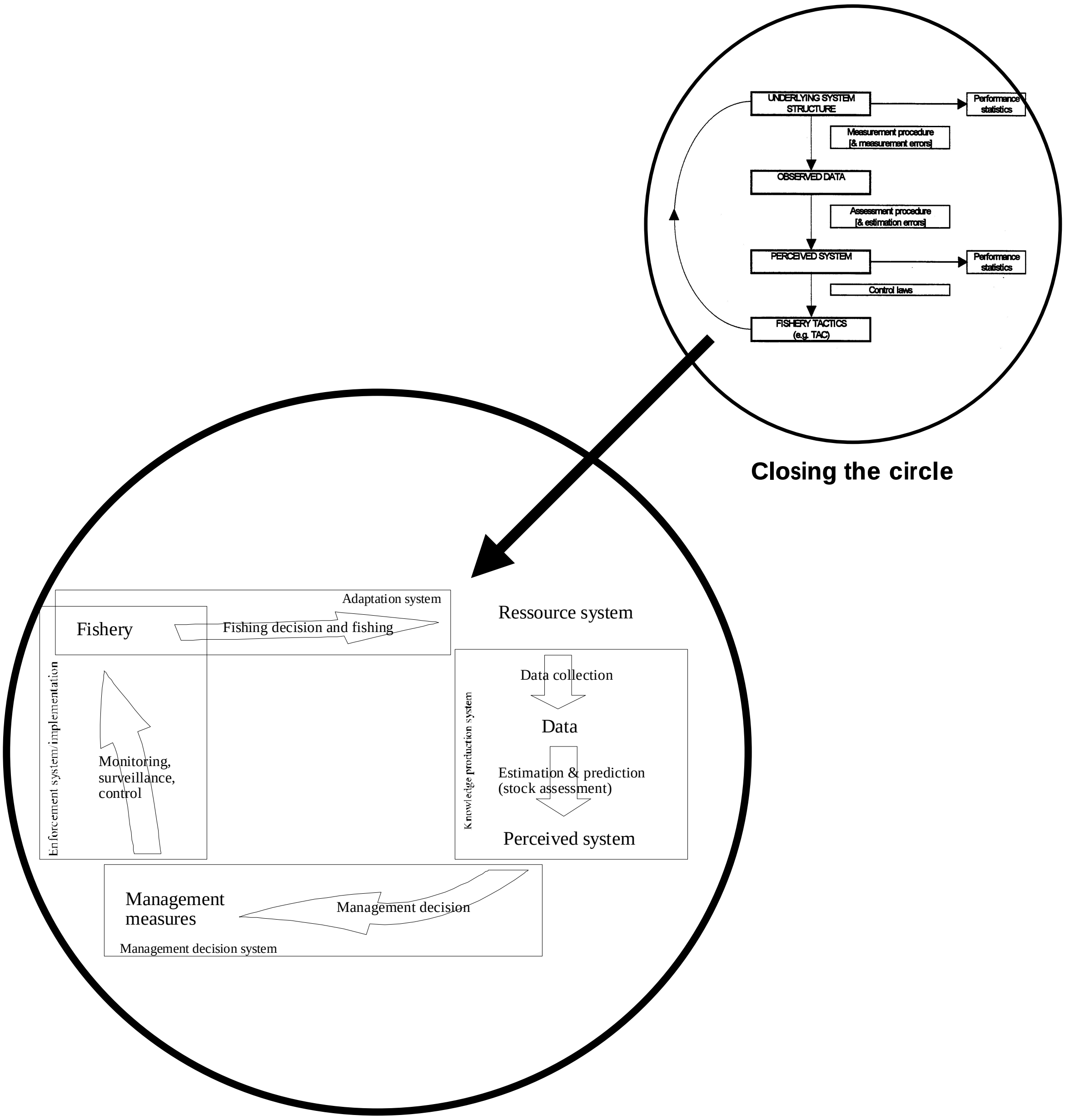
Resource Management Committee **ICES CM 2000/D:02**

Report of the
Working Group on Fishery Systems

ICES, Copenhagen
13-16 June 2000



This report is not to be quoted without prior consultation with the General Secretary. The document is a report of an expert group under the auspices of the International Council for the Exploration of the Sea and does not necessarily represent the views of the Council

International Council for the Exploration of the Sea

Conseil International pour l’Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

TABLE OF CONTENTS

Section **Page**

1 INTRODUCTION

1.1 Participants

Poul Degnbol	Denmark (Chair)
Jon G. Sutinen	USA (Co-chair)
Kjellrun Hiis Hauge	Norway
Holger Hovgaard	Denmark
Eskild Kirkegaard	Denmark (part time)
Knut Korsbekke	Norway
Paul Marchal	Denmark
Sigbjoern Mehl	Norway
Jesper Raakjær Nielsen	Denmark (part time)
Carl M. O'Brien	UK
Martin Pastoors	Netherlands
Per Sparre	Denmark
Robert Stephenson	Canada (part time)
Sigurd Tjelmeland	Norway

1.2 Terms of Reference

At the ICES Annual Science Conference in Stockholm, 1999, it was decided that:

A Working Group on Fishery Systems [WGFS] will be established (Co-Chairs: P. Degnbol, Denmark and Dr J. Sutinen, USA) and will meet at ICES Headquarters from 13–16 June 2000 to:

a) develop a framework and methodology for the analysis of fishery system performance;

b) test and refine this framework and methods using designated case studies;

c) develop a workplan that within 4 years will lead to published protocols for the analysis of fishery system performance;

d) explore the applicability of frameworks such as the FAO 'Sustainable Development Reference System' and guidelines for fishery systems within the ICES region considering its relevance to an ecosystem approach;

e) propose Terms of Reference for interdisciplinary research which will advance ICES future capability in fishery systems analysis;

f) propose Terms of Reference for the future work of the Working Group to be considered by the Resource Management Committee. The Terms of Reference should take into account the priorities outlined in the ICES strategic plan and in particular the priorities adopted by the Resource Management Committee.

WGFS will report to the Resource Management Committee at the 2000 Annual Science Conference.

Justification

The Group is set up to forward ICES in particular in respect to priority 3c of the draft strategic plan-Evaluate the potential of new management regimes and strategies which are robust, cost-effective and sustainable of the draft strategic plan. The strategic plan is detailed by RMC in setting its priorities and this group responds to the RMC priorities 3 Establish and maintain links and dialogues with scientists in other disciplines, fishery management agencies, and other interested parties and 4 Establish a framework for evaluation of management regimes and alternative management strategies (including property rights, capacity or effort reductions, and taking into account biological, economic and social concerns.

The work done within WGCOMP and CFEWG has been diverse and has included assessment methodology, evaluation of specific fish stock assessments, broader multispecies and interdisciplinary considerations, performance studies of fisheries systems and studies on the incorporation of economic mechanisms in the fisheries models. The CFEWG *[chairs comment: should probably be SGMPFS] has worked by correspondence. The new Group will merge the activities of the two groups and focus it on a priority of RMC.*

The case studies should be defined by the Steering Group based on their potential for contributing to methodological development. This will be done by the Chair inviting participants to present case studies and among those offered select a few (about 3) suitable for focusing the meeting on three issues 1) models of the decision making process leading to implementation of regulations, 2) models of implementation and 3) model of the industry adaptation to regulations.

Methodological issues are within the mandate of this Group but for the purpose of this meeting this issue is not on the agenda. Fish Stock assessment methods are referred to the Methods WG that has been set up.

A Group with the following membership: Chair, Co-Chair, RMC Chair, Sakari Kuikka, Finland, Dan Lane, Canada and Kevin Stokes, UK, will work by correspondence to develop the agenda for the June 2000 WGFS meeting and in particular to select appropriate case studies to be presented for the analysis envisaged under TOR item c).

ICES will seek widened participation for this group including contact with relevant academic and intergovernmental organisations for this meeting (including FAO, OECD and IIFET) for this meeting.

***Membership**: This would include scientists working with fisheries management both from an economic, social and biological perspective.*

Participation is sought from ICES countries and by scientists both from disciplines and scientific circles not normally represented at ICES but also from countries not normally involved with ICES work, e.g. Australia and New Zealand.

1.3 The need to rethink fisheries management

The past few decades have seen considerable innovation and development in the evaluation, management and regulation of fisheries worldwide. However, in spite of these developments, fishery failures have continued to occur indicating the critical and urgent need for a new approach. Shortcomings of most current fisheries management systems include the inability to make analytical decisions that account for the scope and the multidisciplinary nature of entire fishery systems.

