability of occurrence. To evaluate risk a list of criteria should be handled: impact categories (probability of occurrence, extent of damage, reversibility, incertitude and others) and the risk classified (they suggest a set of risk classes). The idea is that an assessment of the systemic risks helps the risk managers to understand the uncertainties so that the risk(s) can be classified. Risk management will then depend on the risk class, where a good control of the uncertainties and damage can be based on science while less control demands precautionary and discursive strategies.

4.9 Summary and comparisons

Since the beginning of the 1990s risk is an emerging topic into fisheries management (Francis and Shotton, 1997). The first step for incorporating risk into the decision-making framework in fisheries is to define a common terminology. However, there is a long debate in the literature on establishing appropriate technical concepts.

For example, there are two ways for defining "risk". The first one is as the probability of something undesirable happening (Hilborn *et al.,* 1993; FAO, 1995b; Lane and Stephenson, 1997). Either explicitly or implicitly, this is the usual practice within ICES (see Section 5 for a more detailed description on current ICES standards). The second one refers to the combination of the probability of something undesirable happening and the magnitude of its associated consequences (Rosenberg and Restrepo, 1994; IPCC, 2004; Burgmann, 2004; Willows and Connell, 2003). This definition is more general and is related to decision theory (Berger, 1985).

Since FAO (1995b), there seems to be a general agreement on defining uncertainty as “lack of knowledge”. However, as it is discussed in detail in Section 4.7, it is not so clear how uncertainty relates to risk and therefore on the ways uncertainty is classified.

Other terms, like risk assessment, risk analysis or risk management are also usually confounded. The most common approach (Francis and Shotton, 1997; Lane and Stephenson, 1997; Willows and Connell, 2003) is to distinguish two separate processes within the process of dealing with risk: the first one (risk assessment) dealing with the formulation of advice for managers, and the other one (risk management) dealing with the ways managers use that advice to make decisions. Risk analysis is then used to refer to the overall process (risk assessment and risk management). However, there are other approaches like the one in Burgmann (2004) in which risk assessment is understood as the “completion of all stages of the risk management cycle, a marriage of risk analysis, adaptive management, decision tools, monitoring and validation” and where “risk analysis is part of the risk management”.

Additional concepts like risk characterization (EPA, 1998), risk identification (Willows and Connell, 2003), risk evaluation (Willows and Connell, 2003), risk estimation (EPA, 1998; Willows and Connell, 2003), risk screening (Willows and Connell, 2003), risk description (EPA, 1998), risk ranking (Burgmann, 2004) or risk communication (Burgmann, 2004) are also common in the literature.

When such differences are found on the basic terminology, differences regarding the elements or steps leading up to management decisions could be expected to be even larger. However, and without taking into account the wording, most of the works reviewed identify most of the following steps:

a) Problem identification, stating clearly the management objectives;
b) Translate the management objectives into a conceptual model and define assessment endpoints;
c) Identify hazards and their consequences;
d) Estimate the likelihood and the magnitude of the consequences associated to the hazards (if possible);
e) Communicate the results;
f) Make a decision;
g) Implement, monitor and evaluate the decision.

In many of the cases (Burgmann, 2004; Francis and Shotton, 1997; Lane and Stephenson, 1997) it is emphasized that the process has to be iterative, so that past experience can help to improve the current decision making process. Furthermore, in Willows and Connell (2003) the framework is circular, so that at the end of each of the stages if something is susceptible of being improved is pointed out or new information is available it is recommendable to go back to a previous stage.

In general, a larger effort has been made in environmental management in comparison with fisheries management for defining a common framework. A unique work (Lane and Stephenson, 1997) describes explicitly a framework for decision making in fisheries. In the rest of fisheries applications the framework is only separated into risk assessment and risk management and the emphasis is on the tools that are used for risk assessment and management (Francis 1992; Rosenberg and Restrepo, 1994; Lane and Stephenson, 1997; Francis and Shotton, 1997). On the contrary, the environmental management framework is described more in depth and the focus is on the underlying conceptual model (EPA, 1998; Burgmann, 2004; IPCC, 2004; Willows and Connell, 2003). This allows risk management to be directed not only to choose the option that minimizes the risk, but also the one that addresses specific cause-effect within the conceptual model.

Although several of the reviewed papers and reports address difficulties in quantifying uncertainties and risks, the usual underlying assumption is nevertheless that the uncertainties can be quantified and values can be given quantified weights. There are exceptions though, where the need for communicating non-quantifiable uncertainty is stressed. For example, the IPCC workshop (2004) reflects this in the following recommendations: "An assessment should always include a statement on the confidence of the results, all uncertainties should be clearly stated and rather than presenting the prediction in which the scientists have most confidence, all reasonable predictions should be presented." We interpret the rationale for this to be that quantified uncertainty is not necessarily a sufficient basis for decision-making. Of the papers, books and reports we have reviewed, Klinke and Renn (2006) have maybe been most explicit on the role of non-quantifiable uncertainty as they argue it should affect the approach taken in risk management. While risk management can essentially be based on science in cases with good control of the uncertainties and the magnitude of possible damage, less control of the uncertainties demands precautionary and discursive strategies, giving science a less dominant role in risk management.

Finally, most of the reviewed works agree on and emphasize the importance of joint work and continuous collaboration and communication between scientists, managers and stakeholders.

5 Current ICES practice of handling risk

In this section we will have a closer look at how ICES deals with risk in advice and at how this is developing within the ICES system, all in light of the papers, books and reports reviewed in the previous section.

5.1 Context

A number of white papers and international agreements state more or less explicit general objectives concerning the state and uses of the marine ecosystems. These are sustainable use of the resources, the precautionary approach to fisheries management, the ecosystem approach to management etc. The concern for future generations is significant and the regulation of fisheries is a major component in achieving several of these objectives. For some fish stocks, there are agreed harvest control rules, which represent far more specific management objectives like stability of annual catches or stock recovery. In providing advice ICES needs to take both the general and the specific objectives into account.

Most fish stocks are managed separately. Often in fisheries management, the fishing industry contributes with opinions, concerns and advice, but is seldom part of the final decision-making.

Agreements, also state socio-economic objectives, like maintaining settlements in coastal areas, maintain/increase standard of living etc. that ICES does not (have the expertise) to take into account.

Due to time constraint we did not have the opportunity to check whether there are agreements that contain specific objectives related to risk management. It is our feeling though, that they are implicitly embedded in more general objectives.

5.2 Identified harmful events and its consequences

ICES fisheries advice has traditionally focused on one single harmful event; recruitment failure or impaired recruitment. Sustainability is naturally dependent on recruitment, and Blim is chosen as a proxy for impaired recruitment. The definition of Blim is:

The value of B_{lim} is set on the basis of historical data, and chosen such that below it, there is a high risk that recruitment will be impaired (seriously decline) and on average be significantly lower than at higher SSB.

There are two points worth noting regarding this definition. One is the use of the term “risk”. In this case “risk” means “probability” and ICES does not deal with the costs (like loss of yield) of an impaired recruitment. ICES thereby, operates with another meaning of “risk” than in most of the reviewed books, papers and reports in Section 4. Another point is that it presupposes that rebuilding is possible. Irreversible states of the fish stock or ecosystem are imaginable, but not part of the ICES advice framework.

Fisheries management deals with several requirements for obtaining sufficient spawning stock biomass: regulations on measure size, regulations on landing size, closed seasons and areas and regulating the fishing effort and/or annual landings. To avoid impaired recruitment, also in the longer run, ICES gives advice in accordance with a precautionary framework consisting of reference points for fishing mortality rate and spawning stock biomass.

At the moment, there is a change of focus from avoidance of recruitment failure to target levels in fishing mortality (at least within ICES). The precautionary reference points have in many cases been adopted as target levels by fisheries managers and has, at least by ICES, regarded as unfortunate. The underlying idea of the alternative target level is thus to try to avoid some experienced problems, but also to suggest fishing mortality rates that maximizes yield or at least improves the utilization of a stock. In a risk context the loss of yield can be defined as an undesirable event. However, ICES does not provide much information on the cost of management decisions. Standard ICES advice states whether a stock is overexploited compared to highest yield and presents both graphs and tables on yield per recruit. This gives an indication on loss of yield, but costs in terms of lost yield (or in monetary value) are not handled.

Fishing may cause other events defined as harmful like by-catch of birds and mammals or damage of coral reefs. Advice on stock exploitation and advice on other effects from fishing are treated separately in ICES. At present ICES is developing advice for an ecosystem approach to management, implying that harmful events caused by other sectors than the fisheries sector will be identified and addressed.

ICES do not cover socio-economic aspects of risk.

5.3 Identifying the uncertainties

For clarifying reasons we separate the following uncertainties in this section:

- The uncertainty in defining the harmful event or defining a proxy for it;
- The uncertainty in assessing or predicting the state, and
- The uncertainty from setting/defining the borders of the risk problem.

There is undoubtedly uncertainty associated with the definitions and calculations of Blim as a proxy for impaired recruitment. We will not elaborate this issue, but simply state that this uncertainty is not part of the ICES advice for fisheries management.

The assessment/prediction uncertainty is reflected in the precautionary reference points, Bpa and Fpa. The framework reflects an average uncertainty; meaning that advice does not take into account variations in the uncertainty from year to year. There are a few exceptions of this like the advice on Barents Sea capelin. SGMAS (ICES, 2006) recommends taking into account a list of assessment and prediction uncertainties when evaluating harvest control rules. The report shows that the existing evaluation tools can take various uncertainties into account.

The annual stock assessments, on the other hand, are still quite limiting concerning uncertainty aspects.

ICES expresses advice on all stocks rather similarly as if the complexity, uncertainty and risks associated with each stock were the same for each stock. (We are well aware of the exceptions when ICES considers the data basis is too poor for giving standard advice.) Mixed fisheries, stock recovery, interactions with other stocks, environmental impacts and internal stock dynamics affects the complexity and inherent uncertainties associated with the stock of concern and may vary substantially from stock to stock, not only by scale but also more qualitatively. This should be kept in mind when developing a risk strategy. Stock estimation, predictions and quantification of uncertainties may be difficult or impossible. On the other hand, if the objective is to minimize risk it is possible to deal with some uncertainties in an asymmetric manner. For example, if there is reason to believe that the food supply for a certain fish stock is below average, predicted growth can be set at the precautionary side. Ecosystem considerations can also be used in characterizing perceived irreversible risks to supply the information on the probability of an impaired recruitment. (For further suggestions, see Section 7).

5.4 Interpreting the significance of the results and communication

There is no standard for expressing confidence in results, which ICES advice is based on, but is eventually done. Sensitivity analysis may be carried out, but is not done on a regular basis. However, FLR is an example of tools being developed to enable this. The interpretation of results from simulations when harvest control rules are evaluated seems far more developed (see SGMAS, 2006).

