ICES Resource Management Committee
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Report of the Working Group on Fishery Systems (WGFS)

26–30 April 2004
Lowestoft, UK

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Summary

The Working Group on Fishery Systems (WGFS) attempts to integrate across disciplines to develop analytical and investigative approaches to study and evaluate the performance of fishery systems. As such the group is part of the ICES system but also studies (among other) the role of ICES scientists within European fisheries systems. The Working Group met from 26–30 April 2004 in Lowestoft and had 16 participants from widely different disciplinary backgrounds (e.g., sociology, anthropology, human geography, biology, economics, and mathematics).

Case studies

There are a number of case studies on fisheries systems taking place that are coordinated through the WGFS. One group of studies analyses existing fishery systems using mainly social science methodologies with the aim of generating understanding of the key social processes and institutions involved. This includes the cod studies of the North Sea (Policy and Knowledge in Fisheries Management), of Georges Bank and Gulf of Maine (Fishermen's Experience Based Knowledge), and the Northeast Arctic (Boundary Negotiations in Mandated Science). Another group of studies works toward numerical simulation approaches of theoretical fisheries systems, to see whether the results can be used within a decision making framework. This group of studies works more generally toward the integration of quantitative and qualitative information about the fisheries (including fishermen's behaviour) into models used for understanding and decision-making. The working group acts as an important source for coordination in the case studies mentioned above.

Review of decision support systems

We identified four strategies for the complementary use of quantitative and qualitative information in fisheries management. Two of these strategies are based on interactive processes. The first is the use of public input to comment upon quantitative information. The second is having decision makers and other stakeholders interact with models to explore different scenarios (Section 3.4.4) to help them clarify their options. These strategies have educational potential but do not aid decision making directly. A third common strategy is treating qualitative information as a measurement problem for quantitative models. The advantage of this approach is that a set of numbers is produced that may be directly useful for decision-making. The disadvantage of this approach is that, if the information was really qualitative in the first place, the underlying measurement problems are never really solved. The danger then arises that the numbers produced are treated in management debates as truly quantitative results, which may undermine the legitimacy of management.

The last strategy, writing caveats to disclose the weaknesses in quantitative results (Section 3.4.3), is the most common way that ICES working groups and advisory committees integrate quantitative and qualitative information. This is an extremely important process that the WGFS recommends should be made clearer and more systematic.

Understanding fisheries adaptation to management regulations

A review of the use of qualitative information in evaluating fishermen behaviour was presented based on work in different EU research projects. The typological behavioural patterns that resulted from the studies could be useful in assisting in the quantification of behavioural responses in modelling context. A further review was presented of the use of quantitative methods for evaluating fishermen behaviour. In general, the behaviour of producers (both short-term and long term) can be thought of as a utility maximising problem, where individuals strive to get the best results according to their preferences and capabilities. The most prominent areas of analysis in terms of the economic behaviour of the fishing operation are (1): investment behaviour, (2) technological change, (3) gear and targeted species choice, (4) fishing location choice, (5) discards, and (6) choice of landing harbour. Analysis based on random utility modelling indicated that past effort and past catch rates affect choice of fishing location. However, studies to date show that some of the 'rules' that may apply to behavioural activity, cannot yet be accurately estimated. This is clearly an area where qualitative information could be used to inform the quantitative analysis.

Monitoring, control and surveillance

The Working Group briefly considered that the topic of developing an approach for the comparative analysis of monitoring, control and surveillance (MCS). The development of an approach for comparative studies on fisheries MCS for example within the context of the CFP would as a start benefit from reviews of such systems. The group concluded that very useful work has been carried out outside of the ICES arena and that it is important to liaise with these initiatives.

The group proposed to organize a short workshop during its next meeting in 2005 where external experts will be invited to present their analysis.

Precautionary approach reference points

The Working Group was requested to identify the factors that influence decisions about the definition of precautionary approach reference points. Precautionary reference points are benchmarks for guiding management decisions. The definition and estimation of such reference points are of critical importance because they regulate the division of responsibilities and interaction between scientists and managers. The calculation of precautionary reference points has a technical component that belongs to the scientific domain, but their use as benchmarks for guiding management decisions include notions of social acceptable risk levels and belongs to the domain of management and politics. The definition, estimation and use of precautionary reference points represent an important boundary issue within the current management institution. The Working Groups did not have the information required to give a comprehensive answer to this request. However, the group noted that at least two ongoing case studies are going to analyse the role of reference points.

Publication plan

The working group discussed a publication plan for work related to fisheries systems. Members felt that this is a critical role for the WGFS to play. Publications of results from the many research activities aimed at improving fisheries management in ways that place those results within a fisheries systems perspective is one of the primary practical ways that this perspective can benefit ICES. The production of fisheries system publications that bring together a broad range of research projects is seen as an important, ongoing activity of the WGFS. For the immediate future the WGFS envisions a three-step plan focussed on collating results from current projects. The first step will be a set of panels to take place in the 2005 Annual Science Conference meeting.

1 Introduction

1.1 Participants

Alyne Delaney	Denmark
Anne-Sofie Christensen	Denmark
Bonnie McCay	USA
Douglas Wilson	Denmark
John Casey (part-time)	United Kingdom
Kåre Nolde Nielsen	Norway
Kevin St. Martin	USA
Kjellrun Hiis Hauge	Norway
Laurence Kell	United Kingdom
Martin Pastoors (Chair)	Netherlands
Niki Sporrong (part-time)	United Kingdom
Petter Holm	Norway
Simon Mardle	United Kingdom
Teresa Johnson	USA
Trevor Hutton	United Kingdom
Wim van Densen	Netherlands

1.2 Terms of Reference

The Working Group on Fishery Systems [WGFS] (Chair: M. Pastoors, The Netherlands) will meet in Lowestoft, UK, from 26–30 April 2004 to:

a) review the use of decision support systems integrating quantitative simulations with qualitative process knowledge in a management decision context;

b) review, develop and implement approaches for the fishery adaptation module of the fishery management system framework;

c) coordinate work on on-going case studies;

d) develop an approach for comparative studies of fisheries monitoring, control and surveillance systems;

e) identify the factors influencing decisions about how precautionary reference points are defined and estimated; and

f) finalise the outline and publication plan for a *Cooperative Research Report* on the fishery management system framework and case studies.

WGFS will report by 20 May 2004 for the attention of the Resource Management Committee, ACFM, and ACE.

1.3 Scientific justification of the meeting

The past few decades have seen considerable technical innovation and development in the evaluation, management and regulation of fisheries worldwide. However, in spite of these developments, fisheries management in the ICES area has encountered a range of problems including collapses or near-collapse of fish stocks, persistence of over-capacity in the fishing fleets and limited acceptance of the fisheries policies amongst both the fishers and the general public.

The limitations of current approaches to fisheries management include an inability to make analytical decisions that account for the scope and the multi-disciplinary nature of entire fishery systems. ICES has recognized the need to develop methods and approaches for the evaluation of fishery management regimes and to develop and evaluate alternative management strategies.

The work undertaken by WGLTMM (ICES 1993, 1994, and 1995) and WGCOMP (ICES 1996, 1997a, 1999a) was diverse and included assessment methodology, evaluation of specific fish stock assessments, broader multi-species and interdisciplinary considerations, performance studies of fisheries systems and studies on the incorporation of economic mechanisms into the fisheries models. The WGFS merges the activities of these two groups, and extends their remit to consider other aspects of the fishery management system.

The WGFS first met in 2000. At its second meeting in 2001 the group developed a framework for case study analysis and identified European (North Sea cod) and North American (Georges Bank mixed fisheries) case studies. The group did not meet in 2002, pending application for funding. An application for funding for the European case study made in 2001, and subsequently revised and re-submitted in 2002, was approved: the PKFM project (see Section 3.2.1) has been funded by the EU under the Framework V Programme from the 1 January 2003. Funding for the North American case study from the National Science Foundation began September 2003 and ends May 2006 and included funding for collaboration with PKFM.

The framework which has been developed by the Working Group on Fishery Systems [WGFS] is an extension of those used by earlier ICES working groups (e.g., WGLTMM, WGCOMP). These groups focused on the processes involved in the construction of a perceived system, the basis of data sampling, stock assessments and management tactics. The extended framework developed by the WGFS added to this other sub-systems and process in the fishery systems which are essential in an analysis of performance including management and policy decisions, management implementation and the adaptations of the fishing fleet to management measures and policies (Figure 1.3.1).

Initially, the WGFS depicted the processes and interactions between the various sub-systems as operating according to the formal management set up in a one-way clockwise F_{low} (open arrows in Figure 1.3.1). However, the Group recognised that the links between the various subsystems are in reality much more complex and subsequently included various interactions and feed-backs as part of the framework. These take into account, for example, the possibility that the types of models used in stock assessments are conditioned by the main management tools applied or that expectations about fishery adaptation can influence the management decision process.

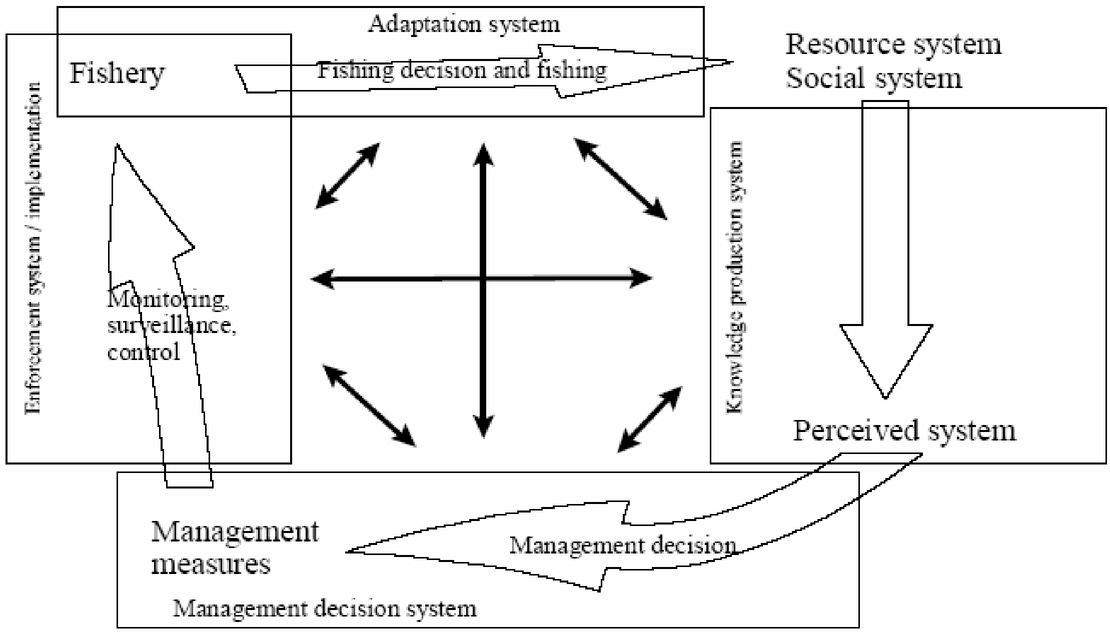

Figure 1.3.1: Fisheries management system framework as developed by the WGFS (source: ICES 2000a, 2001a, 2003b).

The Working Group also discussed management paradigms, institutional frameworks and how the behaviour and preferences of individuals and groups determine the system and the way it performs. The formalised knowledge production subsystem (of ICES and NAFO) focuses almost entirely on the biological resource base. It pays scant attention to the economic and social context of fisheries, although these are clearly relevant to the functioning of the system. The group concluded that knowledge of such factors or their influence is not necessarily absent from the system but rather that it is taken into account elsewhere, in other sub-systems. In addition, the key criteria for performance evaluation, identified in ICES' strategic plan, robustness, cost effectiveness and sustainability, can be expressed in biological, social and economic terms.

The key role for the WGFS is thus to integrate across disciplines to develop analytical and investigative methods/approaches to study fishery systems.

The framework does not pretend to apply to all fishery systems, but is relevant to most fisheries in the ICES area where a formalised process of producing a knowledge basis for fisheries management exists and where management decisions are taken within a formalised framework. In this context, the subsystems mainly represent specific and identifiable institutions.

1.4 Structure of the report

The structure of the report is set up around the Terms of Reference. Section 2 deals with the core of the working group: the coordination of work on case studies and relevant projects (ToR c). A review of integration of qualitative and quantitative knowledge is presented in Section 3 (ToR a). Section 4 presents the results on the analysis of fleet adaptations (ToR b) and an approach to do comparative research on monitoring, control and surveillance (ToR d). Section 5 deals with the way the precautionary approach has been implemented (ToR e) and Section 6 with the publication plan (ToR f). Recommendations are presented in Section 7.

2 Coordination of work in ongoing case studies and relevant projects

2.1 Introduction

Coordination of the case studies of fisheries management systems is particularly close for the three cod case studies: North Sea Cod (PKFM), New England Cod (Georges Bank and Gulf of Maine, FEBK), and Northeast Arctic Cod (BNIMS). Each of these involves critical analyses of discourse, practice, and systemic dynamics in historical and contemporary contexts, sharing foci on cod, scientists who study cod, fishing communities that fish for cod, and the varying institutional dimensions of the production of knowledge about cod and cod fisheries and the interaction of that knowledge with management policy.

Coordination takes place through project design, such as the controlled comparison used for the cod case studies; through technical cooperation, including data collection and analysis (as for example the use of a text management package, QSR, for two of the cod studies); and through interactive development of questions for research at the WGFS meeting and in other venues.

Coordination with and among other case studies includes the new INDECO project, which will bring together expertise on indicators, the ongoing TECTAC project, examining fleet adaptations, and new projects such as COMMIT and EFIMAS, as well as their predecessors such as EASE and FEMS. Coordination takes place through project-level meetings, Working Group meetings (WGFS, the Methods Working Group), and informally in a variety of ways in so far as the participants are linked through a variety of institutional and personal networks.

2.2 North Sea cod case study (PKFM project)

The PKFM (Q5RS-2002-01782: Policy and Knowledge in Fisheries Management – the North Sea cod case) project has been funded under the EU 5th Framework programme and will carry out research in support of some of the WGFS' objectives. The research questions to be addressed by PKFM relate to the production of knowledge, policy and management decisions and their linkage in relation to North Sea cod fisheries management. Specifically, the institutional framework for the production of formal research-based scientific advice: How does the institutional framework within which scientific advice for North Sea cod is produced influence the capacity to produce advice – both in terms of the choice of basic research discourse and the capacities within this discourse?

- the process of producing scientific advice: How precise, robust and cost effective are the methods presently used to produce scientific advice regarding North Sea cod management? What are the limitations and potentials of these methods within the existing institutional and management context?
- the linkage between management decisions and the production of research-based scientific advice: To what extent has the production of knowledge regarding North Sea cod been constrained and framed by demands from the management decision process and other actors in the fisheries system? To what extent are management decisions framed by the research discourse in the advisory institutions?
- the policy and management decision process: How is research-based scientific advice used to inform and justify fisheries management decisions concerning North Sea cod? How are other sources of knowledge used?
- the integration of stakeholders' knowledge in decision-making: How are other sources of knowledge and scientific claims articulated and integrated into the management decision process?

A better understanding of these questions will form the basis for devising modifications to the present set-up which will enable fisheries management to track more closely, and respond more accurately to, the condition of the fish stocks; specifically to the development of North Sea cod. Possibilities for improvement, both technical and institutional, will be evaluated in context by synthesising analysis of the overall setting of policy and management decisions, the institutional framework for production of scientific advice, the technical aspects of the production of this advice and the processes by which stakeholders' knowledge is integrated into the decision making process. The PKFM project will aim to identify options, which are technically and institutionally coherent, as opposed to technical and institutional *fixes* which may seem to represent partial solutions, but which will not work within the overall policy and management framework.

Outputs from the project will include a policy brief with an evaluation of coherent options which will lead to better performance of fisheries management in terms of a more balanced generation of suitable management advice, the efficient use of fishers' knowledge, and a more transparent communication of information available and on decision-making. The results of research components within the project will be published in international peer-reviewed journals and contributions will be produced to the development of a framework for performance evaluations of fishery systems presently on-going within ICES using cases from both the eastern (the presently funded case) and the western Atlantic.

The production of biological advice within ICES and the decision processes in EU and between EU and Norway regarding North Sea cod will be the core object of study. The analysis of this critical management case is designed in two components leading up to the analysis of the relationship between the management decision-making process and the production of the scientific advice that is used in that process. The first component is an analysis of the production of scientific advice and the second component is an analysis of the adoption of scientific knowledge for fisheries management decision-making. The linkage between the institutional setting for the production of scientific advice and the methodology used is analysed as a part of the first component. The linkage between public perceptions of the scientific facts underlying the case and the use of science in the fisheries management decision-making is analysed as part of the second component.

The project is composed of a number of components and work packages (WP):

- An introductory review and description of North Sea cod management - the fleets and fisheries, the management system, the institutional framework and methodology used to produce scientific advice, the management decision processes and the history of implementation (WP 2).
- An analysis of the production of research based scientific advice consisting of -
- An analysis of the institutional setting of the production of scientific advice (WP 3),
- An evaluation of the methodology used to produce scientific advice (WP 4),
- An analysis of the relationship between the institutional setting and the methodology employed based on the outputs of WP 3 and 4 (WP 5).
- An analysis of the use of knowledge for fisheries policy and management decision making consisting of -
- An analysis of the perceptions and communications of science and knowledge among the fishing public (WP 6),
- An analysis of the use of knowledge in fisheries management decision making (WP 7),
- An analysis of the interdependencies between the policy and management decision process and the production of research based advice based on the outputs from the two components regarding production of advice and management decisions respectively (WP 8).

Project management (WP1) is an on-going activity throughout the lifetime of the project.

Project structure and the relationship between work packages are illustrated in Figure 1.1.1 (2003).

2.2.1 Progress with review and description of North Sea cod management

An annotated bibliography of the STECF meetings was prepared to summarise the outcome of meetings held over the last five years (November 1997 – November 2002)*(see* Appendix A*, WGFS 2003*). This document supports partially the PKFM objective in WP 2 to provide*: an identification, compilation and summary of existing documentation on research and management related to North Sea cod to serve as a shared documentary basis for the detailed studies*. The aim of the bibliography was to highlight the advice and studies (i.e., sub-group meetings of STECF) that specifically made reference to North Sea cod either as part of a stock status report or as part of the recent EU recovery plans. The details therein also provide, in terms of the stock report details, a summary of the most recent status of the North Sea cod stock. The collection of documentation regarding North Sea cod management has to a large extent been integrated into other work packages which study different aspects of the production of scientific advice (WP 3), the public debate (WP6) and policy decisions (WP7).

2.2.2 Progress with institutional setting of the production of scientific advice (WP3) and evaluation of the methodology used to produce scientific advice (WP4)

At the 2003 meeting of the Working Group on Fishery Systems, investigators involved with the PKFM work packages 3 and 4 met and identified a set of topics within the production of research-based advice for North Sea cod to be the foci of research.

Two of these topics are related to current questions within the management of North Sea cod. These are the development of the North Sea cod recovery plan and the scientific issues around the management of mixed fisheries.

Five of the topics are related to events in the history of North Sea cod management that will be examined to identify lessons relevant to current and future management issues. Specifically, these include: the introduction of TAC management; the refusal of ACFM to provide advice in the form of quota advice in the early 1990s; the decline in the amount of attention given to the Four M model and related systems approaches to management in the early 1990s; the discovery in the late 1990s that the stock was in a far worse condition than had previously been thought; and the prominence of the precautionary approach to fishery management in the mid- to late 1990s.

Finally, five areas of on-going scientific uncertainty and disagreement related to the management of North Sea cod were identified as research topics. These include: whether, and to what extent, data from the commercial fleets should be used to tune stock assessments, including the general question of how decisions about data inclusion are made; the degree to which statistical methodologies should be used in stock assessments; the best way to deal with missing information in assessment modelling; the feedback loops between management decisions and their impact on the availability and quality of data; and the role of ecological interaction in stock assessments.

In 2003, work concentrated on documenting the historical changes in the stock assessment procedure used for the North Sea cod, and in evaluating the performance of the past assessments and forecasts. The analysis has identified a period of substantial technical development in assessment models from the mid 1970s to around 1990, since when there has little or no further model development. The performance of the assessments generally improved with time up until around 1987, with subsequent assessments being similarly consistent until 1995, since when the assessments have shown a severe tendency to underestimate recent fishing mortality and over-estimate recent stock size. A review of the data and methodological aspects of the assessment conducted in association with the EASE project has identified under-reporting of catches as the most likely cause of this sudden deterioration of assessment performance. Largely as a result of the poor performance of recent assessments, catch forecasts over the same period have been over-optimistic which means that if TACs had been set in line with the advised catches, they would still not have been effective in obtaining the advised reduction in fishing mortality.