The limitations of current approaches to fisheries management are complex, but common characteristics include (after Stephenson and Lane 1995):

- Predominance of biological advice that lacks appropriate economic, social and operational considerations
- An inability of management regimes to deal with the inherent variability of the environmental, biological and economic aspects of fisheries systems;
- Failure to define longer term management goals, and strategies that address biological, social and economic objectives and targets
- A lack of year-over-year accountability in management decision-making and an inability to anticipate or react to the adaptation of the fishery (for example industry adjustment to regulations and changing market conditions).
- Lack of effective involvement by stakeholders and interested parties in fisheries management decision-making

Improvements to fisheries management have been suggested in numerous papers and symposia in the past two decades. These include the need for (i) evaluation of fishery systems (rather than individual fish stocks), (ii) development and evaluation of management strategies, (iii) improved institutional structures, and (iv) use of an integrated problem-solving methodology.

1.4 ICES strategies and perspectives

ICES has recognized the need to develop methods and approaches for evaluation of management regimes and alternative management strategies of fisheries systems.

The ICES Strategic Plan (ICES 2000) states among its scientific objectives as part of objective 3, to 'Develop the scientific basis for sustainable use and protection of the marine environment, including living marine resources' the need to:

Evaluate the potential of new management regimes and strategies that are robust, cost effective, and sustainable.

Justification: A large number of fish stocks in the ICES Area are managed annually with catch controls decided according to prevailing biological and political conditions. Such a process is not only unlikely to achieve management objectives but is also very data- and assessment-intensive. A number of different management regimes have been attempted elsewhere in the world, with a range of success. The use of simulated "management procedures" has shown that management may improve and require less intensive data gathering and analysis through the choice of carefully evaluated regimes or strategies. ICES will continue to explore alternative management regimes, and will develop a framework for the evaluation of these strategies to assist managers and improve the quality of ICES advice.

Develop and improve fisheries assessment tools that utilize environmental information, consider biological and socio-economic interactions, and address issues of uncertainty, risk, and sustainability

Justification: Increasingly there is a demand for ICES advice which is more comprehensive and which is beyond the scope of traditional assessment tools and approaches. There is an increasing need to consider the socio-economic context in which fisheries take place, to assist in the development of management strategies which lead to sustainable fisheries and which are consistent with a Precautionary Approach. ICES will continue to develop methodology appropriate for these needs.

The Resource Management Committee was established in 1997 to encourage development of new methods and approaches to provide the scientific basis for resource management in a broader sense than had been previously the case. Much of the core scientific work of the Resource Management Committee is devoted to fulfilling the strategic plan of ICES.

In order to address the scientific objectives stated above, The Working Group on Fisheries Systems was established by the Resource Management Committee this year to make progress in the development of a framework and methodology for the evaluation of complete fisheries systems, as described in the Terms of Reference.

A number of previous ICES working and study groups have had terms of reference related to this initiative. These include:

<u>Long Term Management Measures WG (1993-1995)</u>

- Evaluate long term measures (technical measures, reference points and uncertainty)
- Consider inclusion of multispecies issues, spatial effects, economic issues
- Define specific assessment needs (databases, model development, data needs)
- Demonstrate framework(s) for evaluating management systems

<u>Comprehensive Fishery Evaluation WG (1996-1999)</u>

- Define comprehensive and interdisciplinary evaluations of multispecies and multifleet fisheries
- Methods for medium term projections and harvest control rules (+other specific method issues)
- Reliability of forecasts when commercial catch rates are subject to significant errors
- Consider PA and HCR in relation to mixed fisheries
- Produce comprehensive evaluations (North sea flatfish, Norwegian spring spawning herring, North Sea herring, Icelandic haddock, Southern Gulf St. Lawrence and Barents Sea cod

<u>SG on the Precautionary Approach to Fisheries Management (1997, 1998)</u>

- Draft new form of ACFM advice with inclusion of PA (1997)
- Provide estimates of PA reference points for ICES stocks (1998)
- Identify generic features of harvest control rules, including recovery plans
- Consider PA in relation to multispecies effects and technical interactions

SG on Management Performance of Fisheries Systems (1999; by correspondence)

- Propose tactics, activities and products which will assist RMC in establishing framework for evaluation of management regimes and alternate management regimes
- Continue to compile case studies on modelling and analysis of overall fishery systems

Other working or study groups relating to the subjects covered by the present working group include

- The Methods Working Group (ongoing) which addresses methodological questions relating to fish stock assessments and the technicalities of management advice
- The Multispecies Working Group which has developed the framework for multispecies stock assessments including multispecies VPA's.
- The Working Group on the Ecosystem Effects of Fisheries
- The Study Group on the performance of ITQ systems

2 FISHERY SYSTEM PERFORMANCE REVIEW

The evaluation of fishery systems, rather than individual fish stocks, has been suggested as a way of improving fisheries management. Some of the limitations of the past and current approaches to fisheries management have previously been highlighted in this report (see Section 1.3). In the current section, however, the need for the evaluation of fishery systems, and the previous approaches to development and evaluation of management strategies is put into the context of this Working Group.

There is a concern to harvest fish stocks in a sustainable way, whilst at the same time providing employment to fishermen and those dependent upon the fishing industry. Whilst there is a desire to evaluate the risks facing marine species, failures in fisheries management have been linked to an inability to understand the inherent uncertainty of fisheries systems (Lane & Stephenson, 1998).

Conducting experiments in the marine environment is both economically costly and logistically difficult. The choice between management options cannot, therefore, be realistically approached through large-scale experimentation in real fisheries. It would be irresponsible to take risks with fish stocks and their fisheries, and the livelihoods of fishermen and their families.

The approach used so far to address this problem in ICES has been to utilise the possibilities to use modern computing power, coupled with well-founded analytical models and computer-intensive techniques, to enable the conceptualisation of computer-based models of the fisheries systems that it is intended to manage. One of the earliest attempts at utilising such an approach was the Revised Management Procedure by the Scientific Committee of the International Whaling Commission (c.f. IWC, 1993). The approach is well established in the resource management context (e.g. de la Mare, 1985, 1986; Punt & Butterworth, 1995) and has been adopted in a variety of fisheries and regions (Francis, 1992; Restrepo *et al.,* 1992; Powers & Restrepo, 1993; Punt, 1995).

Appealing as the simulation approach may be, however, there is still a requirement for real fishery systems to be investigated and characterised. The simulation approach may provide insights into the consequences of uncertainties or errors in the production of research based knowledge on which management is based, but falls short in relation to addressing other aspects of management performance such as the interaction of interests in management decisions, the implementation of management measures and the adaptation of the fishing industry to management.

To date ICES Working Groups and Study Groups have relied on the simulation approach. Within the context of ICES, both the *Working Group on Long-Term Management Measures* (LTMWG) and the *Comprehensive Fishery Evaluation Working Group* (WGCOMP) have utilised the simulation approach of the IWC. This work is briefly reviewed in the next Section 2.1.

2.1 ICES concepts and approaches to date

Before reviewing the initiatives undertaken within the ICES LTMWG and the ICES WGCOMP, it is worth briefly discussing the approach of the IWC (see for instance IWC(1993)) to management under uncertainty. Their approach comprises the following basic elements:

<u>*operating model*</u> – based on knowledge and assumptions about biology, population dynamics, stock structure and fleet structure pertinent to the fishery under investigation;
<u>*assessment procedure*</u> – actual assessment methodology applied to determine stock status and to estimate relevant quantities and parameters of interest;
<u>*management strategy*</u> – set of rules applied to mimic management tools; and
<u>*performance indices*</u> – quantities used to test performance.

In the IWC terminology, a management procedure consists of both an assessment procedure and a harvesting strategy. The IWC decided to determine the utility and performance of candidate management procedures using Monte Carlo simulation. One *simulation trial* consists of the generation of historical data using the *operating model*. The *management procedure* is then applied to those data, followed by catch removal and the updating of dynamics; and new data are then generated using the *operating model*. The loop is repeated a set number of times and *performance indices* are calculated. A number of *simulation trials* are run and *performance statistics* are calculated from the set of *performance indices*. The set of *performance statistics* then represents a baseline against which comparisons can be made:

- either the *operating model* may be amended to test the robustness of the *management procedure*; or
- the *management procedure* may be adjusted to allow for comparisons to be made.