Uncertainties, interpretation ambiguities and risks are poorly communicated in ICES advice.

6 Risk assessment and management strategies

6.1 Summaries of WD2 and WD3

The Working Document “Risk evaluation for the current South African west coast rock lobster, hake and pelagic OMPs” was presented to outline how risk has been accounted for in the management of three of the most important fisheries in South Africa: west coast rock lobster, hake and sardine and anchovy. In all three cases Operational Management Procedures (OMPs) have been adopted to set annual TACs. These OMPs are developed taking account of key uncertainties in the underlying operating model of the resource and are tuned to competing objectives such as higher catch, lower inter-annual TAC variability and lower risks. Key uncertainties were accounted for through either a reference set of deterministic operating models or through a Bayesian model, while robustness tests were used to test further uncertainties. The table below summarises the approaches used for these fisheries.

	West coast rock lobster	Hake	Sardine & Anchovy
Management	OMP	OMP	OMP
Measures used to assess risk	Bexp percentile Economic TAC change limits	Bsp percentile Economic TAC change limits	Bsp percentile TAC change limits
Key uncertainties	Resource dynamics Future somatic growth rate Future recruitment trends	Resource status Productivity	Future stock recruitment relationship Potential change in sardine growth rate
Underlying Operating Model: Base case / Reference set (RS)	RS (18 individually weighted scenarios)	RS (24 equally weighted scenarios)	Separate base case model for sardine and anchovy
Stochasticity in Operating Model	Deterministic RS models, stochastic projections[1]	Deterministic RS models, stochastic projections	Bayesian
Robustness tests	Deterministic 'tick' test[2]	Deterministic 'tick' test	Deterministic and Bayesian 'tick' test

New management procedures are currently being developed for the South African west coast rock lobster and pelagic fisheries. The Working Document "Risk-related Aspects of the west coast rock lobster and of the joint sardine and anchovy OMPs to be developed this year" outlined some key issues relating to risk that have thus far been encountered. When testing alternative management procedures, the median of risk measures may not always suffice from a precautionary point of view. A question posed from the rock lobster case study is how low can a 5 percentile of projected/current abundance over, say a 10 year period, acceptably go.

The management procedure for sardine and anchovy is being developed to take into account uncertainty in the number of populations of sardine (1 or 2?), area disaggregation and stock-recruitment relationships. The risk to the resource under the management procedure developed will need to be robust to these uncertainties. The effect of an eastward shift in the distribution of sardine has also raised an additional risk consideration; the economic risk to investment in factories on the south-east coast given the potential for the distribution to shift back to the west coast at some future date.

In addition, the step towards implementing an ecosystem approach to fisheries is being implemented by explicitly considering the risk to the African penguin population resulting from alternative management options. This is being done by coupling a penguin population dynamic model linking penguin abundance and prey availability to the OMP. How this risk is to be measured (for example in terms of breeding pairs or total population) and the thresholds to be avoided with high probability are still to be evaluated.

6.2 Summary of WD4

The working document (reproduced as Appendix 5) outlines the problem of operationally evaluating the behaviour of management procedures (MPs) under robustness tests (trials) that reflect resource dynamics which, though different from that of the current "best assessment" of the resource, nevertheless remain consistent with the information available. To be acceptable, a management procedure must give rise to performance statistics for those robustness trials which are not appreciably worse than those for the "best assessment", in the

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1 Future recruitment was drawn from a distribution based on historic recruitment and observation error was also modelled.

2 'Tick' tests – checks extended only so far as to confirm that anticipated performance under such scenarios did not differ substantially from that for the "central" scenario of which they were variants.

spirit of the Precautionary Approach. However, how much deterioration in performance is acceptable, and how does this relate to the relative plausibility of the trial under consideration? The relatively complex framework to address these questions developed by the IWC Scientific Committee is summarized. In essence, hypotheses (each reflected by an associated trial) are weighted as high, medium or low in terms of their assessed relative plausibility's. Trials accorded low weight are not considered further, whereas those accorded high weight have to satisfy a more stringent criterion in terms of a low probability of unintended depletion of the resource than do those weighted medium. While the details of the IWC approach may be more complex than other fisheries management situations require, nevertheless the general concepts underlying the approach would seem to have wider applicability in the general process of linking the output from robustness trials to rules governing MP acceptability.

6.3 Discussion

This sub-section summarizes discussions and views from a subgroup of the Study Group. There has been no formal adoption of the text in plenary so the views presented here do not necessarily represent the views of the study group as a whole.

6.3.1 Consistency and Credibility with Stakeholders

The desirability of consistency in approaches for dealing with risk both within a resource, e.g. from one assessment to the next, and between resources, was highlighted. Retrospective analysis of risk measures should be presented towards this end. In particular, understanding by and maintaining credibility with stakeholders is enhanced if the same measures of risk (or readily related measures) continue to be employed.

It was noted that the European Commission are proposing long-term fishery-based plans to bring all major fish stocks under their jurisdiction (i.e. in EU waters, and those stocks jointly managed with third countries) to rates of fishing at which MSY can be achieved, there is therefore a move towards a standardised lower target effort strategy through adoption of a target fishing mortality reference points, e.g. $F_{0.1}$ as a precautionary estimate for F_{MSY}. This shows similarities to standard forms of restrictions being placed on all US fisheries under the Magnusson-Stevens Act. However, for a number of stocks $F_{0.1}$ (or F_{MSY}) cannot be calculated directly so that the use of proxies becomes necessary.

An additional complication of this approach is that use of the same target reference point for stocks of two different species does not necessarily equate to the same risk. This is because the two populations may have different levels of natural variability in recruitment or somatic growth (which may include positive autocorrelation), so that the same level of fishing effort would deplete the one to lower levels of abundance (and hence subject it to likely higher risk) than the other. Thus a "one-size-fits-all" approach may be inappropriate.

Some account may be taken of this by using some lower percentile of the distribution of, say, F_{MSY} rather than the best estimate, and such a procedure would be in line with a precautionary approach. However, difficulties related to consistency may then arise in standardising over time on the number of factors taken into account in computing such distributions, e.g. using the prior distribution for a parameter for which previously a fixed value was used, and the presumed extents of uncertainties in their values, especially when further research may have indicated changes in such perceptions to be necessary.

6.3.2 Basis for weighting hypotheses

Bayesian methodology provides a basis for weighting alternative hypotheses on the basis of the extent to which they are supported by the available data. Within a single model structure, this can be achieved by integrating over prior distributions for parameters multiplied by the likelihood of the data observed. The statistical assumptions underlying such an approach must nevertheless be borne in mind, for example that successive observations in a time series of data are indeed realisations of iid. (independent identically distributed) distributions; these assumptions are unlikely to be exactly true, and their violation (through for example the presence of positive auto-correlation) will generally mean that such methods underestimate uncertainty and risk.

For this reason, even within a single model structure, rather than perform Bayesian integration over some of the model parameters, it may be more appropriate to apply externally specified weights on either a continuum or more commonly a small number of representative values for each parameter. For different structural models (e.g. one-stock vs. two-stock hypotheses) it is most likely that externally specified weights will be required rather than likelihood-based weights.

In specifying such external weights for a set of hypotheses (and also in specifying priors for a Bayesian approach, unless non-informative priors are used), expert judgement needs to be applied and consensus amongst experts should be sought (though this may be difficult since some of the available experts may have links with interest groups). One approach to this is a Delphi-like method where all the experts participating in the discussion first independently set down their weights for the alternative hypotheses for a factor. The resultant distributions of weights for each hypothesis are then made known, coupled to further discussion and in particular motivation of extreme values by their proponents. The process proceeds iteratively until distributions of suggested weights hopefully narrow, and distribution medians can be accepted by consensus for use in subsequent computations seeking to summarise across alternative hypotheses. In practice, convergence is often attained quite quickly.

An alternative approach is that of the IWC Scientific Committee (see IWC 2005 and Annex 5) which avoids quantification, and instead categorises hypotheses as of high, medium and low weight. In cases where there is no agreement, but a plausible case can be made by some for a high weight, a medium weight is assigned. (IWC 2005 and Annex 5) describes how such weights are incorporated in the decision process.

To avoid experts' choices of weights being influenced by the management implications of an associated hypothesis, these weights should ideally be finalised on the basis of informed discussion concerning the hypotheses alone conducted before any computations related to management import. However, pragmatically, some flexibility on this point may be entertained in the interests of time – for example to identify at an early stage that some hypotheses, although of appreciable plausibility, make little difference in terms of management implications when compared to corresponding default hypotheses, and hence need not be considered further.

6.3.3 Taking formal account of robustness or sensitivity tests in formulating scientific recommendations

Such tests, for both assessments and management procedure evaluations, are often evaluated only on a "tick test" basis, i.e. a judgement is made that the results are not appreciably worse in terms of some important performance attributes than for corresponding Reference Set results. However, particularly in politically sensitive cases, a more formal approach is desirable.

A simpler form of the approach adopted by the IWC Scientific Committee (see IWC 2005 and Annex 5) may be appropriate here. This would be to accord the hypothesis underlying each test, a weight that is either high, medium or low on the basis of consensus following discussion of the judgements of a number of experts. Low weight tests are then discarded, with those of medium weight required to meet a less stringent criterion than those of high weight for the associated management action under consideration to be deemed acceptable. In instances where calculations are combined over a Reference Set of assessments/operating models, this combination could be considered of high weight, with other assessment/operating model variations of this Reference Set judged as of either medium or low weight and treated accordingly.

An alternative use of such approaches in a Management Strategy Evaluation (MSE) context is, perhaps using the Bayesian belief paradigm, to investigate the relative value of different types of additional information to reduce uncertainty or improve control measures with respect to their ability to achieve a variety of management objectives. Thus managers could be advised on the relative merits of committing funding to say, improved compliance, better resource monitoring, or scientific resolution of some key uncertainty. The use of Bayesian Belief Networks requires the weighting of the various hypotheses; weights could be determined either by Bayesian method based upon likelihoods or by using expert judgement as outlined in the previous section.

6.3.4 Exceptional Circumstances

Management Procedures, once implemented, act like auto-pilots and so save considerably on resources otherwise invested in protracted annual assessment exercises while nevertheless operating in a manner consistent with the precautionary approach (Butterworth, 2007). However, they should not be seen as set in stone, but reviewed at regular intervals (whose length is related to the dynamics of the species concerned) to check whether they need modification in the light of new scientific or related advances in the interim.

Even so, “Exceptional Circumstances” may arise that require such reviews to be brought forward, and/or action to be taken different from that output by the Management Procedure in the relatively rare events that compelling evidence arises that the assumptions underlying the testing used for selecting the Procedure were flawed. An example of such an instance is provided by updated data or assessment results showing the resource to have moved outside the range of future abundance trajectories projected at the time the Procedure was tested (see for example Figure 6.3.4.1).