2.2.3 Progress with analysis of the perceptions of science and knowledge among the fishing public

The key question in WP6 is: How are scientific claims and other sources of knowledge articulated in relation to discussions of policy and management decisions regarding North Sea cod? In this context, "scientific" information may be 1) research-based scientific information such as that produced by advisory process, 2) junk science, information which has little scientific basis but is used to support claims, or 3) other types of information and knowledge, for example observations of the resource by fishers, which do not conform to the conventional scientific paradigm.

Two kinds of data are used in order to answer the question; 1) A database of relevant newspaper articles and other public documents, and 2) interviews with stakeholders. The stakeholders are defined as those of the "fishing public" who are the relatively defined population of people who feel strongly about fisheries issues. These include fishers, other people economically dependent on fisheries, certain bureaucrats, politicians that represent fisheries dependent areas, and, increasingly, members of environmental organizations. Based on the methodology designed at a meeting in Hirtshals in October 2003, each partner involved in WP6 is in charge of collecting data and preparing a national review of the structure of discourses appearing in the public debate.

Data gathering for discourse analysis is ongoing. For the Danish case study, the data come from interviews and from written text. The main idea behind interviews will be to follow one specific topic/argument, which will be taken from the discourse analysis, from a local port to Bruxelles and back again. In this way we should be able to identify what happens with the topic/point at the different levels. *T*he text for the database comes from sources such as a fishers association's weekly newspaper, an on-line database of articles from Danish newspapers; the World Wildlife Foundation; the Danish Society for a Living Sea, and a workers' union. Other relevant stakeholders are being approaches for relevant documents. Discourse analyses are being done with the help of the QSR textual analysis software package.

2.2.4 Progress with analysis of the use of knowledge in fisheries management decision making

Research activities in WP7 have begun with the analysis of documents produced by the EU/Norway decision-making process focusing on two main themes, namely the development and function of the "TAC machine", and the development and function of the Cod Recovery plan. The following have been accomplished:

1) An analysis of the historical development of TAC as a management device, including the development of the PA approach.
2) The functioning of the TAC machine, including its stickiness, as revealed by the series of more or less failed reform attempts, as in the structural policy, the enforcement policy, the attempt to move towards effort management, etc. (see below)
3) Cod Recovery — survey of available documentation and chronology of events.

On the background of these documents, an interview guide for WP 7 was developed. Formal interviews were begun in March of 2004 and will continue through the summer of 2004.

Following is an abstract of « the TAC Machine, » a working document created by Petter Holm and Kåre Nielsen (Annex B):

Within European fisheries, single stock Total Allowable Catches (TACs) have been a main management instrument since the 1970s. This paper explores the historical background and the institutional implications of the TACs getting such a fundamental role in fisheries management. This is relevant because of the curious combination of resilience and failure of the TAC. The performance of fisheries resource management in Europe is poor, and this is often blamed on the TAC. However, the attempts at substituting the TAC with other regulatory mechanisms have failed, and the TAC remains in place. Why is this?

"The TAC machine" forms a key concept in our attempt to answer this question. Our hypothesis is that the whole machinery of fisheries resource management has become tailored to the TAC instrument. First, the key management decisions come in the form of a set of (legally defined) single-stock TACs, which forms the main instrument for control-

ling fishing mortality. Second, scientific advice is produced, within ICES, by way of VPA assessment methodology, in order to facilitate management decisions by way of TACs. This scientific advice is again based on data collection and modelling procedures defined with VPA/TAC decision making in mind. Third, the allocation of fishing opportunities among fleets is based on TACs. Fourth, surveillance and control efforts are focused on the enforcement of the TAC.

The TAC instrument forms an integrated part of the whole system of resource management, including data collection, stock assessment, management decision making, allocation mechanisms, regulation procedures, and enforcement. The paper explores the way the management machinery can be seen as tailored around the TAC instrument. While we want to start with a focus on technical requirements and instrumental linkages across sub-systems, we also want to explore this question from an institutional and cognitive perspective. To what extent is the TAC instrument tied into basic cognitive, moral and political precepts? In other words, is it appropriate to see the TAC machine not only as a technical instrument, but also an institution in its own right?

The paper discusses the origin of the TAC machine in more detail, describing the development of the VPA model and the establishment of the TAC as the primary management instrument. This happened in the period from 1965 to 1976. At the end of this period TACs grounded in VPAs had been defined for all the major fish stocks in the North Atlantic. At one level, the story about the TAC-VPA model can be told as one of co-occurrence – the VPA happened to be at the international scene at the same time there was a demand for a model that could give independent analytical content to TACs. From this perspective, the linkage between the TAC and the VPA is coincidental; another assessment model could have served as well. The focus then is directed at what happened once this historical coincidence had occurred. In particular, we would here be interested in institutionalization processes, that is, processes by which the initial (light) commitment to the TAC-VPA model gradually became embedded in organizational structures, written into law, tied to data-collection procedures and built into computer models, guarded by vested interests, etc. This would be important in explaining the staying power of the TAC-VPA model. In addition to the co-occurrence hypothesis, we also want to explore a riskier hypothesis, namely that the TAC and the VPA constituted each other reciprocally. The idea here is that the TAC regime was made possible by the VPA, at the same time as the VPA method could not have triumphed without the TAC regime. Compared to the co-occurrence hypothesis, the co-constitution hypothesis thus goes further in the degree to which the TAC and the VPA are linked to each other. Instead of a historical coincidence that easily could have been different, this hypothesis proposes that the TAC and the VPA reciprocally conditioned and promoted each other.

Consistent with the co-constitution hypothesis we shall argue that an important side to the TAC-VPA construct is that it allowed for the establishment of a tidy boundary between science and management. The TAC belonged in the province of management; the VPA belonged to the province of science. In contrast to the competing models (e.g., effort management), the TAC-VPA prescribed and made practical a conventional model for division of labour and interaction between science and politics.

2.3 Georges Bank/Gulf of Maine Cod Case Study

The project entitled Examining the Fate of Experience Based Knowledge in a Science Policy Process (hereafter FEBK) has been funded by the U.S. National Science Foundation through May 2006 (NSF #0322570 and NSF #0349907) and will carry out research related to WGFS objectives. FEBK examines the role of experience-based knowledge (EBK) in the marine fisheries management domain; specifically, it looks at the implications of EBK for the development of science/research-based knowledge in the cod fisheries of the Northwest Atlantic (i.e., Georges Bank and Gulf of Maine fisheries of the U.S.). The FEBK project serves as a case study comparable to the PKFM and BNIMS projects.

FEBK will examine how EBK appears within policy-making institutions, how EBK relates to professional or technical expertise, and what difference EBK makes to policies and their outcomes. Comparisons will be made between various instances of public participation that are currently used in the management of Northwest Atlantic cod fisheries.

Two basic hypotheses are examined in this project:

1) The rules and practices governing public participation in and the scrutiny of scientific deliberations have an influence on scientific outcomes. Where EBK is high and where those rules and practices permit greater consideration of that EBK the outcomes will reflect the content of the EBK.
2) User group's satisfaction with policies will be greater where EBK is recognized by the policy process and has an influence on outcomes.

Both of these hypotheses would be predicted by the literature on public participation in policy. The science studies literature, on the other hand, would suggest that these hypotheses would not be confirmed because in situations of high EBK, in particular where rules and practices give space to lay experts, scientists will respond by intensifying their boundary work.

These hypotheses will be examined by looking at several instances of public participation. These include sites of negotiated rule making, public fora, and collaborative research. Four research methods will generate data for these instances.

1) Documentary research will be carried out with related scientific and policy documents.
2) Interviews with scientists will focus on their working conditions, the data they have available to them as they gather information, the strengths and weaknesses they see in the overall process, their experiences with public participation, and the differences between what they believe they actually know about the case study species and the information that they see as effectively used in the advice production process. Interviews with other stakeholders will focus on their perceptions of the use and abuse of science in the policy process and their experiences with the various forms of public participation.
3) Meetings of scientists, advisory panels and other public fora will be observed in progress and participants will be interviewed separately to provide background and insights into their perceptions of the process.
4) Comparative analysis of data from formal surveys will be carried out between the US and the European cases. This is made possible by existing data for the US cases and data gathering that will be carried out by the EU project.

Progress to Date

Research began in September 2003 and is expected to continue until February 2006. The focus has been on public participation and the use of EBK in collaborative research, one of the three instances where high EBK is expected. This work was performed in conjunction with the doctoral dissertation research of Teresa Johnson ("Knowledge Production through Industry-Science Cooperative Fisheries Research in the Northeast and Mid-Atlantic"). Research to date includes the following:

Preliminary semi-structured interviews were conducted with fishermen, scientists (from the National Marine Fisheries Service, academic institutions, and non-profit organizations), fishery managers (from the New England Fishery Management Council and the National Marine Fisheries Service), and non-profit organization representatives involved in collaborative research in this region. Interviews focused on documenting the experiences of individuals involved in collaborative research.

Unobtrusive observation occurred at numerous fishery management council meetings, advisory subcommittees, collaborative research planning meetings, stock assessment review committee meetings, and public fisheries related conferences and forums.

Media sources and reports relevant to the overall science policy process and collaborative research have been gathered but not yet analyzed. Information has been collected with which to document the overall fishery management system, particularly the institutional mechanisms and procedures for conducting collaborative fisheries science.

Instrument guidelines are in development, based on findings from the preliminary semi-structured interviews. Several instances of public participation have been selected for further investigation. A structured interview is also being considered for development.

Issues of interest arising from this research include questions regarding (1) the scale of EBK and the scale of research based knowledge, (2) the different kinds of fishermen's EBK that are being utilized in the science policy process and collaborative research, (3) the use of knowledge produced through collaborative research in fisheries management, and finally (4) the extent that the use of EBK in the science policy process and involvement or knowledge of collaborative research changes individuals perceptions about science and/or fisheries management.

2.4 Science/Politics: Boundary Negotiations in Mandated Science: Northeast Arctic Cod Case Study (BNIMS)

The project is a study of the construction and nature of the boundary between science and management within the context of mandated science, that is, science produced explicitly for policy purposes. The project will be carried out as a case study of the fisheries system dealing with the management of North-East Arctic cod. The project, which is founded by the Norwegian Research Council, extends over three years and is to be conducted by Petter Holm and Kåre Nielsen.

The concept of the TAC machine (see Working Paper, Annex B), which was developed within the PKFM project will be used as a key concept and be developed further within this project. Additionally, the study will draw on the discourse within sociology of science occupied with "boundary work", in order to promote the understanding of boundary construction and organization of boundaries. A key concept in this context is the concept of "boundary objects", which are objects located in different social worlds, enabling the cooperation of actors across the boundary (Star and Griesemer, 1989). The boundary object functions by being open to interpretation within the social world into which it is carrying information, but at the same time it must be sufficiently robust to be a reliable carrier of information across the social worlds. In this context we suggest that the TAC is such a boundary object, which, as it is circulating within the annual cycle of the TAC machine, relates the subsystems of which the fishery system consists.

In this project, we want to examine the mechanisms and processes that allow such boundary objects to stay intact as they circulate across social worlds. In order to do that, a number of empirical and theoretical issues have to be covered. The TAC as a boundary object is a complex and multi-dimensional entity. In practice, the project will be organized in 6 inter-linked work packages, which pragmatically follows the main boundaries imposed by the management system, i.e., that between the knowledge system, the policy system, and the user system. Work Package 1 through 5 thus follows the TAC for Northeast Arctic cod as it is constructed and put into circulation in the management system. Hence, WP 1 takes on the scientific assessment work behind the TAC proposal, with main emphasis on the relevant

ICES Working Group. WP 2 then focuses on ACFM – the main boundary organization between science and management – and examines the process by which the scientific product is transformed into a management device. WP 3 focuses on policy making, with an emphasis on the Norwegian-Russian Fisheries Commission, where binding TACs for Northeast Arctic cod are negotiated. WP 4 examines the allocation of TACs among fleet segments within the Regulatory Council – an important boundary organization between the policy sub-system and the user sub-system. WP 5 examines the user-system, more specifically, the standardized packages and enforcement mechanisms that allow TACs to be translated into binding measures at the fleet level. Finally, WP 6, integrates and summarizes the results and analysis from the previous five WPs.

2.5 Cod Case Study Comparisons

The FEBK, PKFM, and BNIMS projects share a variety of similarities and differences that provide a basis for comparison. These include similarities of species (cod), fishing techniques, histories of community and industry, and experience in terms of science and management. These similarities operate as a general control that will make other comparisons (e.g., processes of knowledge production) possible.

The projects also differ in ways that will directly inform the analytical comparison. For example, levels of public participation vary significantly between the U.S. and Europe. The former has higher levels of participation at all stages of the science/management system (e.g., open meetings, direct stakeholder participation). Also, while both the U.S. and Europe share very similar cultures/practice of science (representing one epistemic community), they differ in important ways at the level of implementation: Europe manages its fisheries using TAC controls, while the U.S. uses effort controls for cod and other groundfish in the Northeast region's multispecies fisheries, although TACs are used for many stocks elsewhere in the U.S.

Beyond the important recognition of case study attributes, there will be a deployment of particular conceptual apparatus, analysis of particular issues, and methods that have been produced jointly during the Working Group meeting (2004). The apparatus and issues form a set of common concerns across all cases and include the following:

- The concept of the TAC machine provides a fruitful metaphor for thinking about the process of science and management as a bounded singularity with an inside and outside. (This is true despite the use of an effort based rather than TAC based management system in the Northeast region of the U.S.). On the inside is the domain of standard institutionalized science and management while on the outside exist a wide variety of objects that are other than what is inside. A number of these exterior objects have acted or are acting as reforms, challenges, and sometimes disruptions to what is inside. These include objects such as EBK, ecosystems management approaches, and precautionary principles. The TAC machine, for all cases, acts as a starting metaphor around which to conceptualize these issues and, in particular, to question the process of boundary creation and maintenance (e.g., between EBK and RBK).
- In addition to the above, coordination has occurred and will continue to occur at the level of research design and analysis. While methods vary across cases, they all share a qualitative interview approach where there is scope for the coordination of interview guidelines if not actual interview protocols and questions. In addition, all cases will utilize surveys where there is again scope for coordination. Finally, the FEBK and PKFM projects both utilize a text analysis methodology (using the QSR software) that will be developed together (e.g., using similar text coding categories, etc.).
- The above coordination is limited to issues of project conceptualization and research design. Plans for coordination that will be ongoing include informal correspondence between project partners and a reconvening of project partners at the 2005 WGFS meeting. The latter will provide a forum for a comparison of project results as well as the development of joint analyses and products (e.g., reports and articles).

2.6 Other relevant projects

2.6.1 Evaluation of European Advisor Strategies (EASE)

The objective of EASE is to provide a basis for more appropriate data collection and analysis programmes in order to support existing and emerging fishery management issues. The present data and advisory structures have developed by a process of evolution and involve considerable commitment of human and financial resources. In general these resources are in short supply and may be declining. It is no longer clear whether present systems can be maintained or whether they are appropriate for emerging issues, notably those relating to a more holistic approach to fishery management.

The first objective of the concerted action is to understand the current balance between resources devoted to data collection and value of these data in the provision of advice. This requires the evaluation of the range of advice requested on fishery management and the data needs to perform the science to support it. Of particular importance is the so-called basic data, that is, routinely collected data to support existing fisheries management since these are used in almost all analyses. However consideration will be given to other types of necessary data.

The second objective is to quantify the quality of the scientific outputs derived from the data inputs. Since much advice is qualitative and relies on expert judgment, this objective will be limited to quantifying the reliability of routine annual stock assessments upon which advice is formulated.

The third objective will be to identify alternative uses of data and alternative analytical methods which could support present fishery management needs as well as those which could address new and emerging issues.

The final objective is to analyze ways of re-deploying existing resources in order to support a modern fishery management system.

So far, the cost base of the current data collection has been reviewed, and the assessment and advice regime for a large number of case studies, representing all the main European stocks. In addition the performance of the advice, based on the ACFM quality control diagrams is being evaluated.

The project is in operation from Jan 2003 to Dec 2005.

2.6.2 Framework for the Evaluation of Management Strategies (FEMS)

The project is developing a computer simulation framework for the evaluation of management strategies by undertaking a variety of case studies for both demersal and tuna stocks. The framework considers sources of uncertainty not currently routinely considered by stock assessment working groups. The intention of developing methods that provides robust advice to managers consistent with the precautionary approach.

The main achievements will be to quantify the benefits of a variety of management strategies in terms of yield and probability of exceeding sustainable limits, developing alternative assessment/management strategies where appropriate.

It is also intended to compare the management strategies of ICES and ICCAT and to contrast the responses of a variety of stocks (from data rich to data poor, from tropical to temperate species and from pelagic to demersal fish) to exploitation.

In addition the project is providing software and methodology that will be used by other EU proposals (e.g., COMMIT, EFIMAS) to evaluate the consequences of improving our understanding of fishery systems.

The project is in operation from Jan 2003 to Dec 2005.

2.6.3 Technological developments and tactical adaptations of important EU fleets (TECTAC)

The carrying idea is the investigation of the dynamics of the elements that cause changes in fleet dynamics: the technological advances in both gears and vessel equipment, and also the overall tactical adaptation of fishing vessels. How do they occur? Why do they occur? What are their consequences on the resource and their socio-economics? In order to address these issues, in relation to the overall objective, this study aims to achieve three sub-objectives. Examples will be drawn from a wide selection of demersal fleets operating in the Baltic Sea, the North Sea, the Eastern Channel, the Celtic Sea and the Bay of Biscay.

The overall objective of this project is to address the poor understanding of the links between management tools, fleet developments and the pressure exerted on fishing communities. An aim is to form a modelling tool for fisheries managers that will allow the evaluation of the impact of regulations (TACs, MAGPs, area and season closures, subsidies) on the dynamics of fleets and fishing mortality.

TECTAC Work packages (April 2004, month 19)	Status	Start month	End month
Description of the important fleets	Complete	1	18
Internal determinants of fleet dynamics	~Complete	6	18
External determinants of fleet dynamics	Ongoing	12	24
Fishing mortality, fleet dynamics and management	Just started	18	30
Fisheries profit, fleet dynamics and management	Ongoing	18	30
Fisheries system simulation model	Ongoing	24	36

Case studies relate to fisheries in the participating institutes' countries of France, Denmark, The Netherlands, Spain, and United Kingdom.

2.6.4 COMMIT – Creation of Multi-annual Management Plans for Commitment

The COMMIT EU Project is developing multi-annual management strategies to facilitate both the long- and medium-term commitment of managers as well as providing a better basis for fishers to plan their activities. The study is interdisciplinary and focuses on what elements must be in multi-annual management strategies to make them acceptable from both a fishers' and other actors' points of view to ensure commitment.

The level of commitment is strongly influenced by social factors such as education as well as the economic constraints under which the fishing unit operates and will be explicitly modelled as it is fundamental in determining compliance with management regulations. Case studies focus on mixed fisheries; the intention is to move from stock- to fishery-based advice.

Various sources of uncertainty encountered in the management of fishery systems and their relative importance to the achievement of management objectives will be explicitly considered. In particular, the interactions between system components and their relative importance to the overall success of the strategies. Strategies will be implemented via harvest rules that attempt to reduce inter-annual fluctuations in catches and or effort by setting appropriate technical measures an/or catch and effort limits and/or targets. Harvest rules will be developed on a case-specific basis by evaluating the biological and economic impacts of candidate rules, including the effects of non-compliance.

The dissemination of the results of the simulation framework will be carried out by Bayesian influence diagrams (see Section 3.4.4). The project is in operation from April 2004 to March 2006.

2.6.5 EFIMAS – Operational Evaluation Tools for Fisheries Management Options

The objective of the EU EFIMAS project is to develop an operational management evaluation framework that allows evaluation of the trade-off between different management objectives when choosing among different management options. The framework will be developed to inform an exploratory, adaptive decision-making process. Evaluation tools will be developed to appraise the biological, social and economic effects of fisheries management measures in the EU, and these will be applied to important fisheries. The tools will take account of the dynamics in the fisheries systems as well as of uncertainties and will include risk assessments.

The overall approach uses stochastic simulation techniques. These cover the full scope of the fisheries system from the fish resources through data collection, assessment and management, and the response of the system to management. The input data to the management system are generated by a descriptive model, which is assumed to represent the "true / real" system. The input data are then processed by a traditional assessment model, or by an alternative model, which is used to generate management advice. By simulating the effect that the resultant management actions would have on the "true / real" system it is possible to generate a range of performance measures, covering the resource and the fishery. These measures can then be compared across different assessment models and management approaches.