The *ICES Working Group on Long-Term Management Measures* adopted this approach at its last two meetings (ICES, 1994a; ICES, 1995) and agreed that the evaluation of management measures is best performed in the context of entire management procedures. These might merely involve simple rules but could be the combination of a particular stock assessment technique with particular control rules and their implementation. A framework for the evaluation of management procedures was the central theme to the deliberations of the ICES LTMWG. The Working Group described an approach to the evaluation of management strategies (see Fig. 2.1) that essentially relies upon *scenario modelling* (ICES, 1995). Their approach required the provision of an underlying system model (the so-called operating model), together with the simulation of both stock assessment and control measures (with feedback to the underlying system model). Performance statistics are recorded from both the operating model and the perceived system (since these need not necessarily be the same). The LTMWG was requested to demonstrate a specific example of the evaluation framework using a prototype single species, multi-fleet system model for North Sea plaice. From this investigation, it was concluded that the commercial fisheries of the North Sea plaice could provide an ideal place to start work on a comprehensive evaluation of various management measures. The last meeting of the ICES LTMWG was held in 1995 and the subsequent year, a new Working Group was created – the *ICES Comprehensive Fishery Evaluation Working Group*.

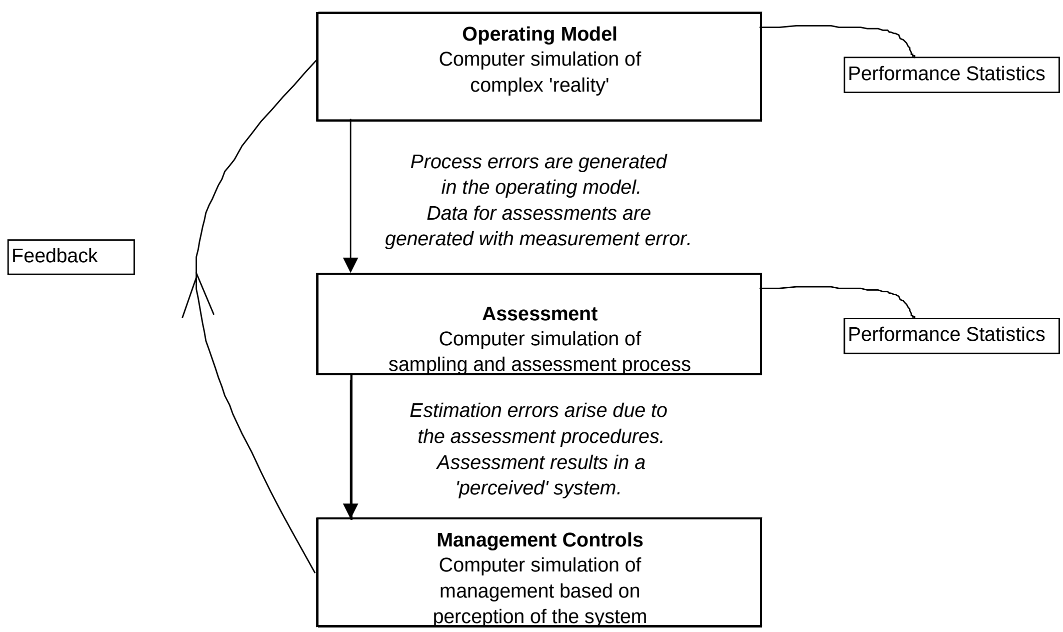


Figure 2.1 Simulation model structure (after ICES, 1999).

The *ICES Comprehensive Fishery Evaluation Working Group* was primarily created to continue with the development of tools for the comprehensive evaluation of fishery systems and to apply those tools to a number of candidate fisheries. The number of case studies increased throughout the life-time of the Working Group and in the end covered the fisheries of the North Sea flatfish, Norwegian spring-spawning herring, North Sea herring, Icelandic haddock, Southern Gulf of St. Lawrence cod and Barents Sea cod. At the last meeting of the Working Group in 1999 (ICES 1999), the meaning of the word *comprehensive* was interpreted within two contexts – comprehensive assessment (CA) and comprehensive fishery evaluation (CFE). It was concluded that CA addresses the status and prospects of the current fishery system; whilst a CFE is geared towards answering *what-if* questions and is directed towards evaluation of management procedures that are not yet in place. The WGCOMP concluded that a CA should in principle precede a CFE. Furthermore, one of the elements of a CFE would be to outline the elements of a CA that would be used in building the operating model in the comprehensive evaluation.

The Precautionary Approach (PA) has been an important issue for some years. The ICES WGCOMP was the first ICES Working Group to consider how the PA could be interpreted in terms of advice on fisheries management (ICES, 1996; ICES, 1997a). The range of acceptable harvest control rules that may be contemplated for a fishery and the way that these rules may be reflected in annual advice is restricted by various international agreements relating to the precautionary approach for fisheries management (Doulman, 1995; ICES, 1996). Advice on harvesting within the ICES area is usually framed in terms of total allowable catches (TACs) corresponding to multipliers of current fishing mortality. An ICES Advisory Committee on Fishery Management (ACFM) Study Group met in February 1997 (ICES, 1997b), to design a form of advice consistent with the precautionary approach, as embodied in the Code of Conduct for Responsible Fisheries (United Nations, 1995b) and the Agreement for the Implementation of the Provisions of the United Nations Convention of the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (United Nations, 1995a). The study group suggested that ICES should explicitly consider and incorporate uncertainty about the status of stocks and their management in scenario modelling. The 1998 ICES Symposium: *Confronting uncertainty in the evaluation and implementation of fisheries-management systems* held in Cape Town, South Africa contains a number of papers addressing these issues.

Within the three ICES Working Groups discussed in this section, the feedback loop in Figure 2.1 was not well-defined. Furthermore, the management evaluation simulations focused on that part of the management system which is the procedures to estimate the status of the fish stock. Relative to these earlier ICES approaches the present working group intends to expand the analysis of fisheries management systems to 1) include the processes within the feedback back loop explicitly into the evaluation of fisheries performance and 2) expand the analysis of the assessment process itself to include an analysis of the discourses on which the cognitive basis for fisheries management are based. This will be discussed in section 3.1 after a discussion of other initiatives to analyse fisheries systems performance.

2.2 Ongoing initiatives to analyse fisheries systems performance

A number of initiatives have been taken to analyse aspects of fisheries systems performance. These include work by FAO to follow up on the Code of Conduct for Responsible Fisheries, the fisheries management study by OECD and some more recently started projects.

2.2.1 Sustainable Development Reference System (SDRS, FAO)

Signs of overexploitation and international conflicts on management led the nineteenth session of the FAO Committee on Fisheries in 1991 to recommend new approaches to fisheries management embracing conservation and environmental, as well as social and economic, considerations. FAO was asked to develop the concept of responsible fisheries and elaborate a Code of Conduct to foster its application. The Code was subsequently developed and published in 1995 (United Nations 1995b)

FAO has developed guidelines for implementation of the Code including constructing indicators for sustainable development of fisheries (hereafter referred to as “Guidelines”). The Guidelines are published on the FAO homepage (FAO 2000). The indicators have been developed in co-operation with the Department of Agriculture, Fisheries and Forestry – Australia (AFFA), and have been reported to ICES (Garcia *et al* 1999).

The Guidelines give several examples of the meaning of “sustainability”, among these the WCED definition "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987). While ICES’ advice on management of fisheries is limited to very simple indicators for what might be the clients’ objectives – most often the total catch – the Guidelines deal with the development of indicators for a wide variety of the biological and societal systems.

Indicators are intended to measure to which degree objectives are met by the fishery, where the objectives can have a wide scope:

- Sustaining fisheries harvesting and processing activities based on specified and identifiable marine ecosystems;
- Ensuring the long-term viability of the resource which supports these activities;
- Catering for the well-being of a fishery workforce within a wider community and broader economic context; and
- Maintaining the health and integrity of marine ecosystems for the benefit of other uses and users including biodiversity, scientific interest, intrinsic value, trophic structure and other economic uses such as tourism and recreation.

(from Guidelines)

Figure 2.2 shows how the Guidelines perceive the relation between the SDRS and a conventional management scheme.