A framework for the application of such Exceptional Circumstances rules should be pre-agreed (see e.g. MCM, 2007). The management action to be taken may be decided at the time, or pre-specified in the form of specific meta-rules. For example, if abundance drops below some pre-specified threshold, limitations on the maximum extent of inter-annual TAC decrease admitted under the core Management Procedure might fall away.

6.3.5 Short-cuts

Monte Carlo simulations can be costly in time and so deterministic (or a limited number of stochastic) runs may be made to identify main effects or important interactions. Following these fully stochastic, simulations may be run for the important trials. For example were deterministic runs initially performed to explore the dynamics, then stochastic simulations that modelled observation error were run to evaluate the perception gained via virtual populations analysis. Where assessment procedures themselves include e.g. Markov Chain Monte Carlo their evaluation by simulation may mean that only a very limited number of runs can be performed, e.g. as in the case of the South African sardine and anchovy (WD2). Furthermore in MP testing if time is short precluding runs with many replicates, informative comparisons remain possible amongst alternative candidate MPs provided random numbers are kept identical between runs.

Also rather than running all possible combinations of treatments, an experimental design can be used to run only main effects and selected interactions.

When running scenarios corresponding to complex processes, e.g. the effect of climate change on productivity and growth (see Kell *et al*., 2005) the actual process can be simulated by characterising it by a simple relationship (i.e. correlating the effect of temperature with the parameters of the stock recruitment relationship) rather than incorporating the full complexity in the simulations. Sensitivity to species-interactions and predation can be evaluated by running scenarios where e.g. natural mortality is allowed to change rather than fully incorporating additional species in an operating model. Where processes are identified as being important then it may be important to incorporate them more fully in the future.

6.3.6 Presentation

Communication of the results from models is necessary when making policy decisions and in communicating the consequences and trade-offs between alternative actions to stakeholders. It will also be necessary to facilitate communication between technical specialists in the fields of biology, economics, and sociology as well as with managers. The separate needs of specialists and managers were identified, i.e. specialists require tools to understand and run models while uncertainty and consequences of alternative actions need to be communicated to managers. Various methods are being employed, for example Influence Diagrams (Bayesian Belief Networks), decision trees or in parts of the US where a reduced number of scenarios (typically 3–5) are presented corresponding to both random variation and structural uncertainty. These are carefully selected to reflect the extent of the uncertainty while excluding extreme cases of low plausibility; for example, three selections might be made which reflect the 25, “median” (best assessment) and 75 percentiles along an axis of the decision variable (TAC).

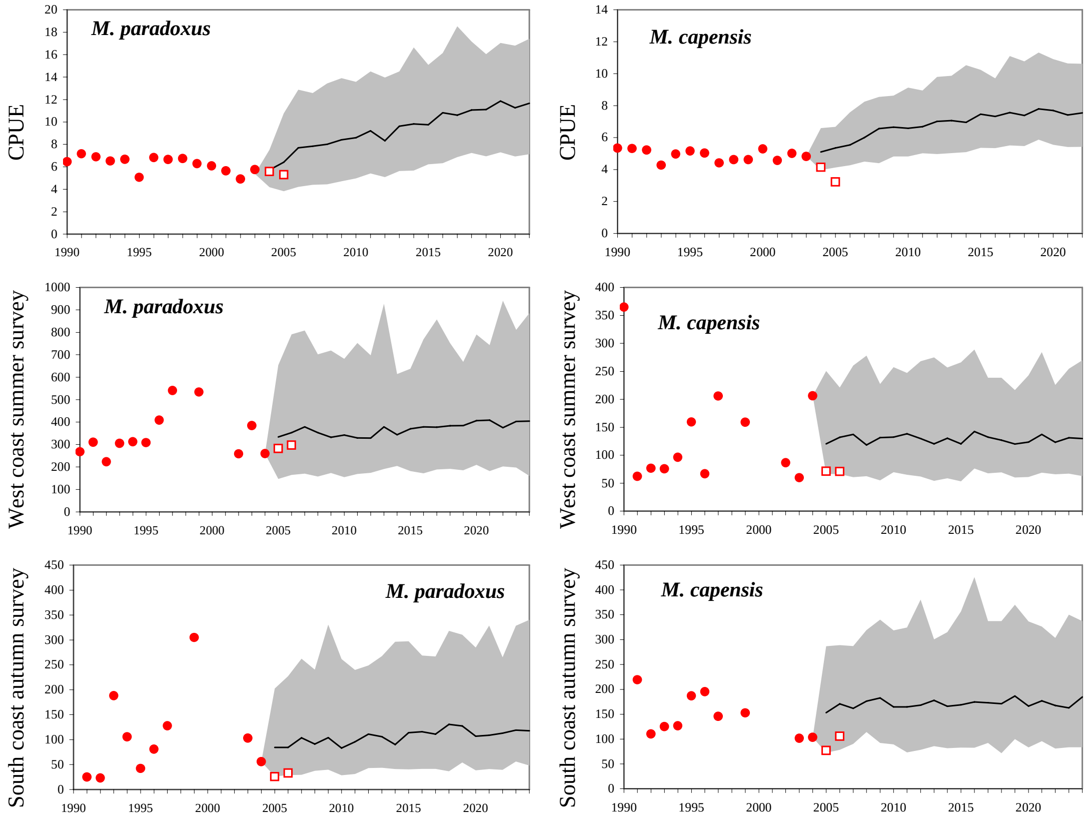

Figure 6.3.4.1. Projections under the Reference Set of Operating Models used for hake OMP testing compared to the most recent two years' resource abundance index data (which were not used in fitting the Reference Set models). The solid circles show CPUE or survey abundance data as used in fitting the Operating Models, while the white squares show the new data points. The lines are the projected medians under the existing Reference Set for OMP1b, and the shaded areas the corresponding 90% probability intervals.

7 Risk assessment as a tool for the ecosystem approach

This section summarizes discussions and views from a subgroup of the Study Group. There has been no formal adoption of the text in plenary so the views presented here do not necessarily represent the views of the study group as a whole.

7.1 Introduction

There are a number of difficulties to be resolved in attempting to design an Ecosystem Approach to Fisheries management (EAF). To be successful such an exercise must:

- Identify which parts of the overall ecosystem should be considered;
- Be able to incorporate a wide range of different sources of information;
- Be able to provide advice and information to managers in an understandable and useful form.

These factors must be considered in the context of limited available resources. Thus the first challenge becomes one of how to prioritize work and be able to achieve the breadth of study required to consider an ecosystem, without losing the depth of detailed quantitative work on the most critical aspects. Incorporating different sources of information, both quantitative and qualitative, within a single framework poses considerable difficulties. Furthermore the complexity of an ecosystem combined with the variety of different kinds of data available makes communicating the results in a meaningful form both critical and difficult. The South

African experience in implementing ecosystem-based Risk Assessments provides one possible model for addressing these difficulties.

The South African experience is described in Section 4.7.2. The overall aim may be summarized as follows. Workshops are conducted, incorporating a broad range of stakeholders involved with the fishery and associated ecosystem. During these workshops issues that need to be addressed in that fishery and ecosystem are identified and prioritized. Scenarios are represented quantitatively using nominal scales to rank issues in terms of their perceived risk. The aim is that scientific modelling work would then be conducted to rigorously assess these key scenarios, and the results presented to managers and a broad range of stakeholders.

7.2 Discussion

Communication between all relevant parties will be a key factor in determining the success or failure of EAF. The required dialogue will of necessity bring together many parties who may not have a tradition of working together. As wide a range as possible of stakeholders should be brought together, this might include: fisheries scientists, managers, representatives from different sectors of the fisheries industry, NGOs, social scientists, economists, other interested parties (e.g. recreational fishers). This diversity of participants will allow the process to examine a wide range of different issues, and identify which issues are most important to consider. It is important to have a full range of stakeholders involved, as those who drive such a process are likely to influence the process and results. In this way a definition of the system to be studied may be arrived at which is not driven by the interests of any one group, and which does not exclude the parties from a sense of ownership of the overall process. This sense of ownership can be fostered by allowing the stakeholder workshops to guide the process. The issues raised by the stakeholders should be ranked by the stakeholders, and issues and scenarios considered of critical importance during the workshop should be subject to rigorous numerical analysis and modelling. This is not just a cosmetic exercise, but is an important component in the Risk Assessment process. Full inclusion of stakeholders is key to acceptance and thus credibility. This broad and inclusive approach forces a wider perspective than that sometimes given by classical stock assessment. It is not possible to fully quantify and analyze all the issues raised, but the process gives perspective, and provides an overview of where the detailed numerical analysis fits within a wider ecosystem context. Only a subset of the ecosystem issues are likely to be addressed, and it is therefore important to obtain as wide a degree of agreement as possible as to which subset should receive the most attention. It is also important to accept that progress will often be made in small steps, with iterative improvements as greater experience is gained.

Facilitation will be the key, as all parties need to feel ownership of the process and all will need to compromise in reaching common ground. In some cases communication between scientific spheres (biology, ecology and stock assessment, as well as economics and social science) may also be a particular challenge. **Transparency** in the use of complex models and concepts is vital in achieving a level of understanding by all stakeholders, and hence a sense of ownership is more likely to be achieved. The objectives of the Risk Assessment workshops should be clearly stated to the stakeholders, who should be involved from an early stage. There should be transparency and agreement on what outputs (scientific, economic and social) will be produced by the Risk Assessment, and how these outputs will potentially be used. EAF considerations need to be given prominence, alongside more traditional stock assessment results, in any report which has historically relied only on stock assessment. Care needs to be taken to ensure that the details of scientific debate do not overwhelm non-scientific stakeholders.

The issues raised in the Risk Assessment process, and the data sources used will vary considerably in nature; some can be assessed quantitatively, some can in principle be addressed quantitatively but raise significant difficulties in practice, while others will be qualitative in nature. Combining these types of information is not a simple process. Two different problems arise. The first is how to move from qualitative to quantitative when setting up scenarios for numerical modelling. A second is how to include such different sources of information within a single advice-giving framework. An important principle here should be that the purpose of the scientist is to provide objective advice. During the workshop competing points of view (industry, conservationists, NGOs, etc) will emerge. In such cases, each party should be given a platform to substantiate their point of view, and arguments would be weighed based on evidence. An important aim of the EAF is that this debate, and the management process, should be informed by objective, accessible, and relevant scientific guidance and advice. The Risk Assessment exercise (Section 4.7.2) can provide a platform to identify what the issues of concern are, and how to provide such advice.