An ongoing evaluation of this tool will be achieved through discussing and testing the evaluation framework with the stakeholders such as the fishing industry, the European Commission and other decision making bodies, and conservation NGOs. Four regional workshops to be held as part of a continuous process of stakeholder interaction which will also include interviews and focus groups.

The project is in operation from April 2004 to March 2007.

2.6.6 Developing Indicators of Environmental Performance of the Common Fisheries Policy (INDECO)

The INDECO project was developed in response to a specific call under the 6th Framework Programme to develop methods to evaluate changes in marine ecosystems from environmental and fisheries perspectives. It has passed the scientific evaluation process, but has not yet been negotiated and agreed with the EC.

Indicators can be valuable tools for tracking change, identifying problems and monitoring implementation of policies. They have an important role to play both in support of management decisions and in communication, and are increasingly used to assess the efficacy of EU policies, including the extent to which environmental concerns are integrated into sectoral policies.

To date, large numbers of quantitative indicators of the status of ecosystems have been proposed by ecologists around the world. Less effort has been spent on indicators of fisheries economics or social aspects in the sector, and on headline indicators addressing the effectiveness of management actions. Very few indicators of any kind have been properly tested and used in management. Efforts so far have also been mostly regional or limited in scope. For indicators to become an effective tool in EU fisheries management, a coherent coordinated effort is needed to bring the scientific expertise together. Moreover, the application of scientific expertise needs to be firmly lodged in the policy-making context.

The purpose of INDECO is to ensure a coherent approach to the development of indicators that can be applied across the EU, in support of environmental integration within the CFP. The principal objectives of INDECO are:

1) To identify quantitative indicators for the impact of fishing on the ecosystem state, functioning and dynamics, as well as indicators for socio-economic factors and for the effectiveness of different management measures.
2) To assess the applicability of such indicators.
3) To develop operational models with a view to establishing the relationship between environmental conditions and fishing activities.

The existing methods developed to evaluate changes in marine ecosystems from environmental and fisheries perspectives will be reviewed. Generic indicators (including 'headline' indicators) will be identified to analyse ecosystem-wide effects of fishing and to distinguish these from changes in marine ecosystems due to other factors, such as eutrophication, where possible.

The project will aim to identify robust and operational indicators making efficient use of available data. Efforts will be made to ensure general applicability across a range of fishery zones, including the Mediterranean, and major habitat types, including sea regions prone to eutrophication.

Policy makers, managers, researchers and other stakeholders not part of the consortium will be closely involved throughout the project, in order to contribute practical knowledge of fisheries management and needs, to identify relevant objectives and also to increase the eventual take-up of indicators once a final set is agreed upon.

In summary, INDECO aims to undertake a review of existing research, synthesis and present the state of the art on fisheries/environment indicators, identify gaps in the current research, data collection and statistical work, and examine necessary policy and institutional changes needed to fill these gaps. This will be achieved by bringing together key scientific and policy experts, as well as end-users and relevant stakeholders in the EU and other regions of the European Research Area, including those currently less focused on using indicators as a management tool.

3 Review of integration of qualitative and quantitative knowledge in decision support systems

3.1 Introduction

The ToR that is relevant to this Section of the report is:

a) review the use of decision support systems integrating quantitative simulations with qualitative process knowledge in a management decision context;

In future, the key role for the WGFS is conceived to be to integrate across disciplines and to develop analytical and investigative methods/approaches to study fishery management systems. An analysis of fishery management systems requires that issues are addressed in a balanced way. This means that processes and their interaction should be included in analysis according to their importance for the performance of the management system and not based on whether they are amenable to specific methodological approaches or not. The aim is to be inclusive of all relevant processes.

Within the ICES Methods Working Group (WGMG, ICES 2004a) and the ICES Long Term Advice Study Group (SGLTA, ICES 2004b), simulation approaches are being developed to simulate those aspects of fishery systems that lend themselves to numerical analysis. Several EU funded projects are currently underway (COMMIT, EFIMAS, FEMS) that aim to provide the numerical toolbox for simulating fishery systems.

At present there appear to be two distinct and complementary approaches to evaluating fishery management systems:

- develop numerical simulation approaches of theoretical fishery systems and test whether the results of such simulations can be used within a decision making framework. This needs quantification of the most important processes or at least a method of incorporating those processes into a simulation environment (EFIMAS, COMMIT, WGMG, FEMS, PKFM).
- develop analysis of existing fishery systems using mainly social science methodologies with the aim to generate understanding of the key social processes and institutions (PKFM, FEBK, BNIMS).

The ToR reflects the basic difference in methodology sketched above and attempts to review the possibilities to integrate quantitative simulations and qualitative knowledge in decision making contexts. In order to do so, this section will first describe the basic properties of the concepts of qualitative and quantitative knowledge (Section 3.2). There will be a brief history of quantification (Section 3.3) and then a number of sections dealing with various techniques that could be used to integrate qualitative and quantitative knowledge:

- Public hearings as a tool to integrate qualitative knowledge into the decision making process (Section 3.4). The EC can be thought of as a central locale where quantitative and qualitative information is available and where decisions are made.
- Review of qualitative knowledge understood as a measurement problem for models (e.g., Fuzzy logic, Traffic light approach, SIMCOAST Coastal Zone management, Multidecision criteria analysis, Bayesian approaches, Preference modelling; Section 3.5)
- Incorporating qualitative knowledge in the form of caveats to the numerical results (Section 3.6): how can the caveats be improved and made more clear, e.g., via schematizations.
- Interactional model use (Section 3.7): Decision support software Coastal Zone Management, Strategy Unit Cod Model as decision support system. Also discusses the role of decision support systems in a decision making context and experiences with those.

3.2 What do 'qualitative' and 'quantitative' mean?

The first thing that must be kept in mind when discussing the difference between 'qualitative' and 'quantitative' is that they are 'essentially contested' concepts of which the definition can never be finally settled. The meanings that these terms take on for the people who are using them in their discussions are so closely tied to their arguments, and to the interests that are related to these arguments, that a final agreement on their meaning is not possible, at least without simultaneous agreement on the substance of the argument. The terms are used in very different ways. Some people used to quantitative modelling, for example, will say 'qualitative' and simply mean 'categorical data', which is a very different understanding than those who see themselves as doing 'qualitative research'. Nevertheless, within the ICES community it is worthwhile to try to outline some of the dimensions of these two concepts.

The distinction between qualitative and quantitative has at least two dimensions: epistemological and practical.

The epistemological dimension has been examined for many years. Kant (1783) distinguished between analytical and synthetic judgements. Analytical judgements depend wholly on the law of contradiction and are a priori in their nature. Synthetic judgements, however, require a different principle than the law of contradiction. He argued that judgements of experience are always synthetical and that mathematical judgements are a priori and not based on experience.

Quantitative methods are the paradigmatic form of science because they tap into the power of these a priori judgements that are free of experience. Quantitative methods begin with in the accurate and consistent measurement of comparable units. When meaningful comparability and accurate measurement can be achieved they make possible a mapping of mathematical laws to a phenomenon under study, and this is equally true of natural or social phenomena. There is no argument about what things mean and there are clear laws that determine outcomes. Disputes must either focus on the comparability and measurement of the units.

This mapping of mathematical laws attains the greatest possible transparency of argument because mathematics is a self-referential, tautological system in which everything that is true is true by definition. It is this transparency that makes quantitative methods the ideal of science is because science based in the ability of someone to explain how they know something, in principle with such clarity that others will make exactly the same discovery if they repeat the process described.

Qualitative epistemology stems mainly from social science. It is also founded in the desire to attain the transparency of argument that makes results scientific, but to do so in a way that avoids reductionism, i.e., the failure to address the research question within the entire context that makes it meaningful. Qualitative research seeks to deal directly with the objects of experience without having to establish the comparability of units and schema for their measurement. This desire may be based in the belief that such comparability and accurate measurement is impossible, but it stems more often from the investigator's belief that a quantitative approach will exclude important information and reduce the object of study to the point where results lose meaning. Because of this concern with reductionism, qualitative researchers often advocate the combination of qualitative and quantitative approaches to single research questions.

Many approaches to qualitative epistemology begin with Gadamer's (1991) work on the 'hermeneutic circle', which owes its inspiration to early work in phenomenology. The basic idea is that the investigator observes one element of the object of study and thus begins to develop a concept of the object as a whole. This concept of the whole then informs the interpretation of the next observation. And so the circle progresses.

This basic philosophical observation was translated into a qualitative epistemology by Glaser and Strauss (1967) who developed an approach they called grounded theory. Grounded theory is a general method of comparative analysis which builds theory through interaction with qualitative data. It is an applied hermeneutic circle which develops the theoretical categories inductively from the data. Part of the job of a social theory is to enable prediction and explanation of behaviour and to do this the theory needs to be able to fit, i.e., the categories the theories use must be readily applicable to the data under study. Grounded theory guarantees this fit. An example of this approach in a fisheries research context is offered in Box 1.

What grounded theory and other qualitative approaches usually do not attempt is to discover covering laws that are argued to be valid outside of specific contexts. The covering law understanding of the goal of science arises mainly from the natural sciences and is a function of the type of phenomena under study. Even within natural science a physicist may place greater emphasis on the discovery of covering laws than an ecologist will. The value placed on the discovery of cover laws in the social sciences is strongly contested and varies widely between disciplines and individuals. Those disciplines that are most concerned with individual behaviours tend to use quantitative methods more often, to use them to test formal hypotheses, and to be more concerned with finding covering laws. Those concerned with institutions use quantitative methods less often, when they do use them they use them to produce summary descriptions rather than test hypotheses, and they usually seek to prefer more contextualized results such as identifying best practices or recommendations for institutional design principles. In all of these cases however, the goal remains the ability to describe in a transparent fashion how the researcher knows what he or she claims to know.

Box 1: An Example of the Results of Grounded Theory-based Research from Wilson and McCay 1998
Investigators observed the various meanings that participants in fisheries management in the US East Coast drew on when using when talking about participation. They arrived at the six categories named in the table inductively through a hermeneutic interpretation of the contents of the 173 documents ranging from transcripts of management meetings, letters written to influence fisheries policy, through interviews and field notes.

Table 1: The Six Categories of Interpretations of Participation and their Relationships

	The Three Basic Categories of Interpretations of Participation	
	The Three Areas of Conflicting Interpretations that Emerge from Tensions between the Basic Categories	
Mobilization	Representation	Working Together
Mobilization	Distrust	Source of Accountability
Working Together	Proper Process	Source of Accountability

Each category in the middle column emerges from the basic categories that flank it on each side.

The table outlines three basic groups of interpretations. The interpretation labelled "Working Together" frame participation as the basis of cooperative action that can be a resource for effective fisheries management. The basic Working Together story line is "participation means we all pull together to make management work." The Working Together interpretations are often, but certainly not exclusively, drawn upon by fisheries administrators. The second group is "Source of Accountability." These interpretations see industry participation as a source of influence on, or as a reason for, a course of action. They usually take the form "if X then the industry will Y." The basic Source of Accountability story line is "participation means we/they had better be ready to respond/explain." Source of Accountability is drawn upon by nearly everyone at different times and this group is the most common interpretation of participation. The third is "Mobilization." It consists of the different ways people talk about participation as mobilizing people who share their management goals. The basic Mobilization story line is "participation means we should go after the management decisions we want." Mobilization interpretations are most frequently used by members of the industry.

Although each of the three groups of interpretations includes contested interpretations, another set of categories focuses specially on conflicting interpretations of participation. These categories are Distrust, Representation, and Proper Process and they exist at points of conflict or tension between the other, less contested interpretations. The Distrust category arises from the contradiction between the Mobilization and Source of Accountability ways of viewing participation. There is a tension between interpreting participation as the industry mobilizing to achieve its own goals and interpreting participation as something that forces people to be accountable to others for their decisions and actions. The Distrust story lines range from talking about participation as a source of obstruction to the management process, to participation as co-optation of the industry by the management system. The second category of contested interpretations, Proper Process, arises from tensions over the procedures through which industry properly influences management. Should participation be interpreted as involving open communications, as someone concerned with ensuring that everyone is Working Together would be likely to do, or should it be interpreted as something that results from formal controls and proper channels, as someone concerned with confronting a Source of Accountability might prefer? Representation is the third category. It expresses a tension between Mobilization and Working Together ways of talking about participation. Does participation mean the "will of the majority" or is it the influence of a few who have established credible claims to speak on behalf of certain interest groups?

The practical dimension of the distinction between qualitative and quantitative is quite different from the epistemological one, although these dimensions are often pushed together in such a away that the epistemological distinction is used, inappropriately, to justify the practical one.

A critical element in the practical dimension is the role of quantification that is discussed in Section 3.3. Quantification promises, in principle, solid reference points for management discussions. References to quantity are used in management as the justification for decisions, even as triggers for particular actions. Such use seeks to import into the decision making process the transparency of argument promised by quantification as it is understood in epistemology. In many practical instances, however, the quantities referred to may be obscuring the basis of the decision rather than making it more transparent. In fisheries management, for example, numbers provided by ICES can be used in such a manner even if they are presented along with many caveats and qualifying assumptions. An interesting recent case was the decision by the autumn of 2003 where WGNSSK declined to provide assessment forecasts for cod because they felt, for various reasons related to the available data and the small size of the cod stock that they could not stand behind such forecasts as a valid quantitative result.

The complexity and uncertainty of statistical assessments can be murky, even other experts may require long explanations to really understand them if they were not directly involve in their calculation. ICES scientists try to address this question through paying attention, (constant attention in the case of key stock assessment working groups and ACFM) to how their results are going to be used by stakeholders.

Presentation of qualitative and quantitative results is different and plays different institutional roles. Quantitative results are easier to present in the sense that extensive information can summarized using mathematical rules. The need for specialized training to understand these rules, however, makes the presentation murky to those without such training. The basis of quantitative results in mathematical rules, as well as claims of accurate measurement and comparability of units, also makes it easier for those who disagree with the results to contest them. People cannot claim to agree or disagree because they are simply interpreting the results differently.

This clarity of presentation also means that quantitative information is more useful for the justification of actions. The basis of the results in mathematical rules creates an aura of objectivity that makes it seem as if it is the situation rather than the decision makers that is driving the decision. They seem to leave little interpretive flexibility when, in fact, the summarization in most cases hides decisions not grounded in mathematical laws.

Qualitative results, on the other hand, are often complex to present as they must begin with the definition and description of concepts that are either unfamiliar or, at the very least, their precise meaning in the particular context being described has to be explained. Because of the amount of interpretation involved, qualitative presentations are harder to directly contest. Disagreement usually takes the form of offering alternative interpretation. Such information often has multiple implications for action. It also usually fails to provide justifications for decision makers actions, at least in the sense that it is hard for decision makers to point to qualitative results and claim that the results, rather than the decision makers, are driving the decision.

In summary, from an epistemological viewpoint, quantification is a mechanism for ensuring transparency. The laws and language of mathematics are so clearly defined that all parties in a discussion are forced to both share the same definitions of concepts and to acknowledge the validity of arguments. Quantification allows a researcher to so precisely account for how a result is reached that the result can be replicated. This transparency in explaining exactly how researchers know what they know is the basis of science. Quantitative research, however, often leads to reductionism, meaning that measurement processes exclude so much contextual information that the research question loses meaning. Hence, qualitative research is also required. Qualitative research must also seek to meet the ideal of transparency of method but this is much more difficult when the language of mathematics is not available.

In practical fisheries management contexts, the epistemological strength of quantification holds the promise of an agreed upon basis for management discussions. Decision makers want to use quantification to make decisions transparent and to facilitate accountability. However, because of the complexity of fisheries management and the high level of mathematical skill required, quantification in practical contexts often makes knowledge less rather than more transparent. Reductionism that is distorting research questions and problems with measurement that are undermining the validity of the quantitative results are hidden.

3.3 Role of quantification (within ICES)

The importance of quantification and standardization in society is explained by two factors (Porter, 1995):

1) A result of making political decisions transparent and accountable,
2) A result of the great success of the science of physics, which influenced other scientific fields and the society in general. In science, transparency and accountability is a means for obtaining objective science. Quantified information has thus been perceived as of higher quality.

The importance of numbers has maintained in society in general. Also ICES emphasizes the importance of transparency and standardization and gives quantitative advice. We here question whether the quantities make scientific information more transparent, more accountable and of higher quality?

The key quantities presented in the ACFM report are often given with too many significant digits compared to the associated uncertainty. When the uncertainty is mainly communicated through the value of precautionary reference points, we consider that the choice of precision level in these quantities makes the advice less transparent. How quantities are presented is of importance to the transparency on the uncertainty.

There have been examples in the ACFM report where discards and unreported catches have not been accounted for in the stock assessment, predictions and/or the advice. This suggests that ICES working groups may be reluctant to utilizing information that is not quantified but still may influence the quantities of interest. Just picking a number to express a piece of qualitative information is often not adequate and estimates are based on expert judgement rather than strictly objective criteria. Examples are choices of models and sub-models, generalizations and at times personal weighting of time series for the tuning (which are a quantification of qualitative knowledge or impression). Such choices are necessary but given the interpretive flexibility in the data, a single quantity decreases the transparency and the accountability in science. Two scientists do not necessarily produce identical assessments with the same assessment tool because the best choices in running the model are not always obvious.

The precision level in the presented numbers contradicts the uncertainty communicated by the precautionary reference points, thus the numbers are presented in a way that it further decreases the transparency. In the text of the ACFM report some caveats may be addressed that still are not taken into account in the calculations. When the advice is presented in a precise way, it may thus look like the problem is not a significant problem, as the precision of the knowledge is not affected.

Taking the Northeast Arctic cod as an example, the 2003 assessment of the stock did not take discards and under-reporting into account. A concern about discarding and under-reporting is addressed in the text of the ACFM report (2003). Still the key numbers in the advice are presented with a high precision level. Presented estimates from the assessment are SSB = 653 307 t (beginning of 2003) and F (2002)= 0.6977. The predictions of SSB and F are given with 3 and 2 less significant digits, where the F(2003) is chosen to be the same as estimates for 2002. The main advice is formulated as follows:

Advice on management: In order to harvest the stock within safe biological limits, ICES recommends a considerable reduction in fishing mortality to less than $\mathbf{F_{pa}}$ (0.40). This corresponds to catches in 2004 of less than 398 000 t.

The uncertainty in the advice is communicated through the reference points (see example below) a statement that the yearly variation in maturity and growth can be substantial and the concern about the under-reported catches. All these three uncertainty considerations are indirect expressions on the uncertainty. When the key numbers and the advice is presented with an exaggerated precision they express that the uncertainty and the concerns are not major problems. Precise numbers can still be provided. The numbers thus make the ACFM advice less transparent.

ICES considers that:	ICES proposes that:
$\mathbf{B}_{lim}$ is 220 000 t (changed from 112 000 t)	$\mathbf{B}_{pa}$ is set at 460 000 t (changed from 500 000 t)
$\mathbf{F}_{lim}$ is 0.74 (changed from 0.70)	$\mathbf{F}_{pa}$ be set at 0.40 (changed from 0.42)

Example of the ICES description of reference points.

3.4 Review of different approaches to incorporate qualitative knowledge into decision support systems

3.4.1 Public hearings

One approach to integrating qualitative and quantitative information in a decision support system is the use of public fora. These are contexts in which discussions between scientists and fishers are used to both explain the stock assessment models and to gather qualitative information about the context in which the stock assessment models are set. These approaches are used very heavily in the United States. The following section describes these for the Mid-Atlantic Region of the Eastern United States. It is excerpted from Wilson and McCay 1998.

In the Eastern United States the management of many fish stocks is the joint responsibility of three bureaucratic agencies. The Mid-Atlantic Fisheries Management Council (the Council) is responsible for the development of fisheries management plans (FMPS) for federal waters, which extend from three to 200 miles. The Atlantic States Marine Fisheries Commission (develops plans and coordinates management by the individual states, which are each responsible for their own waters out to three miles. The Council and Commission work in a close, and legally complex, relationship with the National Marine Fisheries Service (NMFS), the federal agency which both implements such plans in federal waters and must insure that they meet certain national standards. The Council, Commission and NMFS share responsibility for many fish stocks.

There are three public fora for fishers' participation in management. The advisory panels are made up of fishers who are selected to review provisions of FMPS and advise the Commission and the Council on them. Public hearings are required whenever an FMP is created or amended. It is also a common custom for public comments to be made at Commission and Council meetings.