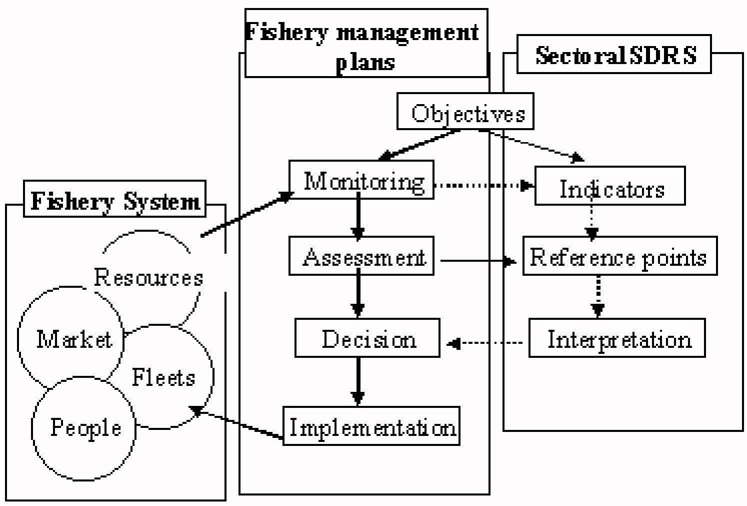


Figure 1. Relationship between conventional management schemes and a sustainable development reference system (SDRS)

Figure 2.2 Relationship between SDRS and conventional management schemes (Figure caption from Guidelines).

There may be a set of indicators for each sector of the fisheries system and to each indicator there is associated one or more reference points that measure how well objectives are met. Simple forms for indicators of performance are already in use in the conventional ICES approach to management. The deviation from the conventional ICES approach to management is not the use of indicators, rather the broadening of scope. The systematic use of indicators facilitates monitoring the developments of fishery systems of increased complexity.

The Guidelines set the following criteria for indicators:

- delivers meaningful information about the achievement of sustainable development and policy objectives (including their legal basis) at the desired scale;
- is inexpensive and simple to compile and use;
- optimizes the use of information;
- handles different levels of complexity and scales;
- facilitates integration and aggregation of indicators;
- provides information that is readily communicable to stakeholders; and
- can contribute directly to improved decision-making processes.

(from Guidelines).

The development of an SDRS involves five steps:

1. Specifying the scope of the SDRS;
2. Developing a framework for indicator development;
3. Specifying criteria, objectives, potential indicators and reference points;
4. Choosing the set of indicators and reference points; and
5. Specifying the method of aggregation and visualization.

(from Guidelines)

For a very specific objective, such as keeping fishing mortality at a certain level, the indicator and its reference point are immediately defined. When the objective is less precise, such as reducing impacts on non-target species, there will need to be some discussion about the choice of an appropriate indicator and its interpretation.

For some criteria, objectives may already be well defined (for example, maintenance or rebuilding of the fish stock). For others, objectives may be implied by international agreements, legislation or public expectation (such as minimizing pollution). For yet others, objectives may never have been clearly articulated or agreed (for example, promotion of local community development).

Indicators may be represented by a single value. However, in order to compare indicators from various parts of the system to each other a scaling is needed. Each indicator could be represented by a ratio, which might be taken as the current value of the indicator divided by the associated reference point.

For the implementation of an SDRS the involvement of the stakeholders and the continued co-operation between stakeholders and experts in various fields are necessary throughout the process. The co-operation involves definition of scope of the SDRS, definition of objectives and definition and scaling of indicators. Also, an important part of this process will be to define simple but effective means of communication.

Multidimensional representation is possible using a kite diagram with several indicators (Garcia, 1997) as shown in figure 2.3.

Representing indicators on a restricted number of axes often requires indicators to be combined. If indicators are to be aggregated into a single value, weighting is essential and would reflect some expert opinion or policy determination of the relative importance given to various indicators. These obviously need to be documented in the presentation of the SDRS.

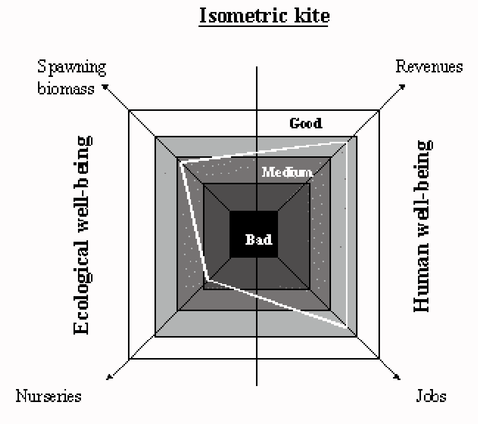


Figure 5. Kite diagram indicating the position of a fishery (white polygon) in relation to four criteria (spawning biomass, revenues, jobs and nursery areas) Source: Garcia, 1997
Note: The scale for each criteria , from "Bad" to "Good", is indicated by the degree of shading.

Figure 2.3. An example of a kite diagram for several indicators (Figure caption from Guidelines).

The performance of the SDRS should be tested and the Guidelines give a checklist for that purpose. In many cases proxy indicators must be used, for instance catch as a measure for economic well-being of fishers. The indicators should therefore be tested to which degree they measure what is intended to be measured. Also, Monte Carlo simulation studies may be a useful tool in the evaluation of SDRS.

2.2.2 OECD

This section summarizes the study by the Organization for Economic Co-operation and Development to determine which fishery management measures are effective in conserving marine fisheries and producing significant economic and social benefits (OECD 1997). The study derives conclusions about the conditions where, and explanations why, specific management measures are effective. The study also attempts to identify fishery management problems and issues in OECD member countries, and the institutional responses to these problems; how management institutions are organized; and how well have the various management measures performed in terms of solving fishery problems.

2.2.2.1 Study Approach[1]

The analytical framework used in the study assumes that regulations imposed on fisheries affect the fisheries' performance. This performance was measured in terms of biological, economic, and social outcomes. Management measures, such as quotas, closed areas and seasons, gear restrictions, tend to change the way fishing activities are conducted and, in turn, affect outcomes (stock sizes, landings, incomes, etc.) in the fishery. Actual outcomes, of course, are determined not only by the set of measures imposed but also by the biological, economic, social, and institutional characteristics of the fishery system (and perhaps by influences exogenous to the fishery system).

Methodology

The methodology involves three steps: the first step develops a set of expected consequences of using specific management measures in a fishery; the second step confronts these expectations (hypotheses) with evidence to discern the extent to which each expected consequence was supported or refuted by the evidence. The third step assesses the theory on which policy was based and draws conclusions concerning the effects of using the measures for fishery management.

The management measures examined were divided into output controls, input controls and technical measures (Table 2.1).

A set of expected consequences, or outcomes, from applying each management measure to a fishery were derived using bioeconomic theory. The expected consequences were loosely grouped according to resource, harvest, market, social and administrative outcomes. The explanations of (or, the reasons for) the expected consequences were based on the current state of general knowledge as reflected in the published literature of fisheries science and economics. The expected consequences were intended to apply to a reasonably general set of conditions, but were not expected to hold in all fisheries.

The second step in the methodology involves confronting the expected consequences (hypotheses) with evidence on actual consequences in managed fisheries. Each management history for a specific fishery consists of a chronological description of the management measures applied and the corresponding outcomes (biological, economic, social, and administrative) observed in the fishery. The fisheries included were those for which a reasonable amount of good quality information was available, and for which source documents were readily available.

[1] This section was excerpted from Sutinen, J. G. 1999. What works well and why: evidence from fishery-management experiences in OECD Countries, *ICES Journal of Marine Science*, 56: 1051-1058.

Evidence on the specific consequences of fishery management measures was divided into biological, economic, social and administrative consequences. The principal biological consequence was the extent to which the target resource stock was protected from over-exploitation. The principal economic consequence was the extent to which the fishery achieves its economic potential, as measured by the net economic benefits to harvesters, processors, distributors, marketers, and consumers. Social consequences involve effects on the distribution of income and wealth, the amount and form of employment, cohesion in rural communities, class divisions, and industry attitudes towards the regulation. Administrative consequences include enforcement costs and problems, catch data quality, monitoring and research requirements, and industry's support and cooperation.

Table 2.1: Management Measures

Output Controls	Input Controls	Technical Measures
Total Allowable Catch (TAC)	Limited Licenses	Size & Sex Selectivity
Individual Quotas (IQs)	Individual Effort Quotas	Time & Area Closures
Vessel Catch Limits	Other Gear & Vessel Restrictions	

Biological consequences

The evidence concerning biological consequences describes changes in the abundance of fish stocks (as measured, for example, by-catch-per-unit-effort, estimates of spawning stock biomass), and the composition of fish stocks (age and species composition).