7.2.1 Qualitative and quantitative

A number of different sources of data are likely to be available for a given ecosystem. Some will be highly quantitative while others may only be available in a qualitative form. In addition to the variety of data sources available, the issues of concern may be raised with different levels of precision or detail. For example, a minimum acceptable stock biomass may be given in quantitative terms, while a concern related to the economic well being of fishing community may be expressed in more general (qualitative) terms. In both of these cases there are difficulties involved in moving from qualitative to quantitative (for example setting parameter values in models), and in comparing the results of quantitative models with more qualitative indicators (e.g. how to balance low zooplankton productivity with concerns over coastal poverty). In some cases further research can produce more quantitative results for data which are initially available in qualitative form only. In these cases an assessment needs to be made if the resources to conduct such studies are available, and if this is considered a worthwhile use of the limited resources available. It may be that such resources are not available, or that precisely quantifying the data or indicator is impractical. Where a concern is initially phrased in a qualitative way (e.g. that environmental change may reduce the profitability of the fishery) quantitative bounds may be placed on the likely magnitude of the changes, and hence produce detailed scenarios that can be analyzed further.

In general there is a need for a framework for assessing qualitative factors, and incorporating them into an assessment process that relies heavily on detailed numerical analysis. This framework should be widely agreed on by the stakeholders. Ideally the framework would include socio-economic models but this may be difficult to achieve in practice. Often when giving scientific advice in a situation where social and economic realities are considered in a qualitative manner it is helpful to have a pre-defined framework in which the work is conducted. The relative roles of scientists, managers and other stakeholders in these processes should be clearly defined in advance.

7.2.2 Scenario modelling

Given the breadth of issues encountered in this process, a realistic strategy is to use a limited but informed number of scenario investigations in order to shed some light on those issues considered critical. The scenarios can address a range of “what if” questions, covering areas such as different management strategies and different model hypotheses. These alternatives can be developed to address the issues raised during the Risk Assessment workshops. These scenarios should be developed collaboratively between scientists and the wider stakeholder community. The likelihood of these different scenarios should be debated at length amongst the stakeholders. Such debate should aim at producing a reasonable number of scenarios for development which will best inform management given typical data and manpower limitations.

These scenarios can be first identified in a qualitative way as being areas of concern, and then refined into numeric scenarios that can be addressed quantitatively. These key scenarios should be considered by a range of stakeholders who should identify; variants of the system considered likely, issues to be addressed, likely ranges for parameters, relative weighting of different scenarios. Cases considered to be of lower risk can also be identified and assessed with a rapid "robustness tests". This provides for the move from qualitative to quantitative, and preserves both the breadth and the depth required within an EAF.

7.2.3 Indicators

Another way of combining qualitative and quantitative data is to use a range of indicators. These indicators may relate to factors such as stock biomass, ecosystem health, fishery sustainability, economic wellbeing, etc. Such indicators have the potential to be useful to identify areas of concern. However there is a concern that, although many indicators have been proposed, few have been formally evaluated for the extent to which they are able to detect and/or predict trends in variables of interest (Fulton *et. al*., 2005). Where indicators are used within an EAF it is therefore considered important to conduct research on their utility in monitoring and predicting changes within the ecosystem. Indicators are often useful for education, contextualization of fisheries within the ecosystem, and communication; some indicators (or the combination of limited set of indicators) may also be rigorous enough to raise a flag. There needs to be a set of decision rules to decide which indicators (or combination thereof) may trigger action and at what level. For a scenario considered and analyzed in advance the "action" may be some pre-determined change in management (e.g. closing a certain area, or changing the quotas). More generally such indicators can identify an area which requires further investigation; in this case the "action" would be to trigger targeted research. These rules should be decided in advance as part of a collaborative process.

The use of multiple indicators is likely to become increasingly important as an EAF may require more information than can be provided by traditional stock assessment alone. It is therefore important to continue work which identifies, evaluates and incorporates different indicators into the management system.

7.2.4 Communication

Participation and transparency are important components of an EAF, but are inherently difficult to achieve when dealing with a complex ecosystem-based approach. Using multiple indicators and multiple modelling scenarios makes producing clear and transparent advice difficult. Research into Decision Support Systems (DSS) based on fuzzy logic and rules is currently underway for the South African Small Pelagic Fishery. These have the potential to be useful for explaining the intricacies of ecosystems and multiple indicators. The issues included in the decision tree underlying the DSS should come from the Risk Assessment workshops and the underlying logic should be arrived at collaboratively with stakeholders. This will reinforce the validity of the tool and the ability of the users to understand it. The tool then provides managers and other stakeholders with an accessible tool to provide an overview of the ecosystem, and indicate some of the possible linkages within that ecosystem.

The group considered this a useful tool but there were several concerns that it may, in some cases, be misleading. One concern is how to interpret and react to conflicting indicators. This is not solely an issue for DSS but is a general concern both within fisheries science (see e.g. ICES WGACEGG, INECO, INDENT, IMAGE EU projects) and has been developed as part of wider multi criteria decision making theory (e.g. Belton and Stewart, 2002). A second concern is where the DSS overlaps with an existing stock assessment model and OMP. Changing parameters within the DSS (e.g. effort) may produce different results to those in a stock assessment model. It needs to be explained that the DSS is a simplified method to give an overview of the ecosystem, and the sub-models within it may differ from more detailed models of the same factors (e.g. existing stock assessment models), otherwise confusion may arise. Finally the decision tree underlying the DSS may include a number of different indicators or relationships for which there is a lack of scientific agreement or understanding. At present the DSS is considered a useful communication tool, however it is not yet clear how one could proceed to using this in a formal management process.

7.3 Conclusion

The Risk Assessment process offers one method to make a start towards achieving an Ecosystem Based Approach to fisheries management. The overall framework can be suggested (see Section 9) but implementation must be handled on a case-by-case basis with wide-ranging stakeholder participation. In particular the group believes that an iterative approach is needed, with an initial process being refined and developed through testing and case studies. Progress in Ecosystem Approach to Fisheries management is only likely to be achieved by actually getting our hands dirty and trying to do it.

8 Additional presentations

8.1 Stock assessment and risk evaluation in Namibia – Hake and seal

A summary of the hake assessment, the decision process, how the process had changed over the years and how the presentations to management take place in Namibia was presented to the study group. An example of setting reference points needed for management plans relating to Namibian seals was also presented.

1) The main uncertainties / risks that were identified:
2) The two hake species are not assessed separately.
3) The clarity of presentations of recommendations to managers.
4) Since no discards are permitted, catches taken are regarded as true.
5) Abundance series and catches (past and present) are used in the models without observational errors.
6) Catch-at-age data is limited and has he concerning influence on the results of the model.
7) Values for parameters like natural mortality and steepness are not available.

The presentation emphasized the need for presentation of results to managers to be clear and transparent.

Some discussion arose on whether the confidence intervals on the different models captured the complete uncertainty associated with an assessment. Results should be presented to managers in order not to bring across the idea that model estimates were absolute in themselves, yet, that the confidence intervals only reflected a fraction of the true uncertainty around model results. Different model specifications are used to test model structure uncertainty, whereas confidence intervals reflect the estimation uncertainty. However, uncertainty also arises from model assumptions, e.g. fixing certain parameters, as well as uncertainty in the data themselves.

The reference points established for the Namibian seals was presented. The reference points were set according to a relatively short time series using highest and lowest stock levels as guidelines and will be changed as more knowledge is gained on the dynamics of the stock.

8.2 The PRONE project

8.2.1 Background

Current European fisheries management does not systematically take into account biological, economic and social risks. Uncertainty in fish stock assessment reflects to management decisions and inflicts risks of unfavourable outcomes in economic and social terms.

8.2.2 Integrated risk management

PRONE studies how risk analysis theories can be applied to European fisheries management. The project will provide an integrated framework for analysing biological uncertainty and the ability to implement management actions. It will also contribute to improved communication between biologists, economists and managers. The integrated risk management framework developed in PRONE leads to improved:

- risk identification among stake-holders.
- risk assessment methodologies which deal with various types of risks, also multidisciplinary.
- risk management by evaluating various risk management options and identifying those with merit for European fisheries, taking into account their economic and strategic impact and using the concept of value-of-control. These will support the roles of actors in management negotiations.
- risk communication by reviewing successful approaches in other fields and exploring how the findings of the current project are accepted by stakeholders.

8.2.3 Project tasks

The project will:

- review the current state of fisheries science and management in Europe, identify its weaknesses, and identify potentially useful risk analysis approaches.
- identify the knowledge requirements for fisheries management and their role in achieving management objectives.
- identify the controllable elements and their role in manipulating the system to achieve management objectives.
- develop tools for risk assessment and management to develop, implement and run appropriate risk management systems in fisheries.
- evaluate the understandability and interest to use risk related information in alternative management systems and in different cultures. Case study areas are Greece archipelago (no TAC), North Sea (TAC), Faroes (ITE) and Iceland (ITQ).

8.2.4 The projects contribution to European fisheries management

The risk management framework developed will contribute to improved economic profitability as well as biologically more sustainable European fisheries. The project will deliver a Policy Implementation Plan (PIP) with a proposal of how the results should be applied in fishery policy on short, medium and long time scales, as well as overall policy guidance conclusions.

8.2.5 Individual interviews vs. group meetings

The different case studies have different groups of stakeholders. In the Faroes selecting the relevant people is simple, as there is a very small community. All interested parties know each other, and are used to working together. In the UK it is harder to identify all stakeholders and interested parties. Currently selecting who should be interviewed.

South Africa gained benefits by having all involved stakeholders in one room for their meetings. This provided a better perspective of the different views and concerns of different stakeholders. It also allowed for "calibration" of the relative risk assessment exercise, so that within a group the different parties came to agree on a scale of risk for the different issues raised. PRONE will not have this, since it will be conducting individual interviews. Interviewing people separately will present problems in comparing between the different interviews, as different people may use the risk category labels differently. On the other hand this method gives genuinely individual views, not just consensus group results (herd effect). One could then bring the individuals into a common framework at a later stage. South Africa had three different meetings, could see both similarities and differences in concerns between the groups.

Managers are a crucial part of this system – communication with managers is an important goal of the PRONE project. Generally more work is needed on how to communicate uncertainties to managers – especially when this uncertainty wasn't made explicit to them previously. PRONE is hoping to run several models and present them to different groups in different ways and see which presentation method works best. How to better communicate uncertainty is an ongoing EU research goal.

8.2.6 Summary of discussion following PRONE presentation

The PRONE project aims to start with interviewing interested parties about their perception of risks to their fishery, and move from this through a risk assessment process, run numerical models for several cases, and finally present results to ministers and other interested parties. There was discussion of the benefits that PRONE aims to produce for the EU Common Fisheries Policy. One of the claimed goals is to encourage "competitive fisheries". This was written to mean "not subsidised", i.e. level competition between EU countries. It was noted that there is also an issue with competition between EU and imported fish.