The advisory panels are organized around specific species or groups of species. One Council member described advisory panels as "a select group of people who are more knowledgeable and more interested" in the management of these species. They are considered an important source of legitimacy for the FMP on which they work. A great deal of criticism, for example, occurred when no Summer Flounder Advisory Panel was used for an extended period of time.

The following quote is from a state fisheries director who was critical of the Council's handling of the Summer Flounder FMP:

> *"Most importantly, something that we have failed to do and it's absolutely vital to anything we do in the future, we've got to get input from the fishers. I was astounded when we realized that we have not utilized our advisory panel, in fact I don't even know if we have an advisory panel for fluke [summer flounder], but that has to be done, we have to hear from the fishers. They are part of the problem, they have to be part of the solution."*

The standard process for creating or amending an FMP includes the creation of a "Public Hearing Document." This is a formal document which includes several possible alternative management actions, of which one is designated the "preferred alternative." This document forms the basis of a series of public hearings at which the public is invited to comment on the alternatives. Many comments are simply expressions of support or opposition to specific actions. Council members sometimes talk about public hearings as sources of new ideas, but few people in management or industry believe that the public hearings have a very broad effect on the content of FMPS. Public hearings happen late in the deliberation process, after the stocks have been assessed, the appropriate levels of exploitation have been debated, and the various alternative management measures have been thoroughly discussed.

In contrast to advisory panels and public hearings, the public comment periods at meetings do not involve managers formally seeking public input. The meetings are all open, by law, and customs have emerged for periods of public commentary. Moreover, the chair of a meeting may elect to ask public attendees to comment on a particular issue. However, Commission and Council meetings, save when advisory panels are specifically invited to participate, are not usually intended to be participatory. This is indicated by seating patterns: the committee members usually sit around an oblong or horseshoe-shaped structure of tables, and public attendees are relegated to an area to one end of this structure, sometimes looking at the backs of committee members. However, a microphone and possibly a sign-up sheet are usually present near the public area, indicating the possibility of participation. Industry representatives acknowledge that their comments can affect some aspects of decision-making, particularly when they concern fine-tuning details of an FMP.

These mechanisms are in the first instance ways to respond to legislative mandates inspired by a perceived need for pubic accountability for public servants. Secondarily they are attempts to both improve the public reception of fisheries management. The production of relevant qualitative information to help the management process is only a tertiary rationale for the events. Of the three, only advisory panels do a good job of bringing out useful qualitative information. The other fora do provide managers with a sense of how assessments are perceived and how management actions will be responded to, but they are so formalized that give and take conversations are not really possible. This limits the amount of new information that managers will get. Advisory panels are longer meetings with a smaller number of fishers and will provide more detailed information if they are well structured and if the panel members are good representatives of the various stakeholder groups both within and outside of fishing.

The Regional Advisory Councils being formed as a part of the reform of the Common Fisheries Policy will hopefully play a similar role in Europe. The usefulness of such an approach can already be seen in Europe through the North Sea Commission Fisheries Partnership and the Study Group on Industry Information. ACFM has already found the meetings with the Fisheries Partnership to be useful. For example, fishers information was helpful in the process of trying to develop fisheries-based management by pointing out issues in differentiating between targeted species and by-catch.

3.4.2 Methods for Treating Qualitative Knowledge as a Measurement Problem for Models

3.4.2.1 Multiple criteria decision making (MCDM)

MCDM is a field that has arisen since the 1960s. It is for the most part a distinct set of modelling approaches, many of which are non-parametric, that can be applied to the investigation of situations constituting multiple objectives. Two categories are clearly defined within this field:

1) *multi-objective programming* (MOP) (see Steuer, 1986; Miettinen, 1999) – appropriate for problems with an infinite number of feasible solutions for (continuous) decision variables subject to certain constraint functions, and
2) *multi-criteria decision analysis* (MCDA) (see Vincke, 1992) – deals with a discrete number of feasible alternatives to be analysed according to decision maker utility.

For fisheries, these may be crudely described as being related to bioeconomic modelling for the first case, and to the investigation of individual utility for the second case. It should be further noted that many paradigms exists for the measurement of objectives within this field, and as such they may be applied to a broad range of investigations. Furthermore, interactive methods exist in each category, where solution development by users is a guided process (Miettinen, 1999).

Recent examples and projects conducted in the field of fisheries include:

- English Channel fisheries bio-economic model (CFBM) – see WGFS (2003) for a brief overview, or Mardle and Pascoe (2003b) for the detailed report;

- EC 5th Framework Project "Multiple Objectives in the Management of EU Fisheries (MOFISH)" (QLK5-1999–01273) (Mardle and Pascoe, 2003a and b);
- Decision support system for South African pelagics (Stewart, 1988a and b); and
- Pacific whiting fishery bioeconomic model (Sylvia and Enríquez, 1994)

The MOFISH project addressed the issues considering multiple objectives in the management of EU fisheries (Mardle and Pascoe, 2003a; 2003b). That is the question of incompatible objectives combined with the different interests of groups involved in the management process. The potential suitability of multi-objective methodology for the development of fisheries management plans from the perspectives of stakeholder groups with differing aims and concerns from management was principally examined. Case studies considered for analysis were the fisheries of the English Channel (UK and French components)[1], two coastal Spanish fisheries considering the Striped Venus and Red Bream, the Danish Industrial fisheries and the North Sea demersal fisheries.

The novelty of the study has developed from the derivation of preferences towards fisheries management objectives for stakeholders. As noted by many commentators, generally the short-term view towards economic variables is not necessarily compatible with long-term sustainability of stocks. However, it is shown in the results that the objectives of improving profit from the fishing activity and increasing stock levels are for the most part complementary. This indicates a more efficient fishery with higher stock levels and vice-versa. For the case studies investigated (except the Spanish), under current management, they appear to follow a path of least change as far as possible.

The preferences were also included in multi-objective models to consider how an optimal fishery may look from different group perspectives of administrators, scientists, industry groups and environmentalists. This aimed to consider the potential effects of interest group preferences on the direction of management.

Overall, the project showed that generally, except for the Spanish cases, such preferences are not reflected in the management process. In many cases, the results indicated that the 'optimal' fishery structure is closer from the industry, scientific and environmental viewpoint than an administrative one, even though the individual weights attached to the different objectives varied. Further, except for the Spanish red bream fishery, the optimal fishery from these interest groups perspectives was characterised by higher biomass and profitability levels, and lower employment than that preferred by administrators. It is particularly interesting to note that in the Spanish red bream fishery, the fishing administration have set up a consulting committee in which all stakeholders participate.

3.4.2.2 Preference Modelling

The use of preference elicitation techniques in the fisheries system framework are designed to link or translate qualitative information into a quantitative form. Often they are described to 'uncover' individual utility towards a given instance, whether that is to describe an importance amongst objectives (or criteria) or to describe that utility over alternatives. Several of these techniques relate to the field of multi-criteria decision analysis (described above), and use structured questionnaires in order to elicit the required information. In the case of discrete choice modelling (random utility modelling), which also attempts to quantify qualitative information does not necessarily rely on questionnaires to provide data. However, survey information may be included within this framework.

In the EC 5th Framework Project MOFISH, two main methods for preference elicitation were adopted (Mardle and Pascoe, 2003a): the analytic hierarchy process (AHP) and conjoint analysis. Both are choice based methods for preference elicitation, where individuals are asked to state their preferences given a set of alternatives. The AHP (Saaty 1977; Saaty and Vargas, 2001) has been used considerably in many fields for the definition and analysis of user (or decision-maker) preferences in a vast range of application areas. It is only in the last ten years that AHP has been applied to fisheries to some degree (Mardle and Pascoe, 1999). An advantage of the AHP is that it can be used to develop importance structures between criteria and/or alternatives. The key feature is that value judgements are incorporated in the process, giving decision-makers the opportunity to explicitly state their preferences with respect to the identified objectives.[2] Conjoint analysis, on the other hand, has its roots firmly based in marketing research (Green and Srinivasan, 1990). Simply, the aim of the approach is to estimate the structure of an individual's preferences, by establishing the relative importance of the attributes that determine the preference. To achieve this, a set of alternatives that are prespecified in terms of levels of attributes are incorporated into a questionnaire. Other preference elicitation approaches that exist include multi-attribute utility theory (Keeney and Raiffa, 1976) and outranking techniques (e.g., PROMETHEE) (Vincke, 1992) all of which have other advantages/disadvantages.

In MOFISH (QLK5-1999–01273), comparative surveys using the AHP were implemented in the UK and French components of the English Channel fisheries, the Danish Industrial fisheries and Spanish bream and clam fisheries (Mardle and Pascoe, 2003a). The results were shown to indicate stakeholder preferences towards the importance of management objectives. As discussed in the WGFS Report (2003), the English Channel case study linked these preferences into a bioeconomic model of the fisheries (see Mardle and Pascoe, 2003b for more details).

The TECTAC project is one of several ongoing EU funded projects that propose to use random utility modelling to investigate quantitatively individual (fisher) utility towards aspects of the fishing operation. Overall, there are several

[1] This case study was summarised in WGFS 2003.

[2] It should be noted that several weaknesses have been shown the AHP, however these are addressed in Saaty and Vargas (1994).

studies in the fisheries literature that implement a random utility methodology (Hutton *et al.,* 2003). Utility, in this case, is typically defined as a (linear) combination of a set of explanatory variables that together are surmised to form (for the most part) the non-random components of the utility, and a stochastic error component. So, for example, for a given person time-event (such as a fishing trip) a choice is made. Both attributes of the choice and characteristics of the individual may be included. In fisheries, multinomial (conditional) logit and nested logit have been mostly applied. Wilen *et al*. (2002) discuss the particular benefits of using the latter. As described in Section 4.2.2 in reference to TECTAC, there is a proposition to link survey gathered information and log-book data in an attempt to quantify behaviour.

3.4.2.3 Bayesian influence diagrams

Bayesian influence diagrams (Kuikka *et al.*, 1999) use probabilistic information to help integrate model structure, objectives and management tools on a strategic level. They can utilise the inputs from a variety of sources including simulation models and are useful as decision analysis tools to integrate a range of processes or factors. They can be used to maximize the value of an objective function or to evaluate the value-of-information and/or value-of-control. Value-of-information refers to which parts of the problem should be known more precisely, and value-of-control is a controllable variable such as licenses, taxes.

The controllability of the system plays an important role and has an impact and Lane and Stephenson (1995) divide different fisheries variables into controllable and uncontrollable ones. For example, what is the probability of achieving a desired effect in the fishery if either the number of fishing days or the number of vessels are controlled. The value-of-information will also depend upon the control variables as well.

Within Europe there are several examples of applying Bayesian influence diagrams in resource management (Varis and Kuikka, 1997, 1999). For example Varis *et al.* (1994) modelled uncertainty in information objectives and model structure for water quality decisions and Kuikka *et al.* (1999) explored environmentally driven uncertainties in the management of Baltic Cod.

3.4.2.4 Fuzzy logic

Uncertainty cannot prevent management of real systems since advice has to be provided even if it is impossible to precisely describe the state of the system or it's response to any action (Ferson, 1994). Fuzzy logic is a formal mathematical theory for the representation of uncertainty and is a methodology to generalise any specific theory from a crisp (discrete) to a continuous (fuzzy) form that can explicitly include uncertainty about the system (Zadeh, 1975).

The fuzzy approach can make it much easier to include uncertain information. For example in developing rebuilding strategies, as information about stock dynamics along the recovery path is often unreliable or even missing altogether. The information may be of a vague nature; for example, conjectures about the spawning of older fish, but without hard fecundity data. This is difficult to develop in a quantitative model, but can be expressed in terms of fuzzy rules. For example in the case of NW Atlantic cod, it was clear that the stock was not rebuilding as quickly as planned (or hoped), and constant readjustments had to be made. Adaptive rebuilding processes are difficult to base on accurate quantitative information, since by the time that there is enough data to establish a clear pattern; it is becoming too late to use the information effectively. Qualitative patterns based on the fuzzy approach, however, could be a promising alternative way to use new information (ICES, 2002b).

There is also a recognised need to simplify and clarify the information used in fisheries management as the available data are often so voluminous or so esoteric that it is not possible to assimilate and analyse them effectively, especially given the time constraints that many fisheries managers face. Furthermore, fisheries concern different groups of people with different backgrounds and various levels of scientific sophistication. Consequently there is interest in finding simplified ways to represent data in a way that can easily be grasped but which preserves the original information without bias. One approach is to use a familiar pictorial representation to express in information in a way that all users recognise (ICES 2002b) and fuzzy traffic lights have been suggested as a means of dealing with the various types and degrees of uncertainty considered when providing advice on management options. In terms of presentation, relevant variables are traditionally represented by coloured indicators of stock condition using the standard red-yellow-green representation of traffic lights. Fuzzy lights extend the traditional formalism using lights that are mixtures of these colours, such as a mixture of green and yellow for variables that are close to the bottom of the acceptable range. This representation makes it possible to present even the most complex data in a form that is easily understood. The traditional traffic light restriction to just three values – red, yellow or green – is clear but too crude for most purposes. The fuzzy approach gives better resolution with little loss of clarity.

3.4.2.5 Strategy Unit Long-run Fisheries Incentives Model for Cod (Decision Support Software)

The Long-run Fisheries Incentive Model was developed in order to analyse flows of fishing capital into and out of the UK component of the North Sea cod fishery. It was developed in the simulation system package Vensim DSS[3]. The model comprises several sub-models that are linked to investigate the effects of fishing capital, effort, productivity, stock biology and financial gain. A simple user interface was developed to 'see' the model, run different scenarios and view outputs and get a feel for its structure. Due to this, where this has been shown to stakeholders, there is evidence of

3 http//:www.vensim.com

a positive response to the software. The positive response was directly towards the presentation and interaction using the software. The communication of the results and the model in this instance could be evaluated as the stakeholders concerned where part of the fishery being evaluated but expressed the usefulness of the approach for a project that focuses on their fishery. Note that, at present, this model is still at the development stage. Features of the model include (see links to the Strategy Unit Report, 2004):

- to explicitly model the capital entry-exit decision, i.e., the decision where fishers decide to fish in the next year, exit the fishery or buy a new boat;
- to understand the impact of differing efficiency levels between individual fishermen/boats (e.g., as a result of skill or simply age of vessel, new boats being assumed to be more efficient than older boats);
- to analyse the effect of annual technical creep as small improvements are made to fishing operations; and
- to find out what happens to capital, productivity and the cod stock when a decommissioning programme or a vessel tie-up scheme is used to reduce effort in a fishery (either permanently, or temporarily).

3.4.3 Incorporating qualitative knowledge via caveat writing

Introduction
As addressed in Section 3.3, the ACFM report is not considered transparent concerning the uncertainties associated to the presented numbers and how the uncertainties affect the advice and the issues dealt with. The scientists that carry out the assessments and predictions will have some qualitative knowledge on the various uncertainties and their characteristics. In this section we discuss how uncertainties are presented in the ACFM report, why the communication of uncertainty is important and we present a suggestion on how to clarify the uncertainties.

Qualitative information and uncertainties
Where uncertainties in the assessments exist, there is generally still a notion of the direction and extent of such uncertainties, as formulated in qualitative terms. These uncertainties have consequences in a generally predictable direction. Fisheries scientists respond to such uncertainties in various ways: neglect, model assumptions, exploratory runs etc. Part of the qualitative information is replaced by quantitative information in the course of time, either progressively with time series growing or instantly via specific research to reduce uncertainty.

Uncertainties documented in reports by Working groups and ACFM
Working groups do not provide ACFM with a standard format for ACFM to gain a quick overview of the uncertainties and the way they are handled by the working groups. Neither produces ACFM a concise report where scientists, managers and stakeholders could easily deduce how stock estimates and thus management advice are affected by which uncertainties and to what extent. The layout, text structure and the use of headings in the ACFM-report actually 'hide' such information to some extent.

Transparency on uncertainties supports the management debate
A tabularized overview of uncertainties, their consequences and the response to those uncertainties by Working Groups and ACFM would serve the transparency of the advice. More importantly it would serve the successive debate on the management advice by scientists, the administration and the resource users. It would help and invite all three to take a clear and more documented stand in this debate.

Suggestion for an uncertainty table
Table 3.6.1 lists the major sources of uncertainty in the estimates for Spawning Stock Biomass (SSB) at three moments in time (see figure 3.6.1) and per category of model input. In Table 3.6.2 the columns typify the uncertainties, their consequences for stock estimates and the way fisheries scientists responded to these uncertainties. Uncertainties listed under the estimate for SSB1 bear on the estimate of SSB2, and successively on that of SSB3. Uncertainties appear either as variance or bias and should be categorized like that. Some examples are presented in Table 3.6.3.

Discussion
We have presented a table (Table 3.6.2) where possible uncertainty elements are mapped and where the scientists can present the uncertainties and how they affect the assessments and forecasts. Table 3.6.3 gives some examples on single uncertainty issues taken from the ACFM report (ICES 2003a). The making of the table is an attempt to improve the communication of the uncertainties so that the sources of the uncertainties, like under-reporting, and the relevance of the advice, like the limit for advised total catches, can be discussed by non-experts also. We consider the suggested table at a premature stage and that the table should be presented in a clearer way. Also the issues in the table related to the uncertainties and how to characterize them should be further discussed. It could be that two tables should be developed, one extensive, presented in the working group report and a comprised one in the ACFM with references to the working group report. However, we consider a table with specific uncertainties and how they affect the key quantities in the ACFM report will be a major improvement in making the uncertainties more transparent.

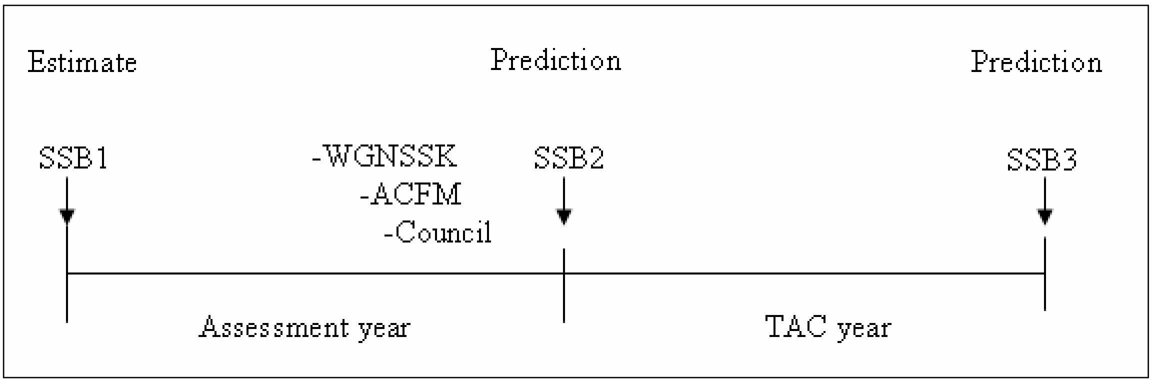

Figure 3.6.1 Schematization of ICES short term forecasts.

Table 3.6.1. List with sources of assessment and prediction uncertainty (see figure 3.6.1 for explanation of terms)

SSB1

- Stock definition
- Total catches
  - Statistical recording error
  - Black landings
  - Discards
  - High-grading
  - Misreporting (weight, species, time, area)
  - Multiplication error (number of boxes * weight in a box)
- Age composition
  - Errors in ageing technique
  - Sampling error (areas, fleet segments)
- Natural mortality
- CPUE surveys
  - Unidirectional change in catchability over the years, e.g., gear change
  - Sampling variance, incl. area coverage
- CPUE commercial fleet
  - Unidirectional change in catchability over the years, e.g., gear change, effort, efficiency
  - Sampling variance
- Weighting of index series
- Mathematical/statistical choices – structural model uncertainty
  - Model choice
  - Choice for statistical distributions
  - Mathematical stability; in search for an optimal solution
- Size/Age at maturity

SSB2

- Catches in assessment year (AY)
- Size at age in assessment year
- Recruitment to exploitable stock in assessment year
- Size/Age at maturity in assessment year

SSB3

- Catches in TAC year (TY)
- Size at age in TAC year
- Recruitment to exploitable stock in TAC year
- Size/Age at maturity in TAC year

Table 3.6.2. Example of an "Uncertainty Table".

Elements in the VPA	Uncertainty		Consequences of the uncertainties		Response towards uncertainties
	Type	**Direction (and extent)**	**Direction**	**Extent**	**Assumptions, research**
SSB1 • Stock definition • Catches • Age composition • Natural mortality • CPUE fleet • CPUE surveys • Personnel weighting index series • Mathematical/statistical choices • Size/Age at maturity					
SSB2 • Catches in AY • Size at age in AY • Recruitment to exploitable stock in AY • Size/Age at maturity in AY					
SSB3 • Catches in TY • Size at age in TY • Recruitment to exploitable stock in TY • Size/Age at maturity in TY					

Table 3.6.3. Examples of an application from the list with sources of uncertainty.