Economic consequences

Direct evidence on economic performance generally was not available. Therefore, the net economic benefits to harvesters, processors, distributors, marketers, and consumers was measured indirectly by examining changes in outcomes in the harvesting and marketing sectors of a fishery. Outcomes in the harvest sector include changes in landings (amounts and seasonal patterns); fishing patterns (season length, race-to-fish); harvesting capacity (fleet size and composition, vessel sizes); harvesting practices (fishing techniques, product handling); by-catch (amounts and use of); product utilization (discards, high-grading); landed product forms; harvesting costs; gear conflicts; gear loss; employment (amount and seasonal patterns) in harvesting and processing; safety; total sales/revenues; vessels owners and crew incomes; and resource rent. Outcomes in the market sector include changes in prices (levels and seasonal patterns); product quality and forms; product utilization; product availability patterns (e.g. market gluts and scarcity); imports and exports; and consumption patterns.

Social consequences

Social consequences include changes in ownership patterns (e.g. family, corporate); life styles (e.g. rural, traditional); class divisions; and perceived inequities.

Administrative consequences

Administrative consequences include changes in the amount of monitoring resources and costs; research requirements and costs; enforcement resources and costs; enforcement problems; information demands; industry acceptance and cooperation, or resistance; and data degradation, including under-reporting of landings and fishing activity.

The evidence on management experiences was organized to focus on outcomes predominantly related to the resource, harvest, market, social, and administrative aspects of each fishery. To the extent that the evidence allows, the goal was to correlate the outcomes with management measures and characteristics of the fishery system to determine the conditions under which the measures conserve fishery resources and improve economic performance.

No ranking of regulatory measures and consequences was made, since there may be several reasons for regulating a fishery. In addition to conserving the resource and improving economic performance of the fishery, management measures are used to prevent or mitigate conflicts among user groups, to affect the distribution of benefits among users and to protect social values and life styles. The results herein only delineate the inherent tradeoffs among the sets of consequences when fishery managers are faced with deciding which management measures to employ.

The quality of the evidence was highly diverse, ranging from sound, scientifically produced data to anecdotal reports. All of the information used in the analysis was reviewed and revised, where necessary, by fisheries experts in the respective country. In addition, the interpretation of the information and conclusions drawn were tempered by the quality of the information.

2.2.2.2 Confronting the Theory

The nature of the information available precludes using formal statistical techniques to confront the expected consequences with evidence on actual consequences in managed fisheries. Instead, an informal, multi-layered procedure was applied. The first step in the process involves examining the evidence in each specific fishery for the time interval following implementation of a management measure, up to the time of a change in management measures. Whether the relevant expected consequence was supported or refuted by the evidence was noted. Then, alternative explanations of the reported outcomes were sought, and any credible alternative explanations were noted.

Once the case-by-case confrontation was completed, the evidence was grouped by management measure, one set of evidence for each management measure. This aggregated evidence was examined for consistencies and inconsistencies with respect to the expected consequences. The numbers of cases that support or refute each specific expected consequence on management measures were reported in the study. A high level of consistency (or inconsistency) allows us to tentatively not reject (or reject) any given expected consequence. In effect, we tried to conduct univariate statistical analysis without using formal statistical correlation methods. But, recognizing that univariate analysis was an insufficient basis for this exercise, the evidence was further examined for other influences, i.e. other causes of the observed outcomes.

Consequences and System Characteristics

Characteristics of the entire fishery system were expected to influence the operation of the fishery and the consequences of management measures, and were accounted for to the extent the information allows. Four classes of characteristics were considered: biological, economic, social, and institutional.

Important biological characteristics include the number of species, the extent of biological interdependence (e.g. competition for food and habitat, predator-prey), mobility, growth and reproduction rates, and recruitment patterns (e.g. density dependent, highly variable). Economic characteristics expected to influence the performance of management measures include the structure of the industry, types of gear, and numbers of distinct user groups. Social characteristics expected to influence the consequences of management include kinship involvement, job satisfaction, education and training, age structure, community character, cultural and ethnic differences, and social cohesion. Institutional characteristics that may influence management consequences include the extent and nature of jurisdiction over the resource (local, national, international), the extent of user involvement in the management process, structure of the management agency, and legal foundations.

Consequences and Exogenous Influences

Influences other than management measures and systems characteristics also were considered as evidence permits. A salient example of exogenous influences was a change in environmental conditions that can have major impacts on fisheries. Other examples include technological progress and market and trade developments. These and other exogenous influences can obscure the influence any one management measure has on outcomes in a fishery. Where possible, these and other explanations of the reported outcomes were investigated.

2.2.2.3 Recent OECD Work

As a follow up to the work described above, the Fisheries Committee of the OECD has conducted a study of the costs and benefits associated with a transition towards responsible fisheries. The results of this study are in a report by D. Lane, *Transition to Responsible Fisheries: The Impact of Responsible Fisheries on Production and Management: Evaluation of Gains and Costs* (AGR/FI/RD(99)2). The study aims to provide a methodology and illustrated assessments of the biological, economic, social and administrative consequences of adopting policy measures that are consistent with the Code of Conduct. The analysis makes use of a quantitative model that integrates the biology, economics, social and administrative aspects of policy through linked spreadsheets that track stock dynamics coupled with standard fisheries business analyses. Social analyses track the annual employment and labor income activities of the harvesting and processing sectors; and the administrative component tracks the annual monitoring, enforcement, licensing, scientific, and management activities. The output performance measures are presented in integrated spreadsheets and provide indicators of the systems' benefits and costs over time.

2.2.3 Overview and discussion

The development of a framework and methodology for the analysis of fishery system performance may draw on past and ongoing studies. The rigorous test system initiated by IWC and elaborated further for fishery systems by LTMWG and WGCOMP lends itself also to testing of fishery system performance in the context of the present WG, where the key idea is to expand the approach to include analysis of the management decision process and the industry response to implementation of different management regimes, as well as the effect on the biological system.

The SDRS developed by FAO-AFFA offers an attractive way of communicating complex responses of the fisheries system, as well as a modus operandi for including stakeholders in the process of defining objectives, performance indicators and reference points. The empirical study of the performance of different management measures across a large variety of stocks undertaken by OECD constitutes a basis for contrasting simulated vs. observed effects of management measures. Studies directed towards investigating the effect of specific management measures as the one aimed at by Woods Hole Oceanographic Institution for ITQs may also be valuable background and provide data for investigating the effects of such measures using the framework being developed with the basis in the present WG.

The shortcoming of many present-day management regimes can be attributed to lack of compliance from the industry. Therefore commitment from stakeholders including fishers is essential in implementing new regimes. In this respect the simplicity and elegance in the SDRS suggested from FAO-AFFA would prove valuable also in the present context. In many respects the SDRS can be considered to cover a part of the present initiative, which undertakes the task of modelling the left part (fisheries system) in figure 2.2. However, there is a danger of under-communicating the dynamic aspect by basing the performance criteria on simple indicators and kite figures like figure 2.3. Systems that perform well for some indicators (economic and social) but poorly for other indicators (biological) may soon be driven to perform poorly on all indicators. The dynamic aspect thus needs to be communicated by including perceived projections of the diagrams. Also, the kite diagrams could be taken in an averaged sense where Monte Carlo simulations of the fishery systems may yield the properties by the management regime as such, measured through the indicator variables.

Basing the development of performance criteria on the SDRS methodology thus provides for using tested methods for communicating system performance to stakeholders as well as a link between the present ICES initiative for developing a framework for analyzing fisheries system performance and experience with similar initiatives other regions of the world.

The OECD study is one of the few, if not the only, comprehensive, bioeconomic analysis of fishery management across a wide variety of fisheries. The value of the study, and of its methodology is limited, however, by the quality of the data involved that precluded rigorous statistical testing of hypotheses related to explaining the performance of fishery management systems. The OECD study also suffers from lack of adequate information on size and sex controls, effort controls and closures in fisheries.

2.3 Initiatives to study aspects of fisheries systems

Some ongoing projects study important aspects of fisheries systems of relevance to the present Working Group.

2.3.1 Woods Hole Oceanographic Institution study on ITQ systems

The Woods Hole Oceanographic Institution currently was attempting to fund an international study of ITQ Fishery Management Systems. The lead investigators are Robert Repetto and Lee G. Anderson; and associate investigators include fishery economists from Iceland, Australia, Canada, Norway, United States and New Zealand. The purpose of the proposed research was to:

1. improve the factual record regarding the consequences of ITQs and narrow the range of disagreement in countries still uncommitted to the use of this management approach;

2. improve the knowledge base in fisheries using ITQs so that adaptive management approaches can correct problems and improve performance; and

3. clarify important methodological issues about how to assess ITQ performance appropriately.