The PRONE project faces issues on how to compare different systems (Mediterranean vs. Icelandic or Faroese vs. North Sea). These differ in a number of important ways:

- Ecosystems, different resilience and diversity
- Number of ports to monitor
- Cultural differences

As a result of these differences in ecosystems, data availability and reliability, and fishing practices, it may prove problematic to produce meaningful comparisons between all of these different fisheries.

PRONE will be using social scientists to conduct interviews. South Africa had problems finding social scientists with an interest in fisheries to assist with their research. They also found difficulties with social scientists working within the methodology defined by the fisheries scientists. Science and social science have fundamental differences in their methodology and approaches to problems. PRONE is aware of these issues, and has found relevant social scientists to work on this project (social scientists and fisheries economists)

It is rare to find a forum in which both scientists and social scientists participate. Work is ongoing in several different Working Groups and EU projects to improve this in a European context. Funding for such work is obviously an issue. Such meetings give a better chance for the two groups to better understand each other.

More generally there is a key issue in how to bring together fisheries science and social science. The EU is keen to have work further done on this. Social scientists generally look at broader picture than fisheries science (ecosystem includes all human activities, not just more species in multi species). Fitting this approach with the narrower, more quantitative fisheries approach represents a challenge.

US may be heading towards giving greater responsibility for quota setting to the scientists assessing the stocks. This, in some ways, solves the problem of having to explain uncertainties to managers. Fisheries management in the US is based on the Magnussen-Stevens act, which lays down explicit, legally binding, management objectives.

The EU may also head in the direction of giving more responsibility to the scientists. As assessments become more complex, and more factors and uncertainties are considered it will become more difficult and time consuming for managers to understand the advice.

8.3 "Risk assessment of North Sea Herring for stock rebuilding purposes using an optimization algorithm"

8.3.1 Summary

Finding better management strategies using risk management approaches that support medium-term management decisions are of increasingly growing importance. The approach presented at the 2007 SGRAMA tries to combine elements of medium-term prediction and risk management using components of operation research and econometrics to create an adaptable framework for rebuilding stocks given a biomass target and F limits within a planning horizon set by managers.

Conventional medium term projections are predictions of the expected stock dynamics based on parameter values (usually fishing mortalities) estimated from the past. Typically projections are run for several different scenarios based on different F values in order to choose the "best" or most "predictive" F. Thus the conventional approach does not provide a direct or automatic method to determine the optimum F or catch values (quotas). In contrast to this, the approach presented to 2007 SGRAMA does not predict the stock development from historic stock dynamics, but provides us directly with optimal annual F values and associated optimum catch quotas (TACs) for a given planning horizon. Hence, the F values are not retrospectively estimated but are realizations of the control variable created through the optimization process to meet the optimization criteria (objective function). Given the data and the optimization algorithm and assuming numerical convergence with a globally optimum solution, optimality here means that there will be no better set of F values and associated catch quotas (TACs) that help to rebuild or recover a stock than the ones selected by the optimization procedure.

The optimal solution is based on a non-linearly constrained objective function to be maximized. The maximization process takes place with respect to catch or yield (in physical or economic terms), while the constraints inter alia include meeting biomass targets, not exceeding F limits, keeping the catch stable, and/or others as desired. It has been shown that the optimization procedure as outlined here is not only "risk averse" but a risk minimization procedure in itself.

To show how the model can be implemented as part of a risk analysis approach we applied it to a stochastic single-species example represented by the case of North Sea herring in ICES Subdivision IVb. We used an age structured model based on the Baranov equation, as planning horizon we took a 10 years rebuilding period. The stochasticity comes into play by

taking into account the uncertainty that is inherent in the stock-recruitment relationship. To model this we used a segmented regression approach as given by the HAWG report by additionally incorporating 1st order autocorrelation. We also added a (deterministic) implementation error of 20% on the optimized F values to take into account the problem of over catching. All other input data (by age) used for initial year 2005 (abundance, weight, maturity, selectivity values, etc.) as well as the reference points for F and B were taken from the HAWG report. The example is simplified to foster the understanding of the procedure. However, the software code used (we wrote the tools in SAS 9.1) can handle more complex situations in terms of bias and stochasticity.

The stock rebuilding approach is considered to be an adaptive dynamic framework that is open and modular in construction and amenable to further improvement as knowledge increases.

8.3.2 Contrasting the method with the South African management procedure approach

The herring risk assessment method is different to the South African management procedure approach. The herring method optimizes the annual F values (decision variable) by maximizing the sequence of annual TACs accumulated over 10 years for each stochastic projection, subject to certain stability and sustainability constraints. By comparison, the South African method does not carry out any explicit optimization, but proceeds by an examination of results integrated over all realizations, appropriately weighted. However, it was noted that it might be interesting to subject the South African method to optimization of, say total catch, w.r.t. the OMP tuning parameters for each stochastic projection to the planning horizon. This follows noting that the herring methodology can be extended to incorporate a feedback harvest rule. For South African researchers this “realization by realization” optimization approach would involve a different way of interpreting the OMP development results, and choosing the preferred management procedure, which may have certain advantages over the existing practice in South Africa. It was also evident that the herring approach takes care of certain issues automatically (stability of interannual catches, sustainability), and the utility of this is particularly valuable in complex multispecies, multi-area, and multi-fleet situations, where the time to find feasible management procedures may be shortened (cf. the South African approach). Having said this there was some confusion expressed about precisely what decisions within the EU context (interaction between ICES and the EU) would flow from the herring analysis as presented here. From this discussion it appeared that the intention is to update these analyses annually to provide some support to management on appropriate TAC levels in the medium-term. This appeared to differ to the South African approach in which the intention was to provide the necessary output to inform the choice of a multi-year management procedure, where the OMP would be the sole determinant of the annual TAC.

The herring risk assessment method as presented here uses an explicit economic objective function, which if desired, could be altered to focus more on social objectives or biological objectives. However, an “economic or social formulation” of the objective function would require drawing biologists and managers together and as such it envisages real economic inputs and a meaningful economic objective. This has highlighted the complexity of the economics of the situation and it was noted during discussion that this economic complexity has not been explicitly addressed in the South African framework. It was noted for example that there are often different operators in a fishery subject to very different economic objectives and constraints.

9 An ICES framework for risk assessment

This section summarizes discussions and views from a subgroup of the Study Group. There has been no formal adoption of the text in plenary so the views presented here do not necessarily represent the views of the study group as a whole.

9.1 Introduction

In this section, the study group presents its suggestion for an ICES framework for risk assessment and how it links to risk management. A main benefit of moving towards risk assessments and risk management, we see, is an increased attention to the consequences of the inherent uncertainties in our knowledge.

As ICES is planning to merge ACFM and ACE into one advisory committee producing a combined advice report, we have had an ecosystem approach to fisheries (EAF) in mind when developing the suggested framework. The FAO definition of the EAF spans broadly regarding issues: "An ecosystem approach to fisheries strives to balance diverse societal objective, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries", (Garcia *et al*., 2003). The Bergen Declaration (NSC, 2002) links the EAF closely to stakeholder participation.

The presented framework is thus designed to enable a broad scope of issues and provides a suggestion on the role of stakeholders. However, the framework can also be used for a much more narrow scope, like in connection with fish stock assessments. In the last case, the issues would be narrower defined and the stakeholders would perhaps not be the same as in the former case.

The main principles for the development of the framework have been 1) to broaden the scope of risk issues, 2) broad participation in the process, 3) the precautionary approach and 4) transparency mutual communication. These are outlined below.

1) Broad scope of issues

The scope of issues in a risk assessment can be restricted to issues related to catch quotas or broadened to include ecological, sociological and economical, in line with the EAF (see Section 4.7 and Section 7). In addition, the scope depends on the choice of unit to take into consideration, which has to be decided by managers. Are the risk issues restricted by those relevant to, say, a single stock, a fleet or maybe a fishery? As SGRAMA does not have the authority to decide the scope, we can only recommend that that the range of issues is wide and that different units are covered, both at the international level, dealing with the common and overarching issues, and the more local, handling the variation in case specific issues.

ICES does not have the expertise to cover all the potential disciplines. So, if the managers choose a broader scope, ICES might need to cooperate with other institutions.

2) Broad participation (scientific disciplines and stakeholders)

SGRAMA considers multi-disciplinary participation to be a requirement for success in developing and applying a framework for risk assessment. This requires expertise from a majority of disciplines within ICES (ACFM, ACE and ACME), but also within social sciences like economy, sociology and, especially, competence on risk management. We also emphasize that without a close connection to the involved managers, parts of the framework for risk assessment sketched here, will be irrelevant.

In addition, SGRAMA considers a participatory process with stakeholders (industry, managers, environmental organizations, consumers and scientists) crucial in risk assessments. Stakeholder participation can increase legitimacy and trust, and, together with multi-discipline representation, participation can improve the quality of risk management and by mutual learning and ensuring that relevant risk issues are included. Yet, we are also aware that participatory processes are more time and resource consuming (and may in some cases even increase the conflict level).

The level and degree of participation can be quite diverse. Participation can be restricted to certain issues and to the level of responsibility, e.g. the stakeholders can participate in deciding the risk issues to be addressed by science (like South Africa hake, see Section 4.7.3), review scientific information and advice (extended peer review) or the stakeholders may be asked for advice concerning management actions (Norway). On the question of responsibility, participation can imply providing advice to the decision makers or actually be part of the decision making body.

Unfortunately, there was no expertise on participatory processes (or social science in general) at the 2007 SGRAMA meeting. SGRAMA recommends pilot projects with focus on participation processes. Existing expertise should be involved and experiences and knowledge should be collected. The issue of participatory processes should be one of the main issues at the next study group meeting.

3) The precautionary approach

Different international agreements have supported the precautionary approach to fisheries management. This requires investigating and taking into account the different sources of uncertainty (see Section 6) and the different uncertainty categories (see Section 4.8). Furthermore, SGRAMA considers assessment and management of risk are valuable steps for the precautionary approach to be applied as it increases the focus on validation and on the consequences of the uncertainty. The aim is thus to enable management that is robust to the critical uncertainties.

4) Transparency and mutual communication

Given that the framework includes broad participation, communication and transparency in the whole process become essential in order to warrant a successful process, in which all the parts are integrated and committed.

9.2 Terminology

A development of a framework for risk assessment necessitates definitions of terminology. There is a multitude of different uses of terminology and definitions. Based on our reviews we recognize that risk assessment frameworks differ in descriptions partly due to differences in context. The similarity of the reviewed frameworks is that they recognize the identification of problems as an important part of the risk assessment in addition to risk estimation itself.

The terminology presented in the following is not an attempt to make a final list of definitions within the field. The description is intended to illustrate the approach taken by the study group.