	Uncertainty		Consequences		Response
	Type	**Direction and extent**	**Direction**	**Extent**	
Black landings of North Sea cod	Bias	Underestimation of catches	Underestimation of SSB		Model run with assumption of 50% black landings
Discards of North Sea plaice	Bias	Underestimation of catches	Small effect on SSB. Is more of a problem when percentage discards changes over the years (affects recruitment to the exploited stock)		Runs with percentage discards from 50 to 80%. Discard monitoring started.
Change in gear in Scottish ground fish survey	Bias	Yet unknown	Yet unknown		Calibration experiments started
Sampling variance in catch rates for cod in the IBTS	Variance	Both directions	Both directions		Adaptation in survey design and sampling strategy?

3.4.4 Interacting with models in decision making processes

Scenario modelling and Trade-off analysis

The ability to undertake scenario modelling and trade-off analysis are significant advantages of system models. By definition, indications of changes throughout the system (including sub-models) are investigated. Scenario modelling is a useful tool in itself when developing models for the justification of advice. However, they also allow links to be made to stakeholders (or more generally 'users') in order to include some of their knowledge within the system. This is particularly relevant for types of model discussed above in the MCDM and preference modelling fields as well as simulation models. Thus, the interactivity associated with this, enables users to follow ideas in models as well as the possibility for users to change the rules in the model. Graphical simulation tools as described in the Strategy Unit model are particularly relevant. For example, when modelling multiple objectives in this way, one user may regard a specific objective to be represented as 'too low' in the system. This may be simply due to the existence of many potential solutions. In this setting, that user would be able to increase the priority of that objective within the system and be guided through 'solution space'. Another example may be that users could alter rules and constraints in the system that they believe to be a useful line of investigation. Simulations can be re-run and the resulting effects analysed in a consistent framework.

Complex models can be difficult to use with stakeholders

In the early 1990s a complex bio-economic simulation model was developed to simulate the North Sea flatfish fisheries, including the spatial dynamics of the resource and the fishermen. Part of the development of the model consisted of a workshop with fisheries managers to evaluate the usefulness of the simulation tool for policy making. The fisheries managers that attended the two day workshop were all academically trained. The objective of the workshop was to introduce the fisheries managers to the technical detail of the model and the type of scenarios that could be addressed by the model. There is no written report of the workshop but the main recollection of the process was that the meeting ended up in very detailed discussions about the technical details of the model which overall dragged the energy away from the questions on the usefulness of the simulation model in policy making or the type of use that could be made of the model. The lesson to be learned could be that interactive sessions on simulation models run the risk on focussing on the content of the model rather than on the potential use of the model within a strategy formulating or decision making context.

3.5 Synthesis

The distinction between qualitative and quantitative information can be understood in two ways. From an epistemological point of view, subjecting information to the laws of mathematics gives such clarity to concepts and the relationships between them that the greatest possible transparency of arguments is achieved. From a practical view point, this transparency of argument can, in principle, provide solid reference points for management discussions. However, the complexity of models and the skills required by quantification can actually make quantification a source of obscurity rather than transparency. Furthermore, quantitative information contains a rhetorical power in these discussions that all stakeholders will want to make use of to support their arguments, this creates motivations to use quantification, intentionally or not, in ways that obscure rather than clarify.

This section has discussed four strategies for using qualitative and quantitative information in a complementary way to support decision making.

Two of these strategies are based on interactive processes. The use of public input to comment upon quantitative information (Section 3.4.1) provides decision makers with contextual knowledge that may allow them to use the information more effectively. Having decision makers and other stakeholders interact with models to explore different scenarios (Section 3.4.4) can help them clarify their options. Using quantitative information as the basis of an interactive process has the advantage of helping participants to better grasp the underlying natural systems and understand the trade-offs they face around both impacts on stocks and on stakeholder groups. The disadvantage is that all these processes really accomplish in the generation of richer qualitative information, which may or may not aid the actual decision-making.

One of these strategies, treating qualitative information as a measurement problem for quantitative models (Section 3.4.2) seeks to produce results in a quantitative form while incorporating qualitative information. This strategy takes many forms and the five summarized above are exemplary of many others. The advantage of this approach is that, in the end, a set of numbers is produced. This set of numbers can then be used to justify decisions and, if stakeholders are sufficiently convinced that the underlying measurement problems have been solved, this justification may serve to give the decision legitimacy. The disadvantage of this approach is that, if the information was really qualitative in the first place, the underlying measurement problems are never really solved. Either some process is used to generate a number from the information that cannot really be thought of as measurement (e.g., some Bayesian approaches that substitute expert opinions for measurement), or aspects of the situation that are amenable to measurement are given more weight than aspects that are not, which leads to reductionism and loss of meaning. In both cases the transparency of argument that gives truly quantitative approaches their clarity and power is not achieved. The danger then arises that the numbers produced are treated in management debates as truly quantitative results, which may undermine the legitimacy of management. The last strategy, writing caveats to disclose the weaknesses in quantitative results (Section 3.4.3) is the most common way that ICES working groups and advisory committees integrate quantitative and qualitative information. This is an extremely important process that the WGFS recommends should be made clearer and more systematic. The advantage of this strategy is that the qualitative information actually enhances the transparency of the quantitative by aiding their intepretation. The disadvantages of this strategy is that complex results can require so much qualification to be truly transparent that the qualitative information becomes difficult to understand. Section 3.4.3 offers some experiments in ways to communicate these caveats more effectively so that the transparency of the quantitative information can be better enhanced.

4 Results of studies on aspects of the fishery system framework

4.1 Fleet Adaptation System

This section in no way attempts to review entirely the state of knowledge of evaluating fisher/fleet behaviour due to the scale of the topic and diversity of fields where it is of interest. However, the aims are to provide a concise view of types of research being conducted, at the present time, primarily under the umbrella of European Union funding. There are also references to the literature where relevant. In this light, at the preparation of this report, the EU 5th Framework Project TECTAC is currently ongoing (2002–2005), two EU 6th Framework Projects EFIMAS and COMMIT are starting (2004–2007).

4.1.1 Qualitative information in evaluating behaviour in fisheries

Qualitative observations of behaviour are typical products of work from disciplines such as sociology, anthropology, political science, and geography, through surveys, interviews, text analysis, participant-observation, and other research methods. In addition, those who work with fishers and study what fishers do often employ non-reductionist and non-formalist methodologies (e.g., Vestergaard, 1997; Nordberg, 2001; Christensen, 2002). This research strategy does not preclude more systematic attempts to obtain either qualitative or quantitative data, but it underscores the importance of the social embeddedness of behaviour and the social construction of ideas and institutions. Fisheries in these studies are described and understood as part of a broader picture and in terms of the everyday exchange of knowledge with other fishers (colleagues and competitors) as well as their interactions with scientists and fishery managers (Wilson and McCay, 1998). It is also understood that fishing behaviours cannot be isolated from the fishers' ordinary life and activities ashore. Institutional economists support this argument to some extent (North, 1995; Raakjær Nielsen, 2003). Raakjær Nielsen (2003) emphasises the need to take into account factors such as industry structure, fleet composition, geography and demography and in particular, individual behaviour and individual expectations within groups of fishers.

National qualitative studies are being carried out as part of the TECTAC project, particularly studies on demersal fisheries in Denmark, France, Spain and England. In Denmark two studies have been carried out: the first targeted 16 fishers who were qualitatively interviewed in sequences (2–3 interviews of 1½ – 2 hours each); and the second formed a survey amongst fishers (270 respondents) with respect to fishers tactical and strategic decisions (Christensen and Raakjær Nielsen, 2004). Both studies focused on three different fisheries in Denmark: the demersal fisheries in the North Sea; the *Nephrops* fisheries in Kattegat, Skagerrak and the North Sea; and the cod fisheries in the Baltic Sea. These Danish fisheries are heterogeneous as indicated through size of vessel, target species, gear used, geographical mobility, number of days spent at sea per trip and per year etc. These differences indicate that Danish fishers do different things, make different strategic investments, and have diverse fishing tactics. In studying the tactical and strategic decision-makings in these fisheries as well as the internal differences, a typological pattern has resulted showing different behaviour among fishers in Denmark. These patterns are particularly useful when used to assist in the quantification of behaviour and activities in a system modelling process. This is ongoing in the TECTAC project.

4.1.2 Quantitative information in evaluating behaviour in fisheries

A conceptual model summarising processors in a fishery adaptation system is included in WGFS (2003) which essentially captures some of key components in the model. Models that subsume ideas of fisher behaviour can be found within the fields of biology and economics. In this part we consider quantitative techniques for the analysis of fisher behaviour from a (micro-) economic perspective.

In general, the behaviour of producers can be thought of as a utility maximising problem, where individuals strive to get the best results according to their preferences and capabilities (Boncoeur, 2002). In the case of fisheries, there is some evidence that this can be approximated by the maximisation of profit (Pascoe and Robinson, 1997). Production factors are key to the definition of costs related to this calculation of profit. Factors, for the most part, include labour, capital and stock where capital includes both fixed and operating (variable) costs.

So, behaviour can be categorised as short-run and long-run. In the EC 5th Framework Project TECTAC, these have more generally been termed tactics and strategies. In fact, this relates to the speed in which decisions can be made in the fishing operation. Decisions such as where to fish are short-run (thus tactics), where investment or dis-investment in a fishing operation is a long-run decision (thus an overall strategy). The clear difference between these categories is the inclusion of fixed costs, as well as discounting (i.e., money flow over time) and opportunity costs (i.e., an indication of other investment opportunities, as related to the market value of the vessel for example).

In the literature there exist studies that have been undertaken to investigate aspects of fisher behaviour. These investigations include the consideration of behaviour from both the individual fisher/vessel and fleet perspectives. The most prominent areas of analysis are: the economic behaviour of the fishing operation; choice of fishing location; relations between leaders and followers; search behaviour; high-grading/discarding; strategy towards enforcement (an external effect); vessel entry/exit behaviour; and technological change.

Of the techniques proposed for analysis, random utility (or discrete choice) models (RUMs) have been shown to of relevance (Bockstael and Opaluch, 1983; Eales and Wilen, 1986; Holland and Sutinen, 1999; Wilen *et al*., 2002; Mistianen and Strand, 2003). The work of McFadden (1976) provides the foundations for RUM, where the premise is that utility drives individual choice with a deterministic component and a stochastic error component. Because fishers' location choice is well suited to the application of RUM, this is a popular analysis at present. This applicability is encapsulated by Wilen *et al*. (2002), who state that "economists believe that an advantage to using micromodels of individual behaviour that incorporate structure… is that they can predict responses to policies that have not been in place over the sample period used to estimate (the) response elasticities". This has particular importance as well as that no assumption of homogeneity amongst individuals is required.

Examples of application include to New England trawlers (Holland and Sutinen, 1999), the California red sea urchin dive fishery (Wilen *et al*., 2002), North Sea beam trawlers (Mardle and Hutton, 2004). In the TECTAC project the aim is evaluate different aspects of behaviour the case studies (fisheries in France, Spain, UK and the Netherlands). The aspects to be considered in each of the fleets are (1): investment behaviour (long-term), that is, vessel entry/exit, (2) technological change (long-term), (3) gear and targeted species choice (medium-term), (4) fishing location choice (short-term), (5) discards (short-term), and (6) choice of landing harbour.

Optimality models (Stephens and Krebs 1986) can be used to model individual vessel decisions and assess effects on catch rates in a fleet (Gillis 2003). These models provide a theoretical skipper or company with a set of options, each with its own payoff (e.g., profit), and it is assumed that the choice will be for the highest payoff. Models investigated in this project will include: Ideal Free Distribution models – IFD (Fretwell and Lucas 1970; Gillis and Peterman 1998) and the central place foraging models. The latter model aims to predict fishing decisions as a function of the distance between fishing grounds and sites to which catches should be returned (Orians and Pearson, 1979; Sampson 1991).

4.1.3 The use of qualitative/quantitative behavioural analysis for WGFS

An indication of how fishers may react to management regulations has clear implications for the success of an imposed policy. To include such information through qualitative/quantitative behavioural analysis offers some potential to the process.

There are various ways qualitative and quantitative data and methods can be included in the analysis of the conceptual fisheries system model. The qualitative analysis undertaken on the Danish fisheries (as part of the TECTAC project) (Section 2.6.3) identified tactical and strategic decisions in these fisheries as well as the internal differences, showing different behaviour among fishers. These typological patterns are particularly useful when used to assist in the quantification of behaviour and activities in a system modelling process. This is ongoing in the TECTAC project and the results will be relevant to the WGFS.

In terms of using methods to quantify behaviour through indications of individual utility (i.e., random utility modelling), there is some promising work being undertaken (see TECTAC) showing that past effort and catch rates affect choice of fishing location. However, as found in studies to date (e.g., Holland and Sutinen, 1999; and Mardle and Hutton, 2004) some of the 'rules' that may apply to behavioural activity may not be picked up. This is a clear area where qualitative information gained through survey may be applied within the quantitative framework to add more detail. This process is complementary in a technique such as RUM, but may also assist in the qualification and reasoning of results.

It should be noted that much of what has been discussed in this section relates to the attempt to consider an analysis of individual behaviour within the process. However, for completeness we mention some of the more general fleet-based modelling assumptions to behaviour that have been made in past studies. For example, Rijnsdorp *et al*. (2000a) used the assumption that vessels allocate effort according to the idea that vessel density is proportional to resource abundance. Sampson (1991) weighted catch rate by distance (by accounting for steaming time as time lost to fishing) and therefore a total trips catch will be lower the further a ground is from port (even if it has the same catch rate if a ground closer to port). One can find many others in this context, however there are few to date that attempt to include results from the analysis of individual utility with a more general model. Of the exceptions, two recent studies (Holland and Sutinen, 2000; Wilen *et al*. 2002) have considered linking RUM with bio economic models.

4.2 Approach for comparative study of monitoring, control and surveillance (MCS)

This sections refers to ToR d)

ToR d) develop an approach for comparative studies for monitoring, control and surveillance (MCS) systems

The WGFS considers that this topic is a very important issue with regards to the performance of fishery systems. The topic is in itself currently not subject to coordinated research within the context of ICES.

The development of an approach for comparative studies on fisheries MCS for example within the context of the CFP would as a start benefit from reviews of such systems. Berg (1999) provides a comparative study of the implementation and enforcement of fishing laws under the CFP in the Netherlands and the UK. Hønneland (2000) studied management control and enforcement in the Barents Sea Fisheries. The development of the requested approach would benefit from developing and incorporating analytical frameworks such as the one provided by Raakjaer-Nielsen (2003). He focuses on the relationships between enforcement and compliance as regards monitoring, control and enforcement (MCE) activities.

The meeting of this Working Group did not include experts on MCS research. The Working Group suggests that a workshop on the topic should be incorporated in the next meeting of the Working Group. In that workshop experts will be invited to present recent studies on this topic.

5 Precautionary approach reference points

5.1 Introduction

This section presents a summary of a working document on PA reference points (Hiis Hauge, 2004).

There were two intentions of the precautionary reference points in fisheries: they were to serve as a management tool for avoiding the danger of over fishing and to serve as a tool for communicating uncertainty.

A key assumption in the definition of the reference points is that the danger of over fishing is reversible. What is not handled is a potential irreducible danger due to many changing conditions in the ecosystem caused by a combination of natural variation and human impact on the ecosystem (is the state of the Northern cod irreversible?). In cases where managers understand the precautionary reference points as a management strategy: to balance on the edge of precaution, it also increases the irreversible danger. An irreversible danger is far more difficult (impossible) to quantify.

The reference points as a tool for communicating uncertainty fail to distinguish the uncertainty in the past, now and in the future, and between risk and uncertainty. Since in general the uncertainty in scientific advice in ACFM reports is presented by the reference points and occasionally in the text, the uncertainty is not well communicated. Scientists may have interest in keeping it this way because they believe it will maintain their credibility, influence and their role of protecting "their" stock. There are also scientists that claim the opposite; that hiding the uncertainty is taking political responsibility and will reduce their credibility.

The idea of the precautionary reference points must be understood in the context of the "best estimate". In spite of interpretive flexibility in the data, it is a common understanding within ICES that an assessment result in a "best estimate". "Best" must be understood as best given a certain set of underlying assumptions that not necessarily are valid. The estimate is expected to be revised the following year. A question is thus whether the estimate is "best" in a management context. Precautionary reference points fit into the thinking that a precise "best estimate" and its predictions are good enough so that it is meaningful to compare them to reference points.

There are some questions related to these topics that may be worth addressing in future research projects.

- How do users and scientists relate to uncertainty and risk?
- How do users perceive uncertainty and risk?
- What are the political and ethical questions related to the communication of uncertainty?
- How can we improve the communication of uncertainty?
- May this imply consequences for how the fisheries are managed?

5.2 Addressing the ToR

This section addresses ToR e):

e) Identify the factors influencing decisions about how precautionary reference points are defined and estimated.

The Working Group was unable to address this ToR fully, because results of ongoing research are not yet available.

The precautionary reference points are benchmarks for guiding management decisions. The definition and estimation of such reference points are of critical importance because they regulate the division of responsibilities and interaction between scientists and managers. Whereas the calculation of precautionary reference points has a technical component, and hence to a certain extent belongs to the scientific domain, their uses as benchmarks for guiding management decisions include notions of social acceptable risk levels and hence belongs to the domain of management and politics. The definition, estimation and use of precautionary reference points hence represent important boundary issues within the current management institution.

The Working Groups considered that it did not have the information required to give a comprehensive answer to this ToR at the time. However, the PKFM project will collect information and analyse the way the PA reference points have been defined and utilized in the management of North Sea Cod, and the BNIMS project will provide such information with regard to North East Arctic cod. A more thorough response to this ToR on the basis of such work will hence be possible in next year's Working Group meeting. Nevertheless, the PKFM and BNIMS projects will not allow a comprehensive assessment of the definitions and uses of PA reference points within the ICES area, since this would require a broader range of stocks.

Having noted the need for more comprehensive analyses on this point, the following observations as to the current situation regarding the functions of the PA reference points and their definition can be noted (Section 5.3).

5.3 Elements of the precautionary approach framework in the European context.

In this section a brief overview is presented of the developments regarding the precautionary approach within ICES and with reference to requests by client commissions to ICES. This overview has been compiled during the Working Group and is by no means exhaustive. The main aim of the table is to show how and where interactions has existed between scientists (ICES) and managers (client commissions) regarding the definition and the interpretation of reference points.

1997,1998	SGPA (ICES 1997b, 1998) The definition and modification of the precautionary approach within ICES started with two dedicated study groups on the precautionary approach (ICES 1997, 1998). ICES has set these study groups to address a request by the client commissions to make proposals for the implementation of the precautionary approach in fisheries management. The group created a list of precautionary and limit reference points for most stocks where analytical assessments could be carried out.
1998	ACFM (ICES 1999b) Application of PA reference points in advice The new "pa" thresholds being proposed in 1998 are a provisional step to the implementation of a precautionary approach. Estimates of thresholds may change as the concept evolves, or with additional knowledge on stock and fishery dynamics. Attempts to integrate this approach with similar initiatives elsewhere (FAO, NAFO, etc.) can be expected to result in changes in terminology.
1999	ACFM (ICES 2000b) No response from client commissions on the proposal of reference points by ACFM? Label in ACFM advice: "Precautionary approach reference points as proposed by ICES in 1998"
2001	Government of Russia request: Reconsider $\mathbf{F}_{pa}$ with reference to the adjusted $\mathbf{B}_{pa}$ for NEA cod Make a new $\mathbf{F}_{pa}$ assessment that would involve recalculation of the entire database from 1946 in catch at age in numbers taking into account the same weights that had been used in revising $\mathbf{B}_{pa}$.
2001	SGPA (ICES 2001b) Reinstallation of study group on precautionary approach. ToR: "review the current status of the Precautionary Approach (PA) as implemented by ICES" (reasoning: was promised at the introduction of reference points)
2002	IBSFC request: Revise the precautionary reference points for cod taking into account the changed exploitation pattern
2002	EC request: For the stocks of plaice in the Skagerrak and Kattegat, herring in VIIg,h,j,k, sole in VIIIa,b and northern hake, evaluate any new relevant information concerning the state of these stocks and review the catch advice provided for the year 2002. ICES should take into account relevant comments by STECF, and in particular concerning the precautionary reference points for hake.
2002	ACFM (ICES 2003a) Terminology: "Precautionary Approach reference points (unchanged since 1999)"

2002	SGPA (ICES 2002b) Proposal for methodology to calculate limit reference points based on segmented regression and to derive PA reference points using the uncertainties in the historical forecasts.
2003	IBSFC request for 2003 Advice on biological reference points for cod, herring, sprat and salmon stocks taking into account inter *alia* current biological parameters and exploitation.
2003	SGBRP (Biological Reference Points for NEA cod) (ICES 2003c) Application of methodology developed by SGPA 2002. Segmented regression to estimate F_{lim} and B_{lim}. Estimation of uncertainty in forecasts as basis to derive F_{pa} and B_{pa}.
2003	SGPRP (Study Group on Precautionary Reference Points For Advice on Fishery Management) (ICES 2003d) Need for review of reference points: When the precautionary reference points were introduced it was envisaged that they should be reviewed and revised on basis of new data and information every 3–5 years. The SGPA 2002a (Anon 2002) reviewed the need for revisions and recommended that a revision process be initiated.
2003	ACFM (ASC 2003) Discussion on revision of PA reference points. No need to revise reference points according to EC observer.
2004	New Memorandum of Understanding between EC and ICES Focus on long term management and target reference points.
2004	WGMG (Methods Group) (ICES 2004b) Discussion on target reference points; not finalized.
2004	NEAFC request for 2004 "When presenting biological reference points (B_{pa} and F_{pa}) ICES should provide information on the probability levels relative to the limit reference points. …ICES is invited to consider presenting biological reference points as percentages of average values for specified periods. NEAFC welcomes the ongoing process of analysing the basis of biological reference points in ICES. NEAFC would like to be informed of possible changes and their possible effects on advice at the earliest convenience."