After selecting a set of ITQ fisheries, the research project will use a comparable analytical framework and comparable performance measures across a range of ITQ fisheries. The principal performance measures are efficiency-related outcomes, distributional outcomes and biological outcomes.

Efficiency-related outcomes will assess changes in input levels and costs, output and value levels, and overall measures of net income, productivity and efficiency. Measures of distributional outcomes will be based on the changes in incomes to crew, operators and owners in the fishery. In addition, data will be assessed with respect to initial quota allocations and changes in ownership overtime, changes in wealth associated with the initial allocation of quotas, and the disposition of vessels that leave the fishery. Biological outcomes will be measured with data on trends in stock abundance, changes in age/size composition of the stock(s), changes in the levels of bycatch and discards, and changes in harvesting methods with potentially destructive side-effects.

The data to be analyzed include cross-section survey data on individual vessels and time series data on the entire fishery. The cross-section survey data will be used to estimate cost functions, efficiency frontiers, technological change parameters and compositional changes in the fishery. The times series data will be used to analyze the changes in net income and quota values over time. To the extent possible, statistical methods will be used to explicitly test hypotheses regarding the performance of ITQ systems.

The project was expected to begin in early 2001 for a duration of approximately two-and-a-half years.

2.3.2 Science and Citizen Participation in Fisheries Management

The science and citizen participation study is an ongoing project funded by the US National Science Foundation and conducted by Bonnie McCay, Rutgers State University of New Jersey, Doug Wilson, Institute for Fisheries Management and Coastal Community Development, Denmark and Madeleine Hall-Arber, Massachusetts Institute of Technology.

The study is an empirical research project to add to our understanding of the relationship between science, environmental policy, and public participation. The project focuses on marine fisheries management in the United States.

Three research questions are explored. The first is how the level of overall scientific certainty about an issue affects the claims made by participants about scientific credibility. The second is how participants make use of scientific information. The third is how legal mandates about scientific issues affect the use of scientific data and claims about credibility.

Four research activities are involved. The first is a series of key informant interviews with fisheries scientists and other participants in fisheries management. This involves talks with with scientists and other personnel working for NMFS, the New England and Mid-Atlantic Fisheries Management Councils, the Atlantic States Marine Fisheries Commission, and state-level agencies and talks with leaders from the commercial and recreational sectors. The second activity is to follow up these interviews with a random sample, email survey of fisheries scientists that will be able to test hypotheses generated from the key informant interviews about how institutional and professional affiliations affect perceptions of how science should be used. The third activity is a random sample survey of a broad spectrum of participants in Federal and State fisheries management activities in the New England and Mid-Atlantic regions. The fourth is a series case studies of the management of the role of science in the management of herring lobster, bluefish, summer flounder and surf clams.

The major part of the data collection in the project is finalized and results from the project are presently under publication.

2.3.3 DST^2

Development of structurally detailed statistically testable models of marine populations (DST^2) is a four-year project funded under the EU Framework V Programme (QLRT-1999-01609). It is a collaborative initiative between eight partners - MRI, Iceland; IMR, Norway; DIFRES, Denmark; SCUI, Iceland; UiB, Norway; FRS, UK(Scotland); CEFAS, UK(England & Wales); and IFREMER, France.

The project is investigating the costs and benefits of using models that provide a detailed description of marine ecological processes; using tools developed, and example data sets identified, specifically for the purpose. The approach being adopted is to construct models that are empirically justifiable in that they contain an amount of detail in their structure that is appropriate to the data which are available. This appropriateness is being evaluated using formal statistical tests. By doing this it is intended to develop fisheries science as far as the information will support such development, but strictly no further. These developments are principally in the area of modelling the effects on populations of spatial variation in growth, predation and migration. These effects are not normally included in models of fish stocks presently used for management purposes, and their importance for this purpose is not known.

The project is intended to support decisions about the most appropriate level of complexity to use in modelling fish stocks for supporting annual management decisions, and also in formulating long-term, strategic advice. To this end, the project is developing statistical tools for testing hypotheses and a corresponding data storage system for general use. These will be implemented in a number of case studies that are designed to act as test-beds for model development and to provide insights into specific issues of appropriate model complexity. This is being achieved by the creation of *warehouses* of data and also models of fish population dynamics disaggregated by space, time, age and length, and with possible interactions with environmental effects. Models are being developed in a common programming framework.

3 FRAMEWORK FOR ANALYSIS OF FISHERY SYSTEMS PERFORMANCE

3.1 Overview

The Long Term Management Measures Working Group (LTMWG) and the Comprehensive Fisheries Evaluation Working Group (CFEWG) have developed and implemented a framework for evaluation of management systems based on the International Whaling Commission approach (see section 2.1). This model traces the estimation procedures and the biases and variances inherent in these from data collection to stock assessments including catch projections. These management system simulations have thus mainly focused on that part of the management system which is the procedures to estimate the state of the stock. The feed back from stock estimates to the stock has not been considered in detail.

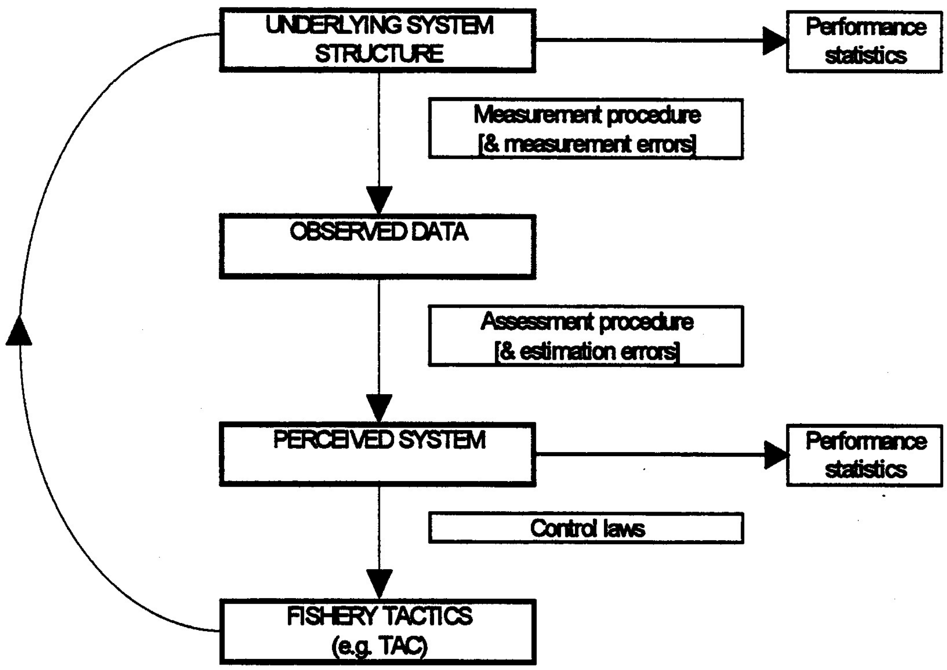


Figure 3.1 The management evaluation model concept used by the Long Term Management Measures Working Group and – in a modified form – the Comprehensive Fishery Evaluation Working Group (ICES 1995)

This approach has been useful to evaluate the implications of uncertainties and biases in the knowledge production system. However, the feed back arrow in figure 3.1 consists of a chain of processes that are critical to the final outcome of the management system. The overall failure of fisheries management to achieve its goal in terms of reducing fishing mortalities and rebuilding stocks has not been strongly associated with uncertain or biased stock assessments. The adaptation of the behaviour of fishing operations to management measures, incomplete compliance and inadequate enforcement, and the decision process leading to management measures have contributed to the lack of efficacy of fisheries management systems.

The CFEWG (ICES 1999) distinguished between

- Comprehensive assessment (CA) which is a description of *what is* - fisheries description, the biology of the resource base, management, evaluation of current assessments, fisheries history

and

- Comprehensive fisheries evaluation (CFE) which is an evaluation of *what if*, that is a CA plus a scenario modelling of the outcomes of specific management measures

However, the CFE of CFEWG did not include details of the feed back arrow in figure 3.1. The present working group proposes to address questions of how the subsystems within the feed back arrow work and why they produce various outcomes. *What if* questions can only be addressed on basis of a model that includes all processes in the system. That is, a framework for analysis of the performance of fisheries system includes a CA plus models of the processes that contain the feedback mechanisms in the full system. These other processes have been identified as:

- The decision making process leading to management measures
- The implementation of the management measures
- The adaptation of the fishing operations to management measures

The performance of the fisheries management should thus be evaluated on basis of a model of the full cycle of these processes in the fisheries system.