Risk

Risk can be defined as potential harm or expected loss from some present or future process or event. The study group chooses to use the term risk in a broad manner as consisting of both a likelihood of an event and the severity of the event or the severity of the consequences of the event. The study group recognizes that the likelihood or probability of an event may or may not be quantifiable or quantifiable only to certain extent and that severity can be linked to costs in monetary terms or other value terms and will in many situations be demanding or impossible to quantify.

Risk identification

The process by which the events with the potential of causing harm are recognized and characterized.

Risk screening

The process to determine which risks should be investigated in detail and dealt with.

Risk assessment

The process of, within a certain context, producing estimates of or knowledge of risk(s). The assessment process may be based on previously identified/defined events or adverse effects, but the identification of risk(s) will usually be a part of the risk assessment process. A risk assessment process includes preparation of and communicating the results of the assessment.

Risk policy

A risk policy formally outlines the objectives and risk management strategy. It documents the roles, responsibilities, accountabilities and authorities that support the approach and processes adopted to achieve those objectives

Risk management

The process by which an action or a group of actions that aim to reduce or manage the risk are decided upon.

9.3 Steps of the risk assessment framework

The framework describes the risk assessment process from risk identification to risk estimation, and how it links with risk management. It allows for a broad spectre of issues and a broad stakeholder representation, where stakeholders both influence the choice of issues and play a role in quality assurance. SGRAMA considers the following cases as extra challenging in dealing with risks:

- When objectives are contradictive (e.g. stock recovery and fishermen's income level) and the different pros and cons need to be compared.
- When knowledge about an issue is very uncertain and basically qualitative (e.g. whether fishing in a certain area affects the reproduction in a nearby bird colony).

Both cases are examples where decisions need to be based on value judgments and caution need to be taken on basing decisions on quantitative measures only. When objectives are contradictive, the decision is more of a value choice: how important are the objectives compared to each other. This is also the case when knowledge is uncertain and not quantifiable: how important is it to be risk averse when you either don't know the impact or cannot quantify the probability. The more contradictive objectives and the more uncertain knowledge, the less likely a problem can be reduced to the two classic risk components, impact and probability, and the more risk management should be based on discursive strategies (Klinke and Renn, 2006, see Section 4.8). The presented framework allows for stakeholder interactions at three stages and thus provides an arena for solving problems where knowledge is uncertain. The framework is illustrated in Figure 9.1.

Step 1 Risk identification and risk screening

Participation

SGRAMA recommends that this process involve broad participation, including all relevant disciplines and stakeholders, to increase legitimacy, trust and quality and to ensure that all relevant aspects are considered.

Input/restrictions

Management objectives, policies, legislations, funding and the managers' decision on the scope of risk issues to be dealt with in this exercise all determine the limits for problem identification and risk screening.

Occasionally, the risk issues may be revised. In advance it may be agreed or set that this is done every X years, when new risk issues emerge or when certain performance criteria of the risk management are not met. In case of a revision, input to the risk identification and screening step may be a review of a set of performance criteria.

Description

In this step problems/risk issues are suggested, a priority list of risk issues is agreed on and suggestions on how to represent the issues, especially in qualitatively described problems, are provided.

Issues may be closely linked to each other, and need measures for comparisons or joint impact, or may be totally independent.

We consider this first step of the framework to be a process that may take some time, especially the first time it is carried out. How many workshops or meetings it requires will vary, and how they best are planned are probably case specific.

An agreement on issues can be settled for a certain time period, say 1, 3 or 5 years, after which the exercise is repeated. Agreed procedures in case of unexpected events or situations should be developed together with performance criteria related to the success of the risk assessment (and management).

Tools

- Procedures for making workshops efficient
- Tools to illustrate possible connection between issues and possible contradictory objectives (influence diagram to map causality and questioned causality (see Sections 4.3 and 6.3.6), fuzzy logic to briefly give the basic idea on how parameters affect the system (see Section 7.6)
- Interactive communication tools for mutual learning.
- Tools already used for management purposes (like tools for deciding reference points, assessing the status or evaluating harvest control rules.)
- Screening tools (e.g. SA hake in Section 4.7.2, or cost-benefit analysis)

Communication issues

The mandate of this group must be clear on how much power and influence the group has. The experts must be clear on the expected difficulties in quantifying the risks of the agreed issues.

Output from step 1

This step provides

- A priority list of risk issues
- And suggestions on how they be dealt with in risk estimation,
- Suggestions on evaluation criteria to revise risk estimation and risk management,

- Suggestions on procedures for robustness trials in management plans or HCRs, a la IWC?
- Suggestions on performance criteria
- Suggestions on action when exceptional circumstances

Step 2 Initial risk estimation

Participation

This is a scientific exercise so that scientists only participate. We suggest a multi-disciplinary participation.

Input

This step needs a list of prioritised risk issues and suggestions on how they be dealt with in the risk estimation. This is provided by step 1.

Description

This is a step to provide measures of the impacts and its probability.

How to measure impact can also be associated with uncertainty. Hambrey and Southall (2002) divide the problem into the following three categories:

- *Impacts or harms that can be directly measured*
- *A proxy is needed*
- *Not quantifiable so that impacts must be based on judgments*

The more quantifiable a risk problem is the more can risk estimation and assessment be science based. It is the opposite the more qualitative information is, in which case stakeholder involvement is more important. This means that the uncertainty in measuring the harm or impact is necessary to communicate. SGRAMA considers both statistical uncertainty and underlying assumptions to be crucial factors for the scientists to express and for the stakeholders to understand.

Probabilities may also be difficult to quantify, but can be substituted by qualitative levels. If trade-offs are incommensurable, expressionist should be clearly stated.

Assessments should be carried out on the suggested performance criteria, evaluation criteria and procedures for robustness trials. There should be pre-agreed procedures on how exceptional circumstances to handle situations when performance is not satisfactory or when the present situation is different from what is experienced earlier. An example is when the latest data point is outside the range of the historical time series and therefore outside the scope of the earlier risk estimation.

Examples of risk issues that might have to be translated to impact levels and probabilities: Overfishing, bycatch, illegal fishing, habitat damage, discards, fishing effort, loss of catches compared to alternative management strategies, other ecological effects of fishing, environmental impacts on a fish stock, fish community or ecosystem and economic and social impacts.

Tools (depending on what already exists)

- Tools for sensitivity analysis
- Scenario models (what happens if)

- Robustness testing
- Uncertainty assessment related to the measures.
- Case specific tools

Communication issues

- Uncertainty and quality of estimates
- Contradictive objectives
- Possible conflicting measures.

Output from step 2

- Measures for the impact of the risk issues.
- Measures for probability
- The tools the scientists suggest for the risk estimation
- Uncertainty assessment to both types of measures (quantitative and qualitative)
- Initial risk estimation
- Assessment of performance criteria, evaluation criteria and procedures for robustness trials.

Step 3 Quality control of risk measures

Participation

This should involve the same group as in step 1.

Description

This step is a quality control of the initial risk estimations to check whether the measures and tools meet the expectations of the group. If not, it may be desirable to identify the disagreements, make recommendations and repeat the risk estimation process.

Tools

Discourse

The quality control is more efficiently carried out when the results and the uncertainty assessment from step 2 is properly communicated.

Output from step 3

- Quality checked measures for the impact of the risk issues.
- Quality checked measures for probability
- Quality checked initial risk estimation
- Agreed performance criteria, evaluation criteria and procedures for robustness trials.

Step 4 Risk estimation

Participation

This is a scientific exercise so that scientists only participate. We suggest a multi-disciplinary participation.

Input

If this step follows step 3: this step needs the output from step 3.

If this step is just an update, this step only needs the latest data.

Description

A refinement of step 2. If in accordance with the risk policy, this exercise may be updated risk estimation.

Tools

- Refinement of tools from step 2 or previous years
- Development of improved and perhaps case specific tools

Communication issues

The same as for step 2.

Output from step 4

- Risk estimation
- Assessment of historic performance
- Uncertainty assessment and validation
- Management advice

Step 5 Quality control of risk estimation and management advice

Participation

Scientist group and non-scientist group to perform a peer review (by experts) and an extended peer review (by non-experts). Normally, a peer review is carried out by others than the ones who have produced a paper or a report. SGRAMA recommends this step to be carried out by others than those in step 1 and 3. Managers should not be part of this.

Input

Output from step 4.

Description

This is a double quality control of the risk estimation and consists of a scientific peer review and an extended peer review, a review by a non-science group to ensure the quality and relevance of the scientific tools and results.

Communication issues

The peer review group needs information on the data, models and underlying assumptions.

The extended peer review group needs a focus on assumptions and limitations and how they affect the risk assessment advice.

Output

Peer reviewed and extended peer reviewed risk assessment and advice.

Risk management

This is not part of a risk assessment and outside the SGRAMA scope. It contains the remaining matters other than risk assessment: forming a risk policy, management decisions, and implementation of the policy, regulations and enforcement. The risk assessment process interfaces with risk management at several steps.

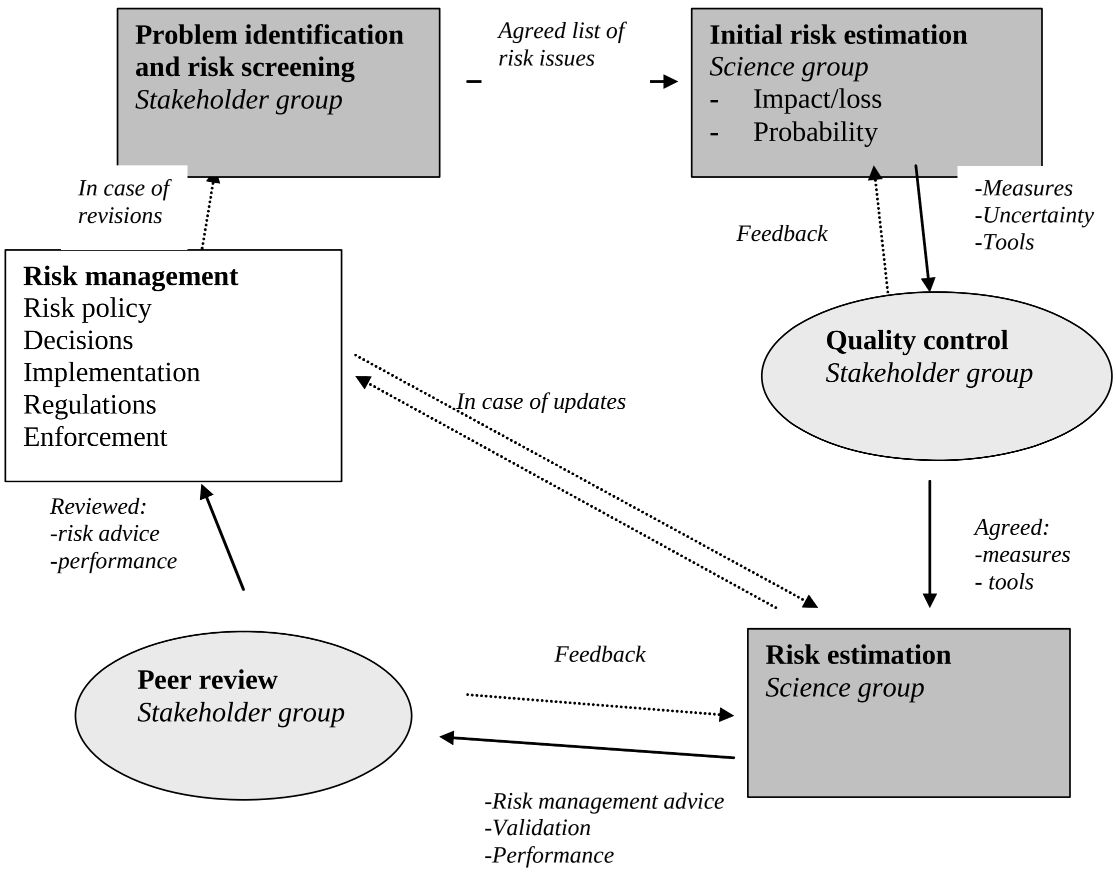

Figure 9.1. *Risk Framework*: Risk assessment is defined by the light and dark grey boxes. The white box contains the other contents of risk management, which are outside the scope of the proposed framework. Problem identification is important in an initial phase of risk management, but may not be necessary every time risk estimation is carried out. The framework consists of two major loops, one for updates of risk assessments and one for revisions. Note the small loops linked to the two steps providing quality controls.