The table above shows some of the interactions between scientists and managers regarding the definition of precautionary approach reference points. Precaution is in itself a contested concept (Degnbol *et al*. 2003) both between scientists and managers but also within ICES, where the definition of reference points like F_{lim} and F_{pa} is often leading to fundamental discussions. Although this clearly needs further study, the table could be used as a first attempt to document the history of these contested concepts within the scientific, political and public arenas. This can then be used to understand the boundaries between science and politics as it is constructed in the debate around reference points.

6 Publication plan

The Working Group discussed a publication plan for work related to fisheries systems. Members felt that this is a critical role for the WGFS to play. Publications of results from the many research activities aimed at improving fisheries management in ways that place those results within a fisheries systems perspective is one of the primary practical ways that the this perspective can benefit ICES. The production of fisheries system publications that bring together a broad range of research projects is seen as an important, ongoing activity of the WGFS.

For the immediate future the WGFS envisions a three-step plan focussed on collating results from current projects. The first step will be a set of panels to take place in the 2005 Annual Science meeting. The papers from this panel will then be published as either a special issue of a journal (likely the ICES journal) or as an edited collection. We also envision that a shorter version of the introductory article would be published in a well known multidisciplinary journal such as *Science* or *Nature*.

The papers to be presented in that panel follow. These are not meant to be titles but rather brief descriptions of the subject matter. Tentative authorship assignments were also made by the WGFS.

Part One: Papers addressing the overall system
1. An introductory paper describing the overall idea of a systems approach to understanding fisheries.
2. A comparative analysis of cod management in the North Sea, the Barents Sea, NE United States and Canada
3. A presentation of the EFIMAS / COMMIT model for evaluating fisheries management alternatives
Part Two: Papers Addressing Particular System Linkages
4. Managers to Fishers: Issues in Effective Communications
5. Managers to Fishers: General Issues in Fleet Adaptation and Compliance
6. Managers to Fishers: Bioeconomic Models of Fleet Adaptation
7. Fishers to Scientists: Data Issues in North Sea Cod Management
8. Fishers to Scientists: Comparative Experiences in Collaborative Research
9. Scientists to Managers: Retrospective Analyses of Models Used in NS Cod Assessments
10. Scientists to Managers: The Setting and Use of Precautionary Reference Points
11. Scientists to Managers: The Use of Science in Policy in North Sea Cod Management

7 Recommendations

1) Recognising that much of the recent research activity in Europe, within fisheries management and advice, has been coordinated and conducted in international projects funded by the European Commission, the members of WGFS will continue to maintain contact with on-going EC-funded activities. WGFS will continue to ensure that links are maintained with EC-funded projects of relevance to its scientific remit; together with establishing links to projects funded from outside of the EU. Therefore, the Working Group recommends that a meeting of this group be scheduled in 2005.
2) The Working Group recommends meeting at ICES headquarters in Copenhagen for 5 days, either from 9–13 May 2005 or from 20–24 June 2005.
3) The Terms of Reference for the WGFS meeting in 2005 should be focussed on
    a) further coordination of case studies and relevant projects
    b) presentation of results of the ongoing analysis of fishery systems and elements of those systems; with reference to presentations at the ICES ASC 2005
    c) include a workshop on studies of monitoring, control and surveillance (with external experts invited)
4) The Working Group recommends having a session at the ICES Annual Science Conference (ASC) 2005 devoted to the evaluation of fishery systems. The session would be operated by invited papers (see Section 6) and additional open papers.

8 Working documents and references

8.1 Working documents

WD1 Petter Holm, Kåre Nolde Nielsen: The TAC Machine.

WD2 Kjellrun Hiis Hauge: Questions related to precautionary reference points.

WD3 Simon Mardle and Trevor Hutton: Location choice for the English North Sea beam trawl fleet in 2000 using a random utility model.

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9 Annexes

Annex A: Definition of terms used to describe the management evaluation framework

The definition of terms presented below was derived from the WGMG 2004. It is the intention that future meetings of WGFS will add to this list.

Term	**Definition**	**Source**
Assessment model	Part of the management procedure that uses information derived from the observation model in order to provide estimates of the status of the stock(s) and fishery.	WGMG2004
Decision-making model	Part of the management procedure that results in harvest decisions that are largely determined by the harvest advice model.	WGMG2004
Error (uncertainty)	Differences between the "virtual world" (in the operating model) and the perceived one. Several types of errors are: *process error* due to natural variation in dynamic processes (e.g., recruitment); *measurement error* generated in collecting observations from a population; *estimation error* that arises from trying to model the dynamic process (i.e., during the assessment process); and *implementation error* since management actions are never implemented perfectly.	WGMG2004
Feedback	Effect of one component in the framework on other components. The term is typically used for effects that cannot be described analytically. Assessment feedback refers to the effects of including an actual assessment model within the framework; management feedback refers to the effect of management on the stocks and vice-versa.	WGMG2004
Harvest advice model	Part of the management procedure that compares the assessment results against a pre-determined set of benchmarks in order to formulate advice. Typically, a harvest control rule will be used.	WGMG2004
Harvest control rule	An algorithm for pre-agreed management actions as a function of variables related to the status of the stock. For example, a control rule can specify how F or yield should vary as a function of spawning biomass. Control rules are also known as "decision rules" or "harvest control laws" in some of the scientific literature.	WGMG2004
Implementation error model	Model that represents how implementation of decisions will differ from intended ones	WGMG2004
Management procedure	A simplified representation of the set of human actions that attempt to understand and control the fish and fishery systems. The procedure can be comprised of: observation, assessment, harvest advice, harvest decision, and implementation of those decisions.	WGMG2004
Observation model	Part of the management procedure that represents the way in which the operating model is sampled for fishery-dependent and fishery independent data.	WGMG2004
Operating Model	A virtual world that is a simplified representation of reality. It's main components are fish and fisheries.	WGMG2004
Performance statistics	Summary indicators for the various components of the framework. They are used to facilitate the analysis of the simulation results, or as benchmarks to evaluate performance.	WGMG2004

Conditioning	The process of selecting specifications/parameter values for case-specific trials to ensure that they are not inconsistent with already existing data.	WGMG2004
evaluation trial	Trials used for formal comparisons of candidate management procedures.	WGMG2004
initial conditions	The set of conditions (assumptions and events) that result in the historical data that are needed to start the simulations.	WGMG2004

limit reference point	Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low.	WGMG2004
reference point	Values of parameters (e.g.,, B_{msy}, F_{loss}, F_{PA}) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability or targets for management. Reference points are an essential element for parameterizing harvest control rules.	WGMG2004
robustness trials	Trials to examine management procedure performance for a full range of plausible scenarios.	WGMG2004
target reference point	Benchmarks used to guide management objectives for achieving a desirable outcome. Target reference points should not be exceeded on average.	WGMG2004

Annex B: Working document WD1 – The TAC Machine

The TAC Machine

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NFH, Tromsø 27.04.2004

Introduction

Within European fisheries, single stocks Total Allowable Catches (TACs) have been a main management instrument since the 1970s. Here, we want to study the historical background and the institutional implications of the TAC getting such a fundamental role in fisheries management. The background for this is the curious combination of resilience and failure of the TAC. The performance of fisheries resource management in Europe is poor, and this is often blamed on the TAC. However, the attempts at substituting the TAC with other regulatory mechanisms have failed, and the TAC remains in place. The TAC, in other words, while a technical failure, is at the same time a great institutional success. Why is this?

"The TAC machine" forms a key concept in our attempt to answer this question. Our hypothesis is that the whole machinery of fisheries resource management has become tailored to the TAC instrument. First, the key management decisions come in the form of a set of (legally defined) single-stock TACs, which forms the main instrument for controlling fishing mortality. Second, scientific advice is produced, within ICES, by way of VPA assessment methodology, in order to facilitate management decisions by way of TACs. This scientific advice is again based on data collection and modelling procedures defined with VPA/TAC decision making in mind. Third, the allocation of fishing opportunities among fleets is based on TACs. Fourth, surveillance and control efforts are focused on the enforcement of the TAC. If these propositions hold true, it is appropriate to talk about a TAC machine. The TAC instrument forms an integrated part of the whole system of resource management, including data collection, stock assessment, management decision making, allocation mechanisms, regulation procedures, and enforcement.

In this note, we want to explore the way the management machinery can be seen as tailored around the TAC instrument. While we want to start with a focus on technical requirements and instrumental linkages across sub-systems, we also want to explore this question from an institutional and cognitive perspective. To what extent is the TAC instrument tied into basic cognitive, moral and political precepts? In other words, is it appropriate to see the TAC machine not only as a technical instrument, but also an institution in its own right?

The TAC machine, as it applies within Europe in general and for North Sea Cod in particular, can be sketched as in Figure 1.

ICES, through the assessment working groups and reviewed by ACFM, is the supplier of scientific management advice. The fish is modelled as individual stocks by way of VPA assessment technology. The advice is given to the Council – reviewed by STECF and elaborated by the Commission – which adopts (after consultations with third countries where appropriate) the TACs for each stock. By the principle of relative stability, these TACs are allocated to the member countries. The allocation is automatic and non-negotiable for individual TACs. While there are a number of surveillance and enforcement mechanisms, the basic principle is for the member states to decide the allocation of quotas within their respective fisheries. There is, however, a duty for the Member states to ensure that the quotas are not over fished, and provide landing data in machine readable form to the Commission.

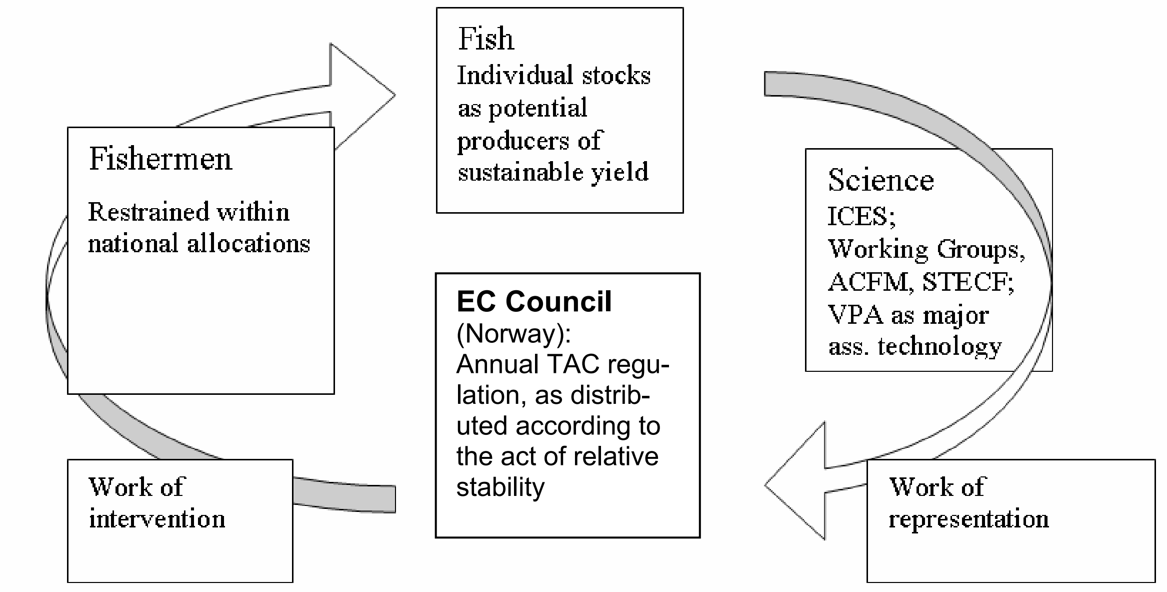

Figure 1. The EU TAC machine.

This is the TAC machine. It produces TACs on an annual basis, and (attempts) to make them binding on the fishermen. It also produces relative stability. In order to produce relative stability it must continue to produce TACs. At least, there is no other entity (e.g., fishing effort) that at the moment can serve as carrier of relative stability. The scientific advice is tailored to the TAC system. Advice is produced for single stocks, and given as TAC recommendations. The VPA assessment methods are the assessment technologies that allow for catch forecast, which are preconditions for analytical single stock TAC advice. The data is collected and formatted with the VPA and the TAC advice in view. Control and enforcement mechanisms are set up with the TAC in mind.

In the following, we shall discuss the origin of the TAC machine in more detail. First, we give an historical background, featuring the development of the VPA model and the establishment of the TAC as the primary management instrument. This happened in the period from 1965 to 1976. At the end of this period TACs grounded in VPAs had been defined for all the major fish stocks in the North Atlantic.

At one level, the story about the TAC-VPA model can be told as one of co-occurrence – the VPA happened to be at the international scene at the same time there was a demand for a model that could give independent analytical content to TACs. From this perspective, the linkage between the TAC and the VPA is coincidental; another assessment model could have served as well. The focus then is directed at what happened once this historical coincidence had occurred. In particular, we would here be interested in institutionalization processes, that is, processes by which the initial (light) commitment to the TAC-VPA model gradually became embedded in organizational structures, written into law, tied to data-collection procedures and built into computer models, guarded by vested interests, etc. This would be important in explaining the staying power of the TAC-VPA model.

In addition to the co-occurrence hypothesis, we also want to explore a riskier hypothesis, namely that the TAC and the VPA constituted each other reciprocally. The idea here is that the TAC regime was made possible by the VPA, at the same time as the VPA method could not have triumphed without the TAC regime. Compared to the co-occurrence hypothesis, the co-constitution hypothesis thus goes further in the degree to which the TAC and the VPA are linked to each other. Instead of a historical coincidence that easily could have been different, this hypothesis proposes that the TAC and the VPA reciprocally conditioned and promoted each other.

Consistent with the co-constitution hypothesis we shall argue that an important side to the TAC-VPA construct is that it allowed for the establishment of a tidy boundary between science and management. The TAC belonged in the province of management; the VPA belonged to the province of science. In contrast to the competing models (e.g., effort management), the TAC-VPA prescribed, and made practical, a conventional model for division of labour and interaction between science and politics.

In the second section below, we go on to show how the TAC-VPA model since 1977 has been embedded within wider institutional structures. (The argument here is does not depend on the co-construction hypothesis above. It follows as easily from the co-occurrence hypothesis.) We will show that, at the European level, the TAC-VPA construct formed the basic building stone in the adoption of the Common Fisheries Policy (CFP) in 1983. Here, the basic quota allocation compromise was based on the TAC-VPA construct, and tied it to the notion of relative stability. The institutionalization of the TAC machine at the centre of the CFP has important practical consequences, the most important of which is the degree to which, and the way, the CFP, fisheries management and scientific advice can be reformed. Since the TAC-VPA model is not a technical instrument, which can be discarded the moment it no longer serves the purpose, but an institution, the foundation of the CFP, the task of replacing it becomes requires considerable skills and political capital.[4] While the final purpose of this note is to allow for a discussion of such issues, we cannot do so here. Most of the work here goes into exploring the origin of the TAC machine. But we shall suggest, in the concluding sections, some of the ramifications for contemporary debates.

The invention of the TAC-VPA: 1965 – 1976

"Since 1974, the TAC has been the magic word in fish stock management in the Northeast Atlantic." (ICES 1985: 78) Why did the TAC become such an important management instrument? One way to answer this is to examine the historical process by which the TAC system developed. We shall here show how the TAC system, grounded in the VPA assessment methodology[5], was established and institutionalized in the 1965–76 period.

There is the breakthrough of the VPA in 1965.[6] Or rather, it is generally claimed that there was a VPA breakthrough in the ICES Working Group on Arctic Fisheries in 1965 (Skagen and Hauge 2002).[7] The crucial shift is that

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[4] At the global level, we want to argue that there are important connections between the TAC-VPA construct and the new oceans regime. As a minimum, there can be no doubt that the new oceans regime represented a legal, cognitive and institutional framework in which the TAC-VPA alliance fitted. We also think that the TAC-VPA construct formed the paradigmatic exemplar of fisheries resource management that the new oceans regime was constructed to facilitate. But we have not had time to explore this theme here.

[5] For an introduction to VPA method see for example (Hilborn and Walters 1992). The initial principle of the method is to sum up the contributions (in number) that a certain year class makes to the catches of a fishery during the sequence of years for which individuals in that year class are present in the fishery. (Fry 1949: 32) proposed that "…this complete contribution of a year class to the fishery shall be termed the *virtual population*". Later VPA models divided the sources mortality on the age class between natural mortality and fishery mortality, and equations were developed such that the estimates of the cohort sizes could be derived from (mainly) the catch data and the estimates of natural mortality. Though the name "virtual" was retained, the models thus aims to estimate the absolute cohort sizes through time that would account for the catches given the estimates of natural mortality.

between the 1959 assessment, relying on the methodology developed by Beverton and Holt,[8] and Gulland's VPA methodology in 1965.[9] Skagen and Hauge (2002) argue, in an attempt to explain the success of the VPA, that it was more precise than the previous assessment and in particular that it was able to solve a particular year-class problem,[10] and also that the data required and the analytical framework was in place.[11]

The VPA is important in this context because it ties in with the TAC system. Rozwadowski (2002: 188), for instance, gives a hand-in-glove argument, saying that "The link between VPA and catch quotas was intimate because the TAC 'is at the end of the VPA calculation." (p 190)[12] The same link is made by the ICES Secretariat's overview of ICES advice procedures in 1985:

Since 1974, catch regulations have to a greater and greater extent been introduced and, at the time ACFM was formed, the ICES product was, for almost every fish stock assessed, a single recommended TAC value for every year. The basis of the recommendation was purely biological. (ICES 1985: 73)[13]

It seems to be fairly safe to conclude here that, once the TACs were in place, there was a demand for an "ICES product" in the form of annual TAC advice. Let us now go more detailed to work and trace the implementation of VPAs and TACs in the North Atlantic.[14]

What came first – the VPA or the TAC?

Interestingly, the sequence of events was generally opposite on each side of the Atlantic. At the ICNAF side, the TACs came first, then the VPAs. Within the NEAFC/ICES area, the VPAs preceded the TACs. The histories of the two sides of the Atlantic intertwine on several points, as will become clear below. Despite some inconveniences, we tell them separately, starting with ICNAF.

Around the mid sixties it became clear within ICNAF that mesh size regulations were not sufficient to regulate the fisheries. The effort was expanding rapidly and the CPUEs were declining. Further increases in effort would only bring about small long term increases in catches – or would possibly even result in declining catches. Accordingly ICNAF became a major arena for extensive discussions on whether effort regulation or TAC regulation would be most suitable (see Anthony and Garrod 1985 for details of these discussions). On the annual 1967 ICNAF meeting, the vote fell in out in favour of quotas because effort regulation was subjected to technical problems of calibration. According to Anthony

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[6] Megrey (1989) gives a useful overview of the different versions of age-structured stock assessment models, of which the VPA is one important family. See also Skagen and Hauge (2002).