The processes are analysed as decision processes involving specific actors or stakeholders. The decision processes and the role of stakeholders are traced through the steps of

1. establishing the state of the stock and technical evaluation of management measures (the Knowledge Production System),
2. setting of management measures on basis of stock knowledge up to detailed regulation measures (the Management Decision System),
3. implementing management measures in the fishery (the Enforcement/Implementation System) and
4. adaptation by the fishing industry to management measures and external conditions (the Adaptation System).

These process chain or subsystems are illustrated in Figure 3.2.

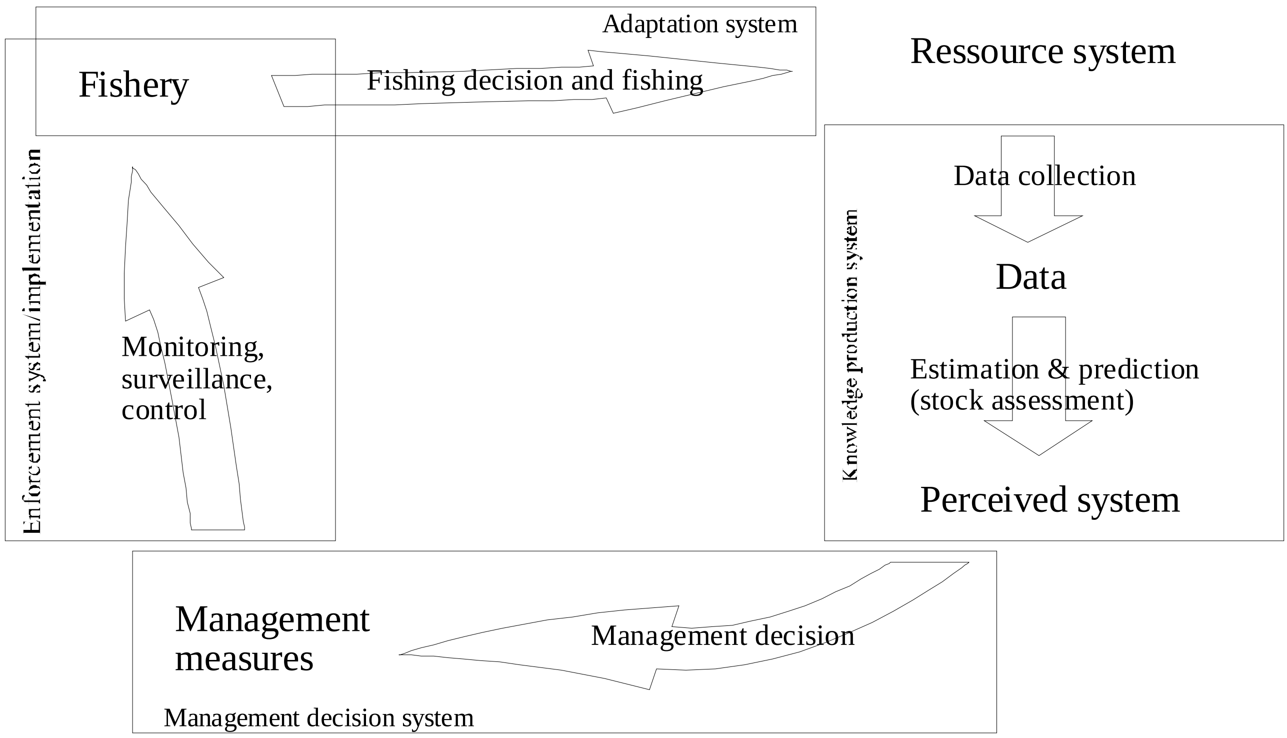


Figure 3.2. The basic framework for analysis of fisheries systems performance: Four Systems Influencing the Performance of Fisheries

The subsystems are closely interlinked, each impacting directly or indirectly the other subsystems. In addition, some subsystems overlap to some degree. For example, the implementation and adaptation subsystems overlap: monitoring, surveillance and control will influence the behaviour of the fleet and the actual implementation is dependent on the adaptation of the fleet both to the MSC efforts and to other determinants of the fleet's behaviour such as markets and the understanding of resource availability.

The full fisheries system includes the four subsystems of human decisions and actions and the resource system *per se,* which is external to the analytical framework. The processes within the subsystems ar

The framework does thus build upon the IWC approach (figure 3.1) but expands this approach in two ways:

1. The feedback loop (fig 3.1) is expanded and qualified to consist of a range of processes, each of which have important impacts on the performance of the fisheries system (fig 3.2)

2. The evaluation of the cognitive basis for management is expanded to include both the technical evaluation of the stock assessment process (as per fig 3.1) and an analysis of knowledge production as a process involving human interaction and decisions within specific discourses.

3.2 Subsystems

3.2.1 Knowledge production system

General description

The knowledge production system (KPS) is understood here as all processes by which observations are generated from other subsystems and how these observations are made understandable for management purposes or to any other system where this knowledge may be used (e.g. in the Adaptation system). Knowledge itself is conceptualised very broadly as any form of understanding that concerns elements of the total fishery system. The actors involved in knowledge production may be diverse, ranging from scientists (biologists, economists, sociologists, political scientists, …) to individual fishermen and representatives of NGO's, each operating on basis of their own discourse. It should be considered that knowledge production in itself is not an un-problematic activity that may be influenced by different system elements. For example, the dominance of the current biological oriented discourse in fisheries management, based on mathematical models of single species fish stocks assessments, tends to preclude other types of knowledge that do not conform to the basic rules of the discourse (Bailey &Yearley 1999; Finlayson 1994; Hiis Hauge 1998). Also, the process of formulating scientific advice to fisheries management constitutes a classic example of so-called 'regulatory science' (Jasanoff 1990) whereby the interaction between knowledge-producer (e.g. advisor) and knowledge-consumer (e.g. manager) together shape both the research agenda and the domain of acceptable answers. In that sense the process of providing scientific advice for fisheries management is in due need of being analysed with the appropriate tools.

Processes to be included (decision processes, actors, parameters)

The analysis of the knowledge production system entails the following general processes:

- description of the actors or actor groups that are involved in producing knowledge that is supplied to the Management Decision system or to any other system.
- description of the interrelationships between the different actors/actorgroups
- description and analysis of knowledge-making processes (observing, assessing, summarizing, presenting). This should include analysis of the decision making processes on the part of the knowledge-producers as to what constitutes appropriate knowledge and how advice should be framed and presented.
- description and analysis of interactions between knowledge-producers and –consumers.

Actors involved in knowledge production may differ depending on the specific case studies but would normally consist of university scientist (from different disciplines), government scientists (also from different disciplines), fishermen, fishermen representatives (may also be scientists!), representatives of NGO's, journalists and even the general public. In principle also fishery managers and civil servants can also be considered as actors involved in knowledge production, because at different levels within decision making processes they will attempt to synthesize relevant information.

Approach to analysis

The analysis of knowledge production could be founded on two general approaches:

1. The analysis of current operation of knowledge production system. The analytical framework for this approach would need to be worked out but would surely include observing and analysing concrete knowledge producing activities (e.g. observing ACFM during its formulation of advice) and using interview techniques to derive attitudes and conceptualisations of different actor (-groups).

2. Modelling the knowledge production system by building simulation models that simulate the process of making observation and producing intelligible results (figure 3.3). The success of this approach would depend on our ability to come up with generic decision making process with the knowledge producing activities. This approach requires the definition of a resource base from which observations can be drawn. Information is collected by sampling from the different subsystems and this information is then processed through an assessment procedure. The knowledge production system is similar to the approach developed during the ICES COMFIE meetings (ICES 1996; ICES 1997; ICES 1999), the difference being that now we are considering not only the a biological underlying system but rather that information is collected from all subsystems including economic and managerial information (ICES 1994). Furthermore, the setup chosen will also allow the inclusion of other types of knowledge, e.g. traditional ecological knowledge or fishermen's personal observations.

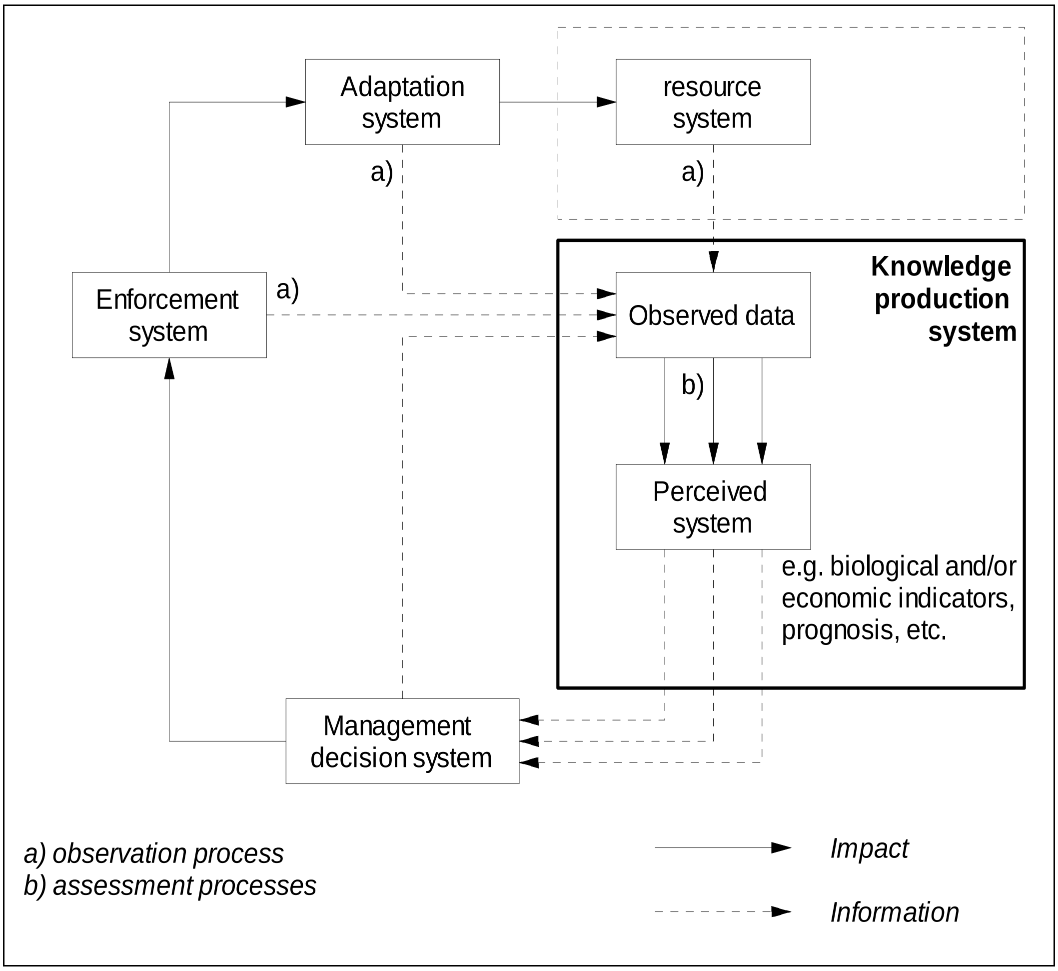


Figure 3.3 Conceptual model of a knowledge production system in relation to the other system elements.

Data needed

Information should be collected from direct observations, literature research (both official and unofficial papers) and interviews of knowledge producing processes. In a simulation model of the knowledge production system, information could be taken from the Resource System, the Management Decision System, the Implementation/Enforcement System and the Adaptation System.

Output generated

The output from the analytical approach to knowledge production will be an understanding of the processes of how different sources of knowledge are shaped and negotiated. It is expected to shed light on the role of ‘scientific’ knowledge in relation to other types of knowledge.

The modelling approach to the knowledge production system will generate artificial observations of whatever data may be necessary for the assessment procedures (plural because different assessment procedures may be used, e.g. biological, economic, social etc.). Output from the assessment processes will be the system indicators that are considered relevant for the management process.

3.2.2 Fishery adaptation system

System definition

Fishery adaptation systems account for actions taken by fishing fleets in response to a number of external constraints, which are related to the social, economical, political, biological and environmental context of the fishery.

Processes to be included

The main processes included in fishery adaptation systems are summarised in a flow chart (Figure 3.4), made up of a number of nodes connected by informational, decisional and influential links. The two parent nodes referred to as “Implementation system” and “Knowledge production system” are described in details in sections 3.2.1 and 3.2.4. The description of the third parent node, “Physical context”, that represents weather and hydrographic conditions, lies outside the scope of the working group. The child nodes are the components of the fleet adaptation system, and these are presented below.

The central node of the system is the individual fishing vessel, which is hereby considered as the production unit. The vessel is steered and/or owned by a skipper, which possibly may belong to a broader production unit: the fishing firm. The skipper is making several decisions, based on information on management regulations being implemented, market context, weather conditions at sea, and his own evaluation on stock density and distribution.

The decision on whether to comply with regulations is affecting effective fishing effort via number of days at sea (catch or effort quotas), effort allocation (area or season closure), selectivity (mesh size and gear restrictions), fishing power (restrictions on horsepower). Compliance to regulations such as single-species catch quota, by-catch limits and minimum mesh size also determines the amount of fish he is not allowed to land legally, and which is either discarded, or sold illegally.

Following his perception of fish prices and exploitable biomass, a fisherman is expected, (i) to drive his fishing activity towards areas and seasons where the most valuable species are present at the highest density, (ii) to choose the most selective combination of gear and mesh size relative to these species and, (iii) to land his load in a port where it can be sold at the most attractive price. However, weather conditions at sea and operating costs limit the travelling time required to join the targeted fishing grounds and landing ports, which a fisherman has to balance with expected gross revenues.

Catches are a function of both effective fishing effort and exploitable biomass. Catch levels alter in return the production system. Total landings, that is the amount of fish caught, which have not been discarded, are expected to alter fish prices through some elasticity process. The official landings, that is the amount of fish landed, which have been sold legally, and number of days at sea, are used as data inputs to the knowledge production system.

Finally, fisherman’s profit is derived from the combination between total landings, fish prices and operating costs.

3.2.2.1.1 Potential approaches to the analysis

A range of multivariate methods have been applied to analyse fisheries behaviour in relation to a number of determinants including gear, fishing ground, fishing season and target species (e.g. Biseau and Gondeaux, 1988; Lewy and Vinther, 1994; Pelletier and Ferraris, 2000). Similar approaches could be used to better understand the links between processes presented in Figure 3.4

A number of studies have been conducted to model and predict fisheries behaviour. Maury and Gascuel (199?) proposed a theoretical dynamic model to describe fishermen's space and time distributions in relation to fish densities, for a single-species fishery. Holland and Sutinen (1999) proposed to model and predict more generally the adaptation of a mixed-species fishery, using discrete choice random utility models. Such an approach could be generalised to model and predict fishery adaptation, using all information received and decisions made by fishermen, as described in Fig. 3.4

An alternative approach to model fleet adaptation systems could be to use Bayesian Networks. Bayesian Networks (BNs), or causal probability networks (Lauritzen and Spiegelhalter, 1988), have attracted a great deal of attention in the early 1990s in medical, psychological and, more recently, agronomic and fishery sciences (Tari, 1996; Hammond and O'Brien, 1999). BNs may in particular be used in relation to chart diagrams such as Fig. 3.4, by interpreting uncertainty and causal links between variables in terms of probability tables.

Data needs

Data on official landings and number of days at sea are required for each vessel by season and space unit (e.g. ICES squares). Such data are generally available in log-books, relative to stocks assessed by ICES, but not necessarily for others, although these may represent an important source of revenue for fishermen (e.g. turbot in the North Sea). It would however be desirable to release extended information relative to such high-valued by-catches.

The reliability of fishing effort data is a measure of compliance to the implementation system, which could be appraised by making available external data sources including questionnaires and interviews. Another measure of this compliance is given by the discrepancy between official landings, total landings and catches, on which information could be made available by conducting on-board investigations on discarding practices and harbor enquiries.

Information on measurable vessel attributes (e.g. gross tonnage, vessel size, horsepower) and gear characteristics (e.g. mesh size, net surface, number of hooks, number of pots) are required to get insights into some of the determinants of fishing power and selectivity. Data on prices, operating costs and profit could be made available through retailers' sales slips and fishermen's accountancy records.

Expected outputs

- To understand the adaptation of fisheries to enforced regulations, weather conditions, market constraints and collected experience on fish densities
- To model quantitatively the adaptation of fisheries to existing informational signals
- To be able to predict the adaptation of fisheries to new informational signals