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Annex 2: SGRAMA Terms of Reference 2006

2006/2/RMC02 The **Study Group on Risk Assessment and Management Advice** [SGRAMA] (Chair: Knut Korsbrekke, Norway) will meet in Cape Town, South Africa, from 5–9 February 2007 to:

a) to review and report on available methodologies for risk assessment and frameworks for risk management within and outside the fisheries sector;

b) on the basis of the review, start development of a framework and operational guidelines, for risk assessment and advice which includes considerations on risk management. Risk assessments should *inter alia* relate to conservation limits and targets for exploitation of fish stocks taking into consideration the ecosystem effects of fisheries and environmental variability and management considerations should relate both to the production of such assessments and institutional aspects of risk management decisions and implementation. The framework should link to the framework for management strategies developed by SGMAS with the scope of ultimately being integrated with these;

c) consider and report on training needs and possible modalities for training to disseminate knowledge about risk assessments to members of ICES expert groups;

d) outline the kind of relevant information that will be required for risk assessments.

SGRAMA will report by 1 March 2007 for the attention of the Resource Management, the Living Resources Committee as well as ACFM, ACE, ACME.

Supporting Information

PRIORITY:	The work is essential for ICES to progress in the development of its capacity to provide advice on fisheries and marine management which includes considerations of risk. Such evaluations are necessary to fulfil the requirements stipulated in the MOUs between ICES and Commissions
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	[Action numbers 3.2, 3.4, 3.5, 3.12, 4.2, 4.3, 4.5, 4.11.2, 4.13, 4.15, 7.2] The SGRAMA report is a first step in establishing guidelines for production of risk assessments and inclusion of considerations of risk management in the advice. Risk assessment and risk management is an important filed in several branches of science. The SGRAMA aims at drawing on the experience from other branches of science, and to include that experience in the development of risk assessment and risk management in fisheries science. The field covered by the SGRAMA is close to the fields of the SGMAS and WGFS. However, the scope of the SGRAMA is to focus on risk issues while that of SGMAS is in developing operational guidelines to enable ICES to respond to managers' request for advice on development and evaluation of management strategies even at present, while the scope of WGFS is mostly on improving the understanding of how fisheries systems work. Clearly, the SGRAMA should draw on the insight provided by the SGMAS and WGFS. The outcomes of SGRAMA will eventually be incorporated in the guidelines for evaluation of management strategies under development by SGMAS.

SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN CONTINUED:	The SGRAMA started its work in 2006, with low attendance, and could only initiate the work on the ToRs. As these tasks require more than one meeting to complete, the ToRs are the same as for the first meeting. There is an offer to host the meeting in Cape Town. Referring to the guidelines for choice of meeting venue: It is imperative for the group to look beyond the ICES area, as well as including scientists from other fields than what is traditionally covered by ICES. In a communication for the General Secretary to the delegates, it was highlighted that 'The Study Group is in need of multidisciplinary participation both from within and outside the ICES'. South Africa has observer country status in ICES. holding the meeting in Cape Town will build a link to the strong scientific environment in the field in South Africa. The link is further strengthened by the Chair having a sabbatical stay in Cape Town at the time of the meeting. So far, the group has only met at ICES headquarters. The cost of travelling to South Africa are not overwhelmingly higher than within the ICES area, and having the meeting in Cape Town should not imply extra costs for ICES.
RESOURCE REQUIREMENTS	
PARTICIPANTS:	Experts with qualifications regarding assessment and institutional aspects of risk assessment and management. Effort should be made to attract participants with experience in risk assessment and management outside the fisheries sector.
SECRETARIAT FACILITIES:	Production of report.
FINANCIAL:	No extra costs for ICES
LINKAGES TO ADVISORY COMMITTEES:	ACFM, ACE, ACME
LINKAGES TO OTHER COMMITTEES OR GROUPS:	RMC, WGFS, AMAWGC and Assessment WGs
LINKAGES TO OTHER ORGANISATIONS:	This work serves as a mechanism in fulfilment of the MOU with EC and fisheries commissions. There is similar work going on within ICCAT, NAFO, and NFMS. Coordination should be assured as a number of participants in EU-funded projects such as EASE, PKFM, TECTAC and FEMS are expected to participate.

Annex 3: Recommendations

General recommendations

The Study Group repeats one recommendation from last year's report: The Study Group recommends that the use of the term "risk" is handled more carefully. Risk should mean something more than the probability of some (potentially) harmful event and we recommend that at least the definition used and context is specified.

Fisheries management advice should include approaches that deal with risk.

Extended peer reviews of risk assessments are conducted.

Risk Assessment requires genuine, committed and wide-ranging participation by a range of different stakeholders.

More specific advice on overall objectives for management is needed at the initial stage of the risk assessment process and should be sought by presenting alternatives to decision makers.

Consistency and transparency is desirable when dealing with risk particularly within a resource, e.g. from one assessment to the next, and between resources. Retrospective analysis of risk measures should be presented and the same measures of risk (or readily related measures) should be employed so that credibility with stakeholders is enhanced.

Risk assessment and Management Procedures

Management Procedures are one approach to take due account of risk. These should be subject to regular review/re-evaluation. A framework for agreeing when exceptional circumstances apply, (typically if the situation has moved outside the bounds within which the procedure was tested) needs to be developed. This may require that reviews are brought forward and/or action be taken different from that output by the management procedure.

Methods for weighting to reflect plausibility's of alternative hypotheses should be explored. These may be either statistically based or depend upon expert judgement, appropriateness of different approaches will depend upon the case study under consideration. The process of weighting is likely to be important in gaining an agreement of the plausibility of the hypotheses and hence appropriate actions in the presence of uncertainty.

The evaluation of risk statistics can be a computer intensive exercise and in circumstances where there are limitations of time, reliable shortcut methods may have to be used. However, the effect of any simplifying assumptions should be justified to the extent possible.

Methods for the readily comprehensible presentation of results, and in particular for showing the trade-offs between objectives for given management options, need to be developed in collaboration with managers and stakeholders.

Risk assessment and the Ecosystem Approach to Fisheries

Risk assessment exercises should be broad and take account of ecosystem effects.

An initial risk assessment exercise that takes account of ecosystem effects (as outlined in this report) can provide a viable method of beginning to conduct an EAF.

Recommendations for future meetings of the Study Group

There be a formal coordination between SGRAMA and other working/study groups with overlapping interest in order to avoid duplication and build on mutual experience.

One or preferably two trial studies of the risk assessment process be commenced (e.g. within the RACs).

Further work is needed on identifying, evaluating, taking joint account/combining and communicating multiple different ecosystem indicators.

Participation (include social scientists).

Annex 4: List of working documents

The following working documents were presented to the study group:

WD1: S.J. Johnston, C.L. Cunningham, R.A. Rademeyer and D.S. Butterworth. Overview of the South African west coast rock lobster, hake and pelagic resources and fisheries. MARAM: Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, Cape Town.

WD2: S.J. Johnston, R.A. Rademeyer, C.L. Cunningham and D.S. Butterworth. Risk evaluation for the current South African west coast rock lobster, hake and pelagic OMPs. MARAM: Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, Cape Town.

WD3: S.J. Johnston, C.L. Cunningham, É.E. Plagányi and D.S. Butterworth. Risk-related Aspects of the west coast rock lobster and of the joint sardine and anchovy OMPs to be developed this year. MARAM: Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, Cape Town.

WD4: D.S. Butterworth. The approach recently developed by the IWC Scientific Committee for taking formal account of the results of robustness trials, together with their relative plausibilities, in assessing risk when selecting between alternative candidate management procedures. MARAM: Department of Mathematics and Applied ***THE WORKING DOCUMENT HAS BEEN INCLUDED AS ANNEX 5 OF THIS REPORT.*** Mathematics, University of Cape Town, Rondebosch, Cape Town.

WD5: Marine and Coastal Management: (Draft) Procedures for deviating from OMP output for the recommendation for a TAC, and for initiating an OMP review.

Annex 5: The approach recently developed by the IWC Scientific Committee for taking formal account of the results of robustness trials, together with their relative plausibility's, in assessing risk when selecting between alternative candidate management procedures

Doug S Butterworth, MARAM (Marine Resource Assessment and Management Group)
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A particular raison d'etre for the management procedure (MP) approach for providing scientific recommendations on management measures such as TACs is that it takes formal account of scientific uncertainties in its assessment of risks (primarily to the resource, but also to the fishery). This is achieved by considering the results of simulation trials (or tests) which project the resource forward under the MP's TAC-setting algorithm, not only under a model seen to best reflect the resource's dynamics, but also under other models consistent with alternative plausible explanations of the data available.

For acceptability, a candidate MP must demonstrate reasonable performance across statistics related to management objectives (such as low risk to the resource), not only under the "best assessment" model, but also under the "robustness trials" based upon these other models. This raises two problems however:

a) with the candidate MP tuned to provide "optimum" performance for the "best" model, performance will deteriorate to some extent for the other models – how much deterioration is acceptable, and

b) the plausibility of these alternative models also needs to be factored into the evaluation of risk in this process – extreme interpretations of the data which will lead to high probabilities of heavily reduced resource abundance can always be advanced, but need they be taken into account if such scenarios are considered to have low plausibility?