[7] Skagen and Hauge (2002) say: "The VPA method gradually became dominant after 1965 in attempts to assess other ICES stocks." (p 529) That is no doubt correct. The formulation above ('generally claimed') is not intended to suggest that another year is appropriate for the invention of the VPA. However, it is often the case that it is only in the light of later developments (here: the VPAs usefulness within the TAC regime) that it is realized that a specific result represented a scientific breakthrough. Because of, among other things, the premium on first discovery within science, there is a tendency to over-emphasize the precedents of an idea and ignore, as is of much more importance for us, the way it is put to use. It is, in line with this, not apparent from reading the 1965 Working Group Report that the VPA method (given in an annex) was a breakthrough; its existence can hardly be traced in the Working Group report itself. It would be interesting to examine when observers started to claim that the 1965 VPA was a breakthrough. (We cannot undertake this here.) What we shall try, instead, is to trace exactly how the VPA was adopted used to generate management advice.

[8] "…these calculations the were based on several shaky assumptions: 1) recruitment to the exploitable part of the stock must be fairly constant for a period of years, 2) total fishing effort must remain steady, and 3) fishing mortality would be constant over all ages. Since the main fishery on Arctic cod was on the spawning area, the fishing mortality rate could not be the same for both the mature and the immature part of the exploited cod stock. The estimates were considered to be extremely shaky" (Skagen and Hauge, 2002: 528).

[9] "In 1965, NEAFC submitted a request to the ICES Liason Committee .. to have the Arctic Fisheries Working Group produce a report on the state of the Arctic fisheries (ICES, 1965). … With the weak points in the 1959 assessment in mind, a new method was presented (ICES, 1966). Gulland, who was working at Lowestoft with Beverton and Holt, had developed this method and described it in the annex of the report. … This method provided an opportunity to calculate fishing mortality rates for each age. .." (Skagen and Hauge, 2002: 528)

[10] "Thus, it seems that the choice of approach, to a large extent, was driven by the need to estimate the effect of the fishery as precisely as possible and separate it from other forces influencing the stock dynamics. The fact that the process was triggered by the disappearance of a presumably large year class may also have contributed to the choice and links this development to the previous discussion on the variations in year-class strength." (Skagen and Hauge, 2002: 528)

[11] "One may also argue that this kind of approach was taken because the conditions, in terms of the necessary data, were in place. Thus, there were catch data from fisheries statistics, there were age data, and there were effort data, at least from some fleet segments. Furthermore, the conceptual framework was largely in place through Beverton and Holt's work not many years before." (Skagen and Hauge, 2002: 528)

[12] The quote here is from an interview with Cushing. On page 191, Rozwadowski says: "Made practicable by VPA and swept into use by political exigencies, TAC quotas debuted in ICNAF in 1969."

[13] That the "purely biological" basis was the VPA is evident from further down: "Further, the introduction of catch quota regulations demanded that ways be found to make very accurate predictions of catches in the years to which the catch quotas were to apply. This is a much more difficult task than indicating the general stock situation (e.g., the position of the present F on the yield-per-recruit curve." (p 74)

[14] We have tried to compile and explore ICES and ICNAF material from the period 1965–1976. However, the Working Group materials and so forth from this period is not particularly easy to acquire or to get a good overview of. The following is not to be regarded as a complete analysis in any sense but rather to indicate where we currently are in our research.

and Garrod (1985: 30), ICNAF in turn instituted a Standing Committee on Regulatory Measures to advice on: "1) The procedure of fixing annual catch quotas, 2) the nature of quotas with respect to species and area, 3) problems of enforcement, 4) principles of distribution of quotas among countries, and 5) the administration of catch quotas within countries". In our terms, the STACREM thus was given the task of preparing the ground for the establishment of the ICNAFs TAC machine version.[15]

Whereas ICNAF did not have the authority to recommend measures for effort regulations or to recommend catch quotas for individual countries, it was within its merits to propose a global TAC. There were, nevertheless, also the possibility of technical regulations such as closed areas and seasons, landing size limits and mesh size limits. At the 1968 meeting, however, USSR declared that it would only consider catch quotas, and ICNAF went on with developing proposals for catch regulations. The first TAC within ICNAF was set for Haddock in 1970 in the ICNAF Sub area 5 (Georges Bank). The following year a TAC for yellowtail flounder in the same area was set, followed by a TAC on herring in 1972 (Anthony and Garrod, 1985: 31).

Were the VPAs involved in these early TACs? No – at least it does not seem to be the case judging from the materials we have at hand.[16] The first VPA assessment in the ICNAF context known to us was performed on the West Greenland cod stock (ICNAF Subarea 1) in 1970. This assessment was performed by A. Schumacher who had been present at the meetings in the Arctic Fisheries Working Group when the VPA was introduced there and at its subsequent meetings (Schumacher 1971). The year after, Pinhorn (working at St. John's, Newfoundland) undertook a VPA on the on the ICNAF Division 2J cod. Pinhorn (1971) introduced his paper as follows:

Because of increased concern for the state of the cod stocks in Subarea 2 and 3 and as a result of increased fishing intensity in recent years, it was recommended at the 1970 ICNAF Annual Meeting that detailed assessments were necessary for these stocks of the type performed by the West Greenland Working Group and presented by Schumacher (1970a, b).

It thus seems that Schumacher played a role in bringing the VPA from the Arctic Fisheries Working Group to ICNAF. The following year Pinhorn performed a VPA on the 3Ps cod, the cod stock of the St. Pierre Bank on the Newfoundland South Coast. Importantly, this assessment was presented and reviewed at a joint ICES/ICNAF meeting, which will be discussed here since it may have played a key role with respect to spreading the use of the VPA technology. Its terms of reference were:

a) the Joint ICES/ICNAF Working Group on cod stocks in the North Atlantic meet in Copenhagen for one week in March 1972 to summarise existing assessments concerning cod stocks in the North-East Artic, Icelandic and East Greenland Waters, as well as the West Greenland, Labrador and Newfoundland cod stocks, and to examine in general terms the effects of possible regulatory measures, with particular emphasis on the interaction between fisheries on different stocks;

b) Mr D J Garrod will be chairman of the Working Group.

Garrod had been present in the 1965 meeting of the Artic Fisheries Working Group. In fact, all the members of that Working Group, except its two USSR members, were present at this ICES/ICNAF meeting. John Pope, who already at this stage had published important papers on VPA theory (Pope 1972) acted as a computer assistant at the meeting. Whether it was a deliberate aim or not this meeting thus was a perfect occasion to promote and perhaps standardise the use of VPAs. Out of the 8 major cod stock complexes assessed/reviewed at the meeting, only one assessment was not a VPA.

Following this meeting, things started to develop faster. For 1973, ICNAF adopted TACs for 24 stocks in North West Atlantic. In 1974–1977, TACs were set for all major stocks (54–58) supporting international fisheries (Anthony and Garrod, 1985: 31). The TACs were set for all important cod stock areas in the ICNAF in one go since otherwise the non-regulated species would be in trouble due to the mobility of the fleets. From the same kind of reasoning, the TACs for the ICNAF stocks established a pressure for introducing regulations on the fishery on the stocks on the ICES side of the Atlantic.

As mentioned, the VPA method had its breakthrough in the ICES/NEAFC area, in the Artic Fisheries Working Group in 1965 at which John Gulland presented a VPA method to estimate mortality rates. This breakthrough was primarily a methodological one; the results of Gulland's assessment were not included in the 1965 report, but were put in an annex (ICES 1965). Gullands method was, however, used for the following reassessment performed at a meeting in December 1968. Moreover, it was only due to lack of time at the 1968 meeting that a VPA was not attempted for another major commercially important stock, the NEA haddock (ICES 1968a). The haddock stock was instead assessed by VPA method on a follow up meeting in January 1969.

In January 1970, and on the subsequent meetings of the Arctic Fisheries Working Group, both the cod and the haddock stock were reassessed by VPA. The terms of reference for the Arctic Fisheries Working Group in 1970 were as follows:

[15] The STACREM is therefore of interest to us but we have not yet had the possibility to go further into the developments within this committee.
[16] We need further information in order to be able to conclude anything here.

At its meeting in January 1969 the Group reviewed previous assessments of the north-east Arctic fisheries and in order to assist NEACF in their consideration of the regulation of fishing mortality in this area, at a further meeting in February 1969 it prepared estimates of the catch that might be taken in the period 1969–1971. After consideration of the Report by NEACF and ICES the Group was asked by ICES (C.Res.1969/2:4) to meet again to update the earlier estimates of future catches in the light of the most recent developments in the fishery. (ICES 1970a:100)

When the Arctic Fisheries Working Group met in February 1971 (C.M., 1971/F: 3) and in February 1972 (C.M., 1972/F: 3), its task was again to update the assessment on the cod and haddock stocks and to provide estimates of the catches for the assessment year and the subsequent year. At this point, the assessment had become annual event, and the catch forecast institution had been established.

Until now there had been no implementation of TACs. This did not happen until 1975, with a failed start the previous year. During 1974 Norway, U.K. and USSR, the three main nations fishing in the North East Artic, agreed to limit their catches of the Barents Sea cod to 500.000t, with an allowance of 50.000t for other countries.[17] When it became evident that the other countries, due to favourable fishing conditions were surpassing the limit of 50.000t, the agreement was cancelled. For 1975 a TAC on 810.000t was agreed (C.M. 1975/F:6: 227), the figure being almost identical to the status quo catch prediction for 1975 from the 1974 assessment of 813.000t[18] (C.M. 1974/F:7: 1721). From now on, the management procedure settled into the well-known pattern of short-term forecasts and TAC advice. The first listed term of reference for the Arctic Fisheries Working Group meeting in March 1975 was to "assess TACs for 1976 for cod and haddock". On the assumption that the 1975 landings would be equal to the TAC, the Working Group then made its first explicit TAC recommendation. The Working Group also recommended a TAC for haddock, for which no TACs had been agreed previously.[19]

In summary, then, the TAC-VPA model was in place at both sides of the Atlantic by 1975. As noted, there is a difference in the development of the model: In the ICNAF area, the TAC preceded the VPA; in the NEAFC area, the VPA preceded the TAC. Whatever the explanation for this difference, the end result was the same: Within ICNAF, the VPA was used as a basis for setting TACs from 1973. Within NEAFC, the first TACs were adopted on the basis of VPAs from 1975.[20]

The Co-occurrence hypothesis

As the preceding story shows, the TAC and the VPA were developed and became linked to each other during the 10-year period before the new oceans regime became a fact from 1977. Let us first look at a few features of this system – compatible with the co-occurrence hypothesis – that have bearing for the institutionalization of the TAC-VPA model. One way to approach this is to look for QWERTY-like mechanisms, that is, path-dependent development processes that make it difficult to change the TAC-VPA model once you start down that road.[21]

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[17] According to the report of the 1975 meeting, the "aim was to limit fishing on the recruiting year classes allowing to permit a recovery of the spawning stock which was expected to reach an all time low in 1975" (C.M. 1975/F:6: 226). The 1974 catch predicted in 1973 to result from status quo F (F in 1972) was, however, 650.000t. It is possible, therefore that we (yet) do not know the exact scientific background for the tripartite TAC decision, unless it was along the line of the following quote from the 1973 report: "A small sacrifice at the present time, by reducing the amount of fishing on these recruiting year classes at the youngest ages, could make a significant contribution to the future size of the spawning stock and would also be expected to increase the overall yield from these year classes" (C.M. 1973/F:3: 1611).

[18] Since the catches later in 1974 were expected to reach 800.000t, which was much more than used as basis for the first catch prediction from March 1974, the Working Group in October 1974 held an ad hoc meeting to revise the basis deciding the TAC for 1975 (C.M.1974/F:48). On the basis of this later prediction, the implied F from a TAC of 810.000t would have been very high. We do not (yet) know if this later prediction formed the basis of the TAC decision.

[19] We add here a brief version of the parallel development for some of the important demersal fish stocks in the North Sea. For the North Sea cod, the first VPA was carried out in 1972 (Holden and Flatman 1972). In March 1974 there was a meeting of the North Sea Roundfish Working Group, for which the principal objective were "to reassess the state of the cod, haddock and whiting stocks in the North Sea, and to recommend total allowable catches for these species" (ICES 1974). The group used VPA assessment for all three species. The TAC advice for cod given by the Working Group, which was restated by the Liaison Committee, was a) 230.000t, preventing the F to increase, or b) 130.000t, corresponding to F_{MSY}. The TAC set by NEAFC for the cod in 1975, which was the first of its kind was 236.000t, slightly higher than the Liaison's recommendation (ICES 1976).

[20] It has not yet been possible for us to track the subsequent rapid expansion in the number of stocks that became assessed by VPA and subjected to TACs within the ICES areas until the introduction of the New Oceans Regime and the establishment of ACFM. Whereas we, therefore, now we have to rely on the statement by the ICES secretariat given previously (page 6), we intend to map this development and also follow it throughout the time of the establishment of the strengthened CFP in1983. Let it suffice here to note that when ICES changed its form of advice in 1981, the basic principle for the advice became to provide catch options within safe biological limits (ICES 1981). While this change in the form of advice had some interesting consequences with respect to the boundary and division of labour between science and management, it also indicates that the analytical (i.e., VPA) assessment, from which catch predictions could be generated, was at this time already perceived as default.

[21] QWERTY is what you get if you start with the Q on your keyboard and read the word formed by the next five keys towards the right. The point is why this standard for key-board has been dominant since the invention of the typewriter, even though it is a very

Now, an interesting feature of the TAC system is that once it is adopted for one stock, it must also be adopted for the other stocks, since the effort otherwise will be diverted to these. The TAC thus has a cascade effect.[22] We see this in practice on both sides of the Atlantic. Once the first TACs were adopted, all major stocks were covered in a few years time. In addition, the TACs, at least when they are grounded in VPAs, are set annually. This is because the VPA is an age-structured assessment model, implying that you for each year get one additional set of data-points on which to base your assessment. The assessment becomes, at least in some respects, a routine activity; it takes form as an updating of last year's assessment – and a review and quality control of last years' predictions. With the TAC-VPA regime, stock assessment, advice production and TAC setting turn into an annual routine. Whereas the older yield-pre-recruit model, connected to mesh size regulations, worked under a long time horizon (e.g., the 6 year span from the Arctic cod assessment in 1959 to the one in 1965) the TAC-VPA regime propelled the whole business of scientific advice/fisheries management into an annual cycle.

There are several interesting institutional points to note in this context. One is connected to the logic driving the cascade effect of the TAC-VPA system. Once you go for TAC-VPA for one stock, you need not only follow up on it next year, but do it for neighbouring stocks too. The decision to go for a TAC-VPA for one stock one year is not independent on what you have decided pervious years and for other stocks. There are positive feedback mechanisms linking such decisions, so that a first decision drastically improves the incentives to do it annually and globally. This is an interesting institutional property,[23] among other things because it will tend to reduce the number of institutional alternatives. Instead of a stock-by-stock adaptation, which presumably would be more sensitive to the condition of each fishery, you get, by this mechanism, one dominant model. This is perhaps more tied to the short time horizon of the organizational cascade than an inherent logic of the model. Since the TAC-VPA was the best available social technology for fishery resource management at the time, this was the technology that was deployed.[24]

A second interesting institutional property of the TAC-VPA model is the degree to witch it allowed and required routinization. This is also directly linked to the year-class basis and total coverage of the TAC-VPA model. In the ICNAF area, the first TAC were adopted in 1969 (for 1970); by 1977 the number had reached 70 (Rozwadowski, 2002: 191). The development in the NEAFC/ICES area followed the same pattern.[25] As we can understand, the demand for scientific advice increased dramatically during these few years. The simple point we want to make in this connection has to do with the development of organizational routines and standards in order to accommodate this demand. We have already mentioned the most important point here, namely that the VPA allowed the production of advice in standard format for a range of fish stocks. When the ICES secretariat talks about "a single recommended TAC value for every year [for almost every fish stock assessed]" as the "the ICES product" (ICES, 1985: 72), this may sound strange for a scientific organization, but it is nevertheless to the point. The VPA methodology lent itself to routinization and annual updating, and hence to the construction of a standardized 'product.'[26] In line with this point, it is interesting to note the different mechanisms employed in order to standardize and control the quality of the ICES product. One example here would be the establishment of the ACFM institution from 1977, as a reviewer of the assessments and the formal advisor to its clients. Another example is the construction of "Typical working group procedures" (ICES, 1985). It is also reflected in the standard format of Working Group Reports; formalization of such standards as in the Quality-Control Handbook, standard terminology, etc. The establishment of the VPA as the standard assessment technology also allows for systematic development and training, as in the Lowestoft courses in VPA, first arranged in 1976. It also allows for the gradual routinization of the tuning of the VPA, as in the XSA program, and in the Methods Working Group. All in all, there is a tremendous amount of standardization within ICES around the requirements of the VPA/TAC instrument.[27] Recalling

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inefficient way to organize the letters. The explanation for the resilience of QWERTY is its connection to the touch method, and the expertise invested in typing skills as held by secretaries etc.

[22] "Implementation of some TACs demanded their application to other stocks in a region. Scientists recognized early that quotas would redirect efforts to underexploited species by forcing vessels to look elsewhere after reaching one catch limit. In 1971, acknowledging this, ICES and ICNAF jointly sponsored a working group to consider all North Atlantic cod stocks together." (Rozwadowski, 2002:191) The reference in Rozwadowski to the ICES work is missing. This should be traced.

[23] Holm (1995) has argued that this was an important side to the success of one institutional form, the mandated sales organization (MSO) in Norwegian fisheries, forming the basis for the predominance of the co-management system in Norwegian fisheries in the 1938–1990 period. A more general treatment of positive and negative feedback is Boudon (1981).

[24] The classic argument on how organizations tend to be 'museums' of the social technology available at the time of their funding is Stinchcombe (1986).

[25] This remains to be documented.

[26] An important point here is the development of the assessment working groups in order to perform the VPA assessment. It probably would be interesting to look in more detail on how new working groups were formed, and established Working Groups reorganized, in order to accommodate the new demand for TACs. An interesting question here would be the logic for grouping different stocks within the same working groups.

[27] "Where a working group in the early 1970s would have had a rather good measure of fishing intensity from long effort series, or a measure of abundance from long catch-per-unit-effort series, both describing fisheries which had been stable for many years, the working groups of the late 1970s found many of these important data series disrupted by the large-scale changes in fleet composition. Further, the introduction of catch quota regulations demanded that ways be found to make very accurate predictions of catches in the years to which the catch quotas were to apply. This is a much more difficult task than indicating the general stock situation (e.g., the position of the present F on the yield-per-recruit curve.)(ICES 1985). For example, Artic fisheries Working Group noted in its1971 report noted that age compositions of the 1970 haddock catches had been made available to the Working Group which should improve the precision of the catch estimates. Accordingly the Working Group recommended "that all countries should make special

the QWERTY example, we need to be sensitive to the developments of such standards and routines, and ask to what extent they create barriers for the introduction of alternative assessment methodologies. We cannot answer this in general here. But it will come up as an important theme when we later discuss the series of more or less failed reform attempts in fisheries resource management.

A third interesting property of the TAC-VPA model, which logically is a sub-point to the routinization argument above, has to do with data collection. Skagen and Hauge (2002) argue that an important reason for the VPA breakthrough from 1965 onwards was that the necessary data were present.[28] This may be true in a restricted sense. Such data were present for major stocks, like cod, and could be used for method development and demonstration purposes.[29] But it is not correct in the sense that the data situation allowed, without major investments, for annual VPA assessment for the majority of commercially interesting stocks. On the face of it, it seems much more likely that the reverse is true, that the breakthrough of the TAC-VPA regime during the 1970s – involving annual VPA assessments for a substantial number of stocks – required drastic strengthening of data collection and refinement procedures.