Evaluation of such robustness trials is often conducted on only a "tick test" basis – on inspection, do the associated performance statistics seem not to be substantially worse than for the "best" model? But particularly in circumstances where groups with appreciably different interests are involved in such deliberations, consensus can prove difficult to achieve on this basis. Hence it is desirable to move towards a more specific framework for formal incorporation of the results from such robustness trials in selecting between alternative candidate MPs.

This paper summarises the International Whaling Commission's (IWC's) Scientific Committee procedures developed to this end, which are set out in detail in the IWC (2005). First, however, some details concerning the IWC's RMP (Revised Management Procedure) for commercial whaling are necessary for background.

The IWC's RMP

The RMP is a generic procedure intended for potential application to any baleen whale resource. At its heart is the CLA (Catch Limit Algorithm) which, given historic catches and one or a series of estimates of abundance from surveys of an area, will generate a catch limit for that area from a Bayes-like estimator based on a simple population model. The algorithm has the property (consistent with the Precautionary Approach) that, other things being equal, abundance estimates with higher variances (i.e. greater uncertainty) will result in lower catch limits being output.

The CLA was evaluated for a wide range of robustness trials, and judged to perform acceptably across a certain range of "tunings". The CLA has a control parameter that can adjust the trade-off between higher catches *vs.* lower risks of unintended reduction in resource abundance regarding which a decision needs to be made in the management of any fish resource. The Scientific Committee deemed that a range from 60 (reflecting higher catches, but higher risk) to 72%[3] (for which catch dropped, but risk was reduced as well) for this tuning was acceptable. The Commission made the final choice of 72% for their adopted MP.

The CLA is designed for application to the idealized situation of a single stock (population), with no uncertainty about stock structure. This situation scarcely ever pertains in reality, so that certain rules are added to the CLA to appropriately spread catches in space (and time within the year if necessary) to limit risk in situations where there is plausibly more than one stock present and the location of the boundaries separating such stocks (or the extent to which they overlap) is uncertain. For example, if most past catches have been limited to a small area, whereas abundance estimates pertain to a much larger area over which whales are distributed, setting catches on the basis of such abundance estimates alone without further restrictions could place at great risk what might be a localized stock from which most of the past catches had been taken.

These rules require the CLA to be applied at the level of "*Small Areas*" into which the overall area surveyed is divided, with catch limits set at this smaller scale. However, because estimates of abundance calculated for smaller areas have larger sampling variances, this process leads to smaller catches overall – perhaps to an unnecessary extent. Therefore there are further rules which may also be applied, e.g. "*Cascading*" under which the CLA remains applied at a larger areal scale, but the catch limit output is then allocated amongst the constituent *Small Areas* in proportion to the abundances estimated in each.

The combination of the CLA with these rules for spreading catches is known as the Revised Management Procedure (RMP)[4]. In a particular instance of "*Implementation*" of the RMP, trials specific to the species and region in question, which in particular incorporate alternative hypotheses for stock structure, are developed to test and thereby select which of these rules to apply.

Taking formal account of results from robustness trials

This section summarises the key steps in the process described in IWC (2005), which sets out in five sections the activities to take place in each of the series of five meetings which provide the overall framework, and specifically Sections 3 and 4 thereof that relate to what follows.

Plausibility

Suggested trials are each accorded one of four weights based on the plausibilities assigned to the hypotheses that underlie them (see Section 3 of IWC (2005)). These weights are high, medium and low, and "no agreement" for scenarios for which a reasonable case can be made for a high weight but there is no consensus.

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3 The details as to exactly what these numbers relate are not important for the purposes of this summary, but in brief they refer to median population levels (relative to the pre-exploitation level *K*) anticipated after the application of the CLA over a 100 year period for one of the low resource productivity scenarios amongst the core trials against which the CLA was tested.

4 For an overview, together with references for further details, see Kirkwood (1992).

Low weight trials are not considered further, and for the purpose of this summary the "no agreement" trials can be considered to be treated identically to those accorded medium weight.

Equivalent single stock trials

A difficulty that arises in multi-stock trials is identifying whether or not the level to which management might have depleted any one of the constituent populations, or allowed such populations to recover, is acceptable in terms of risk. This is not entirely straightforward, because even in the simple case of the CLA applied to a single stock, the simulated final population size distribution after the 100-year management period typically considered is not fixed, but depends on factors such as the size of the resource when application of the RMP is initiated and its productivity.

The underlying concept adopted was that application of the RMP in a multi-stock case should be such that no stock was depleted further than would have been the case in the idealized "single stock + CLA" combination: hence thresholds for acceptable extents of depletion for multi-stock trials are developed from population abundance distributions after 100 years of application of the CLA to an "equivalent single stock trial".

Specific statistics used for comparison

Being generic, the RMP must cater both for situations where future catches will deplete abundance from a level initially close to pre-exploitation equilibrium (*K*), and for those where recovery is sought for a population already heavily depleted.

For the former, the population risk-related statistic chosen is the lower 5 percentile of the distribution of population size as a fraction of *K* after 100 years. To cater for the latter, again the lower 5 percentile is considered – on this occasion of the distribution of the minimum over the projection period of the ratio of the population size under the RMP to that which would have eventuated in the absence of commercial catches[5]. Note that since risk is involved, the statistics specified are lower percentiles of the distributions.

Since these two statistics are each motivated by their respective associated situations described above, and would not have much pertinence in the other situation, acceptable behaviour requires only that the threshold for one of the two is met in a particular trial.

Thresholds and decisions

Thresholds are trial-specific, with two being specified for each of the statistics above, corresponding to applications of the two extreme tunings of the CLA to the equivalent single stock trial in question: 72% as for the Commission's adopted RMP, and the less conservative 60%. Results which are (see Section 4 of IWC (2005)):

i) above the 72% threshold fall in the acceptable category;
ii) above the 60% but below the 72% threshold in the borderline category; and
iii) below the 60% in the unacceptable category.

Decisions as to the acceptability or otherwise of different "RMP variants" (different catch-spreading rules in combination with the CLA) then result from following the flowchart in Figure A.5.1 which is reproduced here with permission from IWC (2005). Key elements of this are that:

a) Failure to achieve the acceptable threshold for **any** *high* weight trial results in a candidate RMP variant being rejected.

5 Note that these reflect subsequent refinements by the Scientific Committee (IWC 2007) of specifications given in Table 1 of IWC (2005).

b) If for some *medium* weight trials, performance is considered reasonably close to the acceptable threshold (while above it for the rest); the candidate RMP variant may be classed as acceptable.

c) If the “reasonably close to acceptable” criterion of b) is not met, yet the candidate shows good catch-related performance, it might remain acceptable on a “research-conditional” basis. This requires the concurrent institution of a research programme targeted at resolving the uncertainty underlying the trial causing the difficulties, together with demonstration that if it fails to do so within 10 years, acceptable thresholds can still be reached over the 100 year projection period by substitution after 10 years of a more conservative RMP variant.

Wider application of these IWC concepts?

At first sight the IWC RMP concept of a generic approach applying across a variety of stocks and species might seem too inflexible to serve even as a starter for fisheries on a wider scale. However, both US and Australian fisheries legislation now includes (or is targeted to include) generic recovery performance criteria and catch control law restrictions – in an attempt at greater inter-resource consistency, most likely as a reaction to failures to achieve recoveries under systems that admitted greater flexibility. Furthermore similar pressures are arising from the developing ecolabelling requirements of the Marine Stewardship Council. These factors suggest that time may bring a more widespread move for fisheries towards elements of the IWC’s approach.

While the IWC’s constructs may be somewhat more complex than necessitate replication in detail in other fisheries management situations, focus on some of the core elements of the approach might nevertheless be immediately useful in taking first steps towards linking robustness trial results to rules governing candidate MP acceptability, *viz.*:

a) categorizing trial weights, in relation to plausibility, as high, medium or low (rather than attempting to provide more specific quantification); and

b) disregarding low weight trials, while requiring candidate MPs to meet more stringent risk criteria for high weight trials than for medium weight trials.

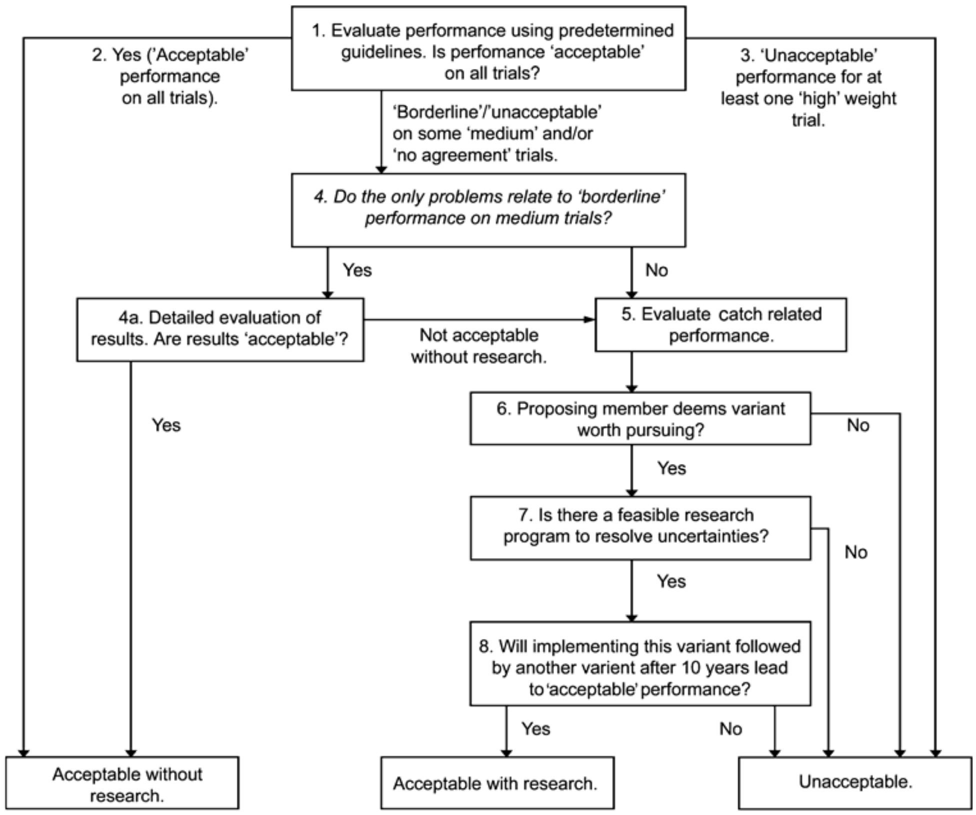

Figure A.5.1. Flowchart to guide decisions the by IWC SC on the acceptability or otherwise of different RMP variants, based on trial results and given the assignment of 'high', 'medium', 'low' and 'no agreement' to weight the plausibility of each trial. (Copied with permission from IWC (2005).)