The literature is in general not particularly interested in this question, and we probably need to go into primary sources here. Let the following be a first indication of what we are looking for, and what we expect to find. First, the heavy data requirements of the TAC-VPA regime were mentioned as one of its disadvantages as against effort regulations by the ICNAF group of experts in 1973.[30] Second, the ICES secretariat's 1985 overview, it is pointed out that the data requirements within a TAC-VPA regime are very different from the old yield-per-recruit/mesh size regime.[31] One of these differences pertains to the annual cycle of the TAC regime. In addition comes the different emphasis on data with the VPA regime. While the focus earlier was on effort and catch data, the VPA diverted attention to catch-at-age data. There is an interesting observation here (ICES 1985), quoting (ICES 1972) that the introduction of TACs disrupted old effort data series.[32]

Thirdly, there is, we propose, a link between the establishment of the VPA-TAC regime and the increasing emphasis on precise stock identification. The old management regime, consisting of mesh size regulations on the one hand and Beverton/Holt's yield per recruit assessments by use of effort and CPUE data on the other, was a relatively information extensive system. In contrast to this the TACs based on analytical forecasts building on VPAs had much higher data requirements. An important part of this was the struggle to identify stocks appropriately. Although work to separate stocks had been carried out throughout a much longer period, it seems to have intensified rapidly from the mid 1960s and onwards.[33]

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efforts to provide data on the composition of landings for the year before the first for which catch estimates are required;…" (ICES 1971). These points were stressed by the Working Group at its 1973 meeting where Working Group complained that the available data was insufficient and unreliable; certain catch figures and data on age compositions were missing. Accordingly the Working Group, in a preamble to the report, stated: "For the meetings of this Working Group it is especially important to have available precise information concerning the year classes entering the fishery as a basis for the assessments for recommendations for future management of the fishery. On the basis of recent experience the Working Group is obliged to make the following strong recommendation: in future, this Working Group should meet only when sufficient data are available."(ICES 1973).

[28] "One may also argue that this kind of approach was taken because the conditions, in terms of the necessary data, were in place. Thus, there were catch data from fisheries statistics, there were age data, and there were effort data, at least from some fleet segments." (Skagen and Hauge 2002). S and H also points out the importance of Hjort's preoccupation with year classes, and the practice of age measurements.

[29] The existence of age-structured data, a legacy of Johan Hjort, was in particular important here. See (Skagen and Hauge 2002).

[30] The formulation of the disadvantages of the TAC system pertaining to data is this: "1. Difficult to do (a) Do not know the theory (b) Cannot get data." (ICNAF 1973b: A4). Se below under "The Co-constitution hypothesis" for a more detailed presentation of the pro-contra discussion of TACs against effort regulations within ICNAF.

[31] "Where a working group in the early 1970s 1985 would have had a rather good measure of fishing intensity from long effort series, or a measure of abundance from long catch-per-unit-effort series, both describing fisheries which had been stable for many years, the working groups of the late 1970s found many of these important data series disrupted by the large-scale changes in fleet composition. Further, the introduction of catch quota regulations demanded that ways be found to make very accurate predictions of catches in the years to which the catch quotas were to apply. This is a much more difficult task than indicating the general stock situation (e.g., the position of the present F on the yield-per-recruit curve.) (ICES, 1985: 75)

[32] We should also examine the relationship between the VPA regime and the trawl surveys. Were the ties, the scientific trawl surveys established to accommodate the VPA? It would be interesting to trace these changes within the ICES system and within the national labs preparing data sets.

[33] When the ICES North Sea Roundfish Working group was established in 1969, its second term of reference was to: "… study the interrelationship between cod in the different parts of the North Sea, with a view to reconsidering, on a regional basis, the assessments made, by the North Sea Working Group on the North Sea cod stock as whole" (ICES 1969). The Working Group met in 1970 where it reviewed all known information related to the structure of the cod stock in an Interim Report (ICES 1970b). Another example of the importance of stock structure identification is the early assessments of the Icelandic cod stock. When the North Western Working Group met to assess this cod stock, it found that there was more mature fish in the catches, which was inconsistent with the high mortality estimates from previous assessments – unless some of this mature cod had migrated to the Icelandic fishing grounds from other areas. It was known that mature cod from Greenland, at least of some year classes, had migrated to Iceland (ICES 1968c). The extent and the effects on the stock structures were, however, not clear. The Demersal Fish Committee accepted the 1968 report, but "noted its importance to proposals at present before NEACF", and that NEAFC had requested additional research on the Icelandic cod. Accordingly a research program was developed during the meeting of the Demersal Fish Committee (ICES 1968b). The program scheduled research, which included trawl sampling, echo surveys, biochemical and otolith sampling and encouraged tagging experiments to be conducted whenever possible (ICES 1968b).

In summary, the introduction of the new management regime implied high demands not only on the quantity data (on the whole array of stocks under TAC regulations), and their timing (as input in annual regulations), but also on their precision (on precisely identified stocks). The data requirements of the TAC-VPA model, which gradually becomes built into measurement systems, trawl survey procedures, and data collation mechanisms. The TAC-VPA model hence ties into an extensive specialized metrological system, built up and refined over many years and at considerable cost. When going into another management/assessment system, say effort management, this requires the construction of a different metrological system.

The co-constitution hypothesis

In the previous section, we focused on mechanisms by which the TAC-VPA model becomes embedded within organizational structures and tied to specialized measurement technologies. The argument so far is consistent with the viewpoint that the TAC and the VPA – at least from the start – were reasonably independent entities, connected to each other primarily by historical coincidence. Had another management technology than the TAC been available during the 1970s, the VPA could perhaps have been made to serve it. Had another assessment technology been available at the time, it could have done the job of providing a biological grounding for the TACs. The world of fisheries management would then have looked different. But the same type of institutionalization mechanism would have taken place, gradually tying the management mechanism and the assessment technology to each other by way of organizational routines and structures, investment in measurement infrastructure, etc.

In this section, we want to ask to what extent the TAC and the VPA can be seen as two sides of the same coin. Can the TAC and VPA be seen as part of the same package? As a starting point, we can note that there seems to be a nice fit between the two. Rozwadowski (2002) says that "TAC is at the end of the VPA calculation" (p 190) and that the VPA fits the TAC as "hand in glove" (p 188). Furthermore, we have noted the co-evolution of the VPA and the TAC. This is not a clinching argument in itself, of course, since it is the nature of this co-evolution we are probing here – were the TAC and the VPA independent from the start, or did they enter the world as Siamese twins? It is suggestive here that the development of the TAC and the VPA takes a slightly different track at the opposite sides of the Atlantic. In ICNAF, the TAC comes first, creating a demand for VPAs on which to ground them. In the NEAFC/ICES, the VPA comes first, generating advice formulated as if TACs were the inevitable management measure.

But this is hardly conclusive evidence. We can note, for instance, that while the VPA can be made to produce advice in the form of TACs, it can as easily produce advice in the form of (target) fishing mortality.[34] On this basis, it seems that there is no compelling technical linkage between the VPA and the TAC. Fortunately, for the co-constitution hypothesis, there is more to be said about this issue. We can tap into the discussion within ICNAF on the merits of TAC in contrast to its main historical alternative, namely effort quotas. The TAC was first deployed, as we now know, in the ICNAF area. But the TAC was not the only management option considered. During the late 1960s and early 1970s, there was a battle here, with the Soviet Union on one side and the US (with some support from Canada), over what kind of management measures should be used – TACs or effort limitations. The TACs won out when the Soviet Union in 1968 declared that they would only accept TACs (Anthony and Murawski 1985: 43). We do not know exactly why USSR went for the TACs, but it seems likely that it was a mix of considerations over distribution issues and a concern for the technical and political practicability of standardizing effort units across fleets/countries.[35] Despite the Soviet decision, however, effort control was not completely dead within ICNAF, and the US brought it up again in 1973 (Anthony and Garrod 1985: 31). As part of this initiative, an ICNAF expert group was set down by STACREM in order to review the problems involved in measuring fishing effort and how to device effort quotas (ICNAF 1973b, 1973a). This work took the form of a pro and contra comparison of TACs and effort regulations. While the following remarks are only preliminary, we believe that this discussion can give us some clues both with regard to the ties between TACs and VPAs, and to the preference for TACs over effort quotas.

Table 1. Excerpt of Table 1 from ICNAF (ICNAF 1973a). Table text is: "Advantages and disadvantages related to proposed management schemas." We have excluded Option II, which is "Total Catch Quotas (a) with some species quotas (b) with all species quotas. Option I is a system of single-stock TACs based on VPAs. Option III is a total effort quota system, probably based on a CPUE model.

[34] A note on the technical side of this. Also, perhaps, a note pointing out the increasing reliance on F advice with the advent of Precautionary reference points.
[35] We haven't examined the literature for work on these negotiations. This will be done later.

Option I Species (single or group) Catch Quotas → All		Option III Total Effort Limitation with some species quotas	
Advantages	Disadvantages	Advantages	Disadvantages
1. Most precise estimate of MSY in theory	1. Difficult to do (a) do not know the theory (b) cannot get data	1. Alleviates by-catch problem	1. Intercalibration of fishing units
2. Readily understood, hence more acceptable	2. Failure leads to over-fishing	2. Less precision in assessment required	2. Variability in catchability in time (species)
3. Flexibility to adjust quotas	3. Necessity to predict recruitment and rate of by-catch	3. Minimizes probability of over-fishing	3. New concept (no precedents)
4. National allocation – more readily acceptable	4. Does not prevent excess capitalization per se → difficulty in regulating catch at proper level	4. Need not be adjusted for variability in stock density and recruitment	4. Difficulty in establishing historical basis for national allocation (lack of data)
5. More options for fleet deployment	5. Difficult to set and control appropriate quotas because of by-catch		

At the time the work this table comes from was undertaken, ICNAF had already embarked on the first attempts at single-stock TAC regulations on selected stocks. This is important to note: The background for the renewed interest for Effort limitations was a claim that the TAC regime was a failure. Here is Anthony and Garrod's (Anthony and Garrod 1985) review of the situation:

> In 1973, however, it became obvious that single-species catch quotas were not reducing fishing activity. The regulation on selected species simply caused fishing to switch to unregulated species. The failure of the catch quota system to control mortality on all species led the USA to call another special meeting in STACREM in 1973 to consider a new effort proposal (ICNAF 1973h).

The major problem involved here, which comes clearly out in this quote, has to do with the already mentioned cascade effect of the TAC system. When you introduce a TAC on some stocks in a mixed-fisheries complex, you have to follow up on the other stocks - otherwise the excess capacity will switch to these. This was exactly the situation in which ICNAF found itself in 1973. The two major alternatives to solve this problem was either to go for single-stock TACs for all the species (Option I), or to complement the single stock TACs already in place with an effort limitation scheme (Option III). It is on this background the ICNAF expert consultations were initiated. Let us now briefly review the results, as summarized in Table 1.

Let us start with the reason the effort limitation scheme was rejected by ICNAF. Anthony and Garrod (Anthony and Garrod 1985) say that, after considering the two expert group reports (ICNAF 1973b, 1973a) ICNAF "concluded that the calibration problems associated with the fishing gear of so many countries were insolvable." The calibration problem had different dimensions. First, there is the problem of the relationship between the management measure (i.e., days on ground) and the effective fishing mortality (disadvantage 3 of Option III). Because of variability in catchability, the same fishing effort could produce different fishing mortality, between years, seasons, or fishing grounds. This is in part a feature of migration pattern, temperature and other ecological effects. But it is also one linked to strategic fleet adaptation, technical improvements and learning. Second, there is the problem of intercalibration of effort measurement units (Disadvantage 1), which brakes down to a technical problem of defining appropriate international standards and data collection routines, but also goes to the politically sensitive issues involved in such definitions having distributive consequences across fleets and nations. The third problem is that of finding an equitable first distribution of effort quotas (Disadvantage 4). While the definition of appropriate standards and data collection instruments over time could solve many of the above problems, there remained the acute problem of negotiating a first allocation. The historical data on which to base such a decision were of variable quality. This was all the more problematic since such first allocation usually forms the default position for the re-negotiation next time around. The risk involved here was substantial. With all these problems, the task of negotiation an effort regulation scheme that would be perceived as equitable was considered unmanageable. Perhaps these points are effectively summarized by the Disadvantage 3: "New concept (no precedents)": The effort limitation scheme, because it is new, is fairly open to political definition and strategic positioning.

Instead, ICNAF decided to proceed with the TAC solution, but complemented the overall quota with a second-tier quota (less than the sum of TACs for individual stocks) in order to solve the by-catch problem (to accommodate Disadvantage 5 of Option I). Now, as compared to the effort quota option, for which the calibration problem across countries were a major disadvantage, the major pro of the TAC system is easy to divide up between countries (Advantage 3). While there also may be difficult negotiations to be undertaken to reach an agreement here, the data basis for basing such a division is present (historical landing data, standardizable across countries). Furthermore, since the units involved (catch or landings) are reasonably stable over time, such negotiations would be a one-off event. Instead of continuous negotiation over the division of a nebulous entity, the TAC option offered a stable, objective and readily divisible unit. From a negotiation viewpoint, this no doubt was an important thing. Whereas the TAC system simplified the negotiations, the effort quota option generated a host of new, intractable problems.[36]

Now, the above points do only go to explain the advantages (within an international negotiation environment) of the TAC option as against the effort quota option. What is of greater interest to us in this context is the degree to which the TAC and the effort quota options were grounded in different assessment technologies. While this is not made explicit in the reports, we believe that there is such a connection, so that the TAC option comes with the VPA, while the catch quota option is based on a CPUE model.[37] The connection of the TAC system to the VPA model is apparent in its first pair of advantages/disadvantages: "1. Most precise estimate of MSY in theory" and "1. Difficult to do (a) do not know the theory (b) cannot get data." It seems reasonable to read these remarks as references to the most sophisticated and data-intensive assessment model available at the time, the VPA. Now, with regard to the effort quota option, it is quite clear, from the list of advantages given for it, that it was tied to a different assessment technology. The second advantage of this model is hence "Less precision in assessment required." Instead of annual, data intensive assessments for all stocks involved, the catch quota option would be based on long indexes (CPUE, yield-per-recruit) for mixed mixed-fishery complexes.

As this indicates, the linkages of the TAC and the effort quota to the VPA and the CPUE respectively, are historical facts. That does not mean that such linkages are technical necessities. At least, there is no compelling technical reason, as already mentioned, why the VPA cannot be used to generate effort regulations. But in the historical context, there were good pragmatic and institutional reasons for such a link. A major advantage of the effort quota/CPUE model was that it represented a robust and non-expensive alternative to the TAC/VPA model. Instead of massive investment in data collection and assessment work in order to make the TAC/VPA model practical, the catch quota/CPUE model offered a simple, robust, cheap – but unfortunately impracticable – alternative.

The last point here goes to the implication of the two models for distribution of tasks and relation between science and management. The effort quota/CPUE option was, at least in the international context where it originated, simple on science, but complex on management. In this model, while science could provide simple and effort targets, the main problem, the solution of which would remain with management, was getting a firm and equitable grasp on a continuously slippery effort measure. As we see in the ICNAF reports on catch limitations, STACREM asks the experts give them firm, objective, transparent, workable definitions and data handles on fishing effort, but the experts keep playing it back to them. Within this model, there are no natural and workable division of labour between science and management. At least, this was not the case in the early 1970s. In contrast, the TAC-VPA model came with an effective and conventional division of roles. The scientists would assess the stocks, and come up with advice in the form of recommended TACs. The role of management would be to authorize (as recommended or adjusted) this TAC, and divide it up. A nice, conventional model for science and politics, in which science provides objective facts, and politics distributes pies. While the TAC-VPA model was expensive and data intensive, it had extremely attractive institutional properties. Here is a contemporary view from science side, as reported by Rozwadowski (2002: 192–3):

> Lowestoft biologist Colin Bannister recalled accompanying Graham to an ICNAF meeting in 1971 with the North Sea Flatfish working Group report in his briefcase. "That was gold-plated information, if you like. It was totally agreed. … It was the recipe for management and it couldn't have been achieved in any other way at the time." By 1980, General Secretary Hans Tambs-Lyche explained: "By separating the scientific advisory function from the management function, one achieves that management is provided with internationally agreed scientific advice, which is generally acceptable to all parties."

So here is the argument about TAC and VPA as co-constitutive. An important feature for the TAC-VPA is that it allows for the establishment of a tidy division of labour between science and management. It constructed a boundary between fishery science and management, which prevented, to a large extent, politics to flow into science (which effort quotas could not do), while it allowed a restricted set of boundary objects (TAC recommendations) to cross from science to management without the loss of scientific authority. The TAC-VPA model, in this view, is thus constitutive of the ICES model of fishery science.

The CFP and the TAC Machine

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[36] Such problems of the effort quota system are of course more pronounced within a negotiation system with low degree of centralized control. With the new oceans regime, the capacity to implement catch quotas, at least for stocks within a single jurisdiction increases.

[37] We should add here that we are not completely proficient in the language of the reports here, and will need assistance from assessment biologist before we finalize this section.

In Europe, the adoption of the new CFP in 1983 also provided, on the European level, a legal/political framework for the TAC Machine. Here, we shall argue that he TAC Machine and the CFP constituted each other reciprocally. In addition, of course, the 1983 CFP came as a direct result of the new oceans regime. Here is the story about the CFP and the TAC Machine.

The first CFP originated in 1971, and was adopted the day before the membership negotiations with Denmark, Ireland, UK and Norway opened. The basic principle of the CFP was that fishery policy should be an EC issue, more specifically the principle that all member state water was EC common waters, and hence open to fishermen from all EC member states. Since the old members were poor in fish, while the new members were rich in fish, this was seen as an attempt at fish stealing. This story is relevant for at least two reasons. One is that it might explain the controversial nature of fisheries policy in Europe, imbued from the start in dogfight over shares in fish resources. Second is that the principle of a common CFP was established before the new oceans regime. The principle of a common CFP was already firmly in place, which meant that the management responsibility conferred to the coastal state with the new oceans regime fell on the European Community. Accepting this, the negotiation over the CFP focused on principles of sharing out the common fishery resources – defined as single stock TACs produced by way of VPA assessment technology – among the member state. These negotiations took 6 years, and ended with the 1983 compromise. These negotiations established what is referred to as "relative stability", a formula for producing national shares of each and every TAC. Here, we just want to stress the main point, namely that the principle of relative stability is the closest we get to an untouchable institutional principle within the EU. The reason here is simply that there is no willingness to open this up, because of the fear to be thrown back at the chaos that reigned in the 1977–1983 period. It is better to have relative stability, which allows non-perfect but routine policy production in the fisheries, than to have no fisheries policy at all. But this should of course be documented in some more detail. That should not be particularly difficult. Our proposition is that a main product of the EU management policy is relative stability, in the form of member state shares of TACs. In order to produce relative stability, TACs must be produced, and that is done on the basis of single stock VPAs. Hence, the institutionalization of relative stability puts the TAC-VPA machine firmly in place as a cornerstone of the CFP. This also have consequences for any attempt at reform. Because of the centrality of relative stability, any reform of the CFP must be compatible with this principle. Or rather, the extent to which a reform attempt touches the principle of relative stability, the mobilization required to have it adopted increases dramatically. In examining the long series of more or less failed reform attempts, the degree to which they are compatible with the principle of relative stability becomes a key issue.[38]

The reform attempts

The notion of the TAC machine is double edged. It comes with the observation that the TAC machine is a tremendous success, but that it doesn't work. It has some extremely powerful properties as an institution (tidy division of labour between science and the coastal state, inscribing social goals in nature, allowing routinization of scientific work, etc), but, at the same time, it makes it difficult to regulate the fisheries properly – in particular mixed fisheries. This means that right from the start, the very success of the TAC machine has been accompanied with failure and reform attempts. The first one is almost parallel with the breakthrough of the TAC, namely the attempt to make effort regulations work within ICNAF. And there are many other attempts after that. We propose there to go through these more or less failed reform attempts, and see if we can find out how and why they failed. Here's a provisional list:

- Effort quotas 1971–1973;
- ACFM attempt to move to effort regulations in the early 1990s
- Present attempt to go towards effort regulations
- Multispecies management
- Fisheries based advice
- Mixed fisheries advice
- Precautionary approach
- Structural policy
- Recovery plans
- Ecosystem based approach

[38] This is the short version. We need to fill this story out with a more detailed analysis of the marathon negotiations and its results (the major source is Holden 1994). And then we should qualify the analysis of the relationship between the TAC/VPA within the CFP. One issue here is the technicalities involved in dividing up TACs to national allocations. A second one is the degree to which TACs are grounded in VPAs (i.e., the distinction between analytical and precautionary TACs). A third issue is the discussion of the TAC Machine as a fiction: In practice, the coupling between all the major linkages in the TAC machine are loose. Given that, is it appropriate to talk about a TAC Machine?

While most of these attempts have failed, some have had minor impacts, or been implemented so as to be compatible with the TAC machine. This perspective will allow us to evaluate the current reform attempts, and guess at their probable success. But we should not necessarily insist that the TAC machine will remain in place forever. Perhaps the strains on the TAC machine are greater now than it has been before? Perhaps the stricter advice from ACFM will have effect? Perhaps the recovery plan mechanism will destroy the TAC machine? Perhaps ecosystem management will take over? These are the questions we should end up with. And they are of course at the heart of PKFM. The notion of the TAC machine is useful here because it is a (provisional) diagnose of the basic workings of the management system.

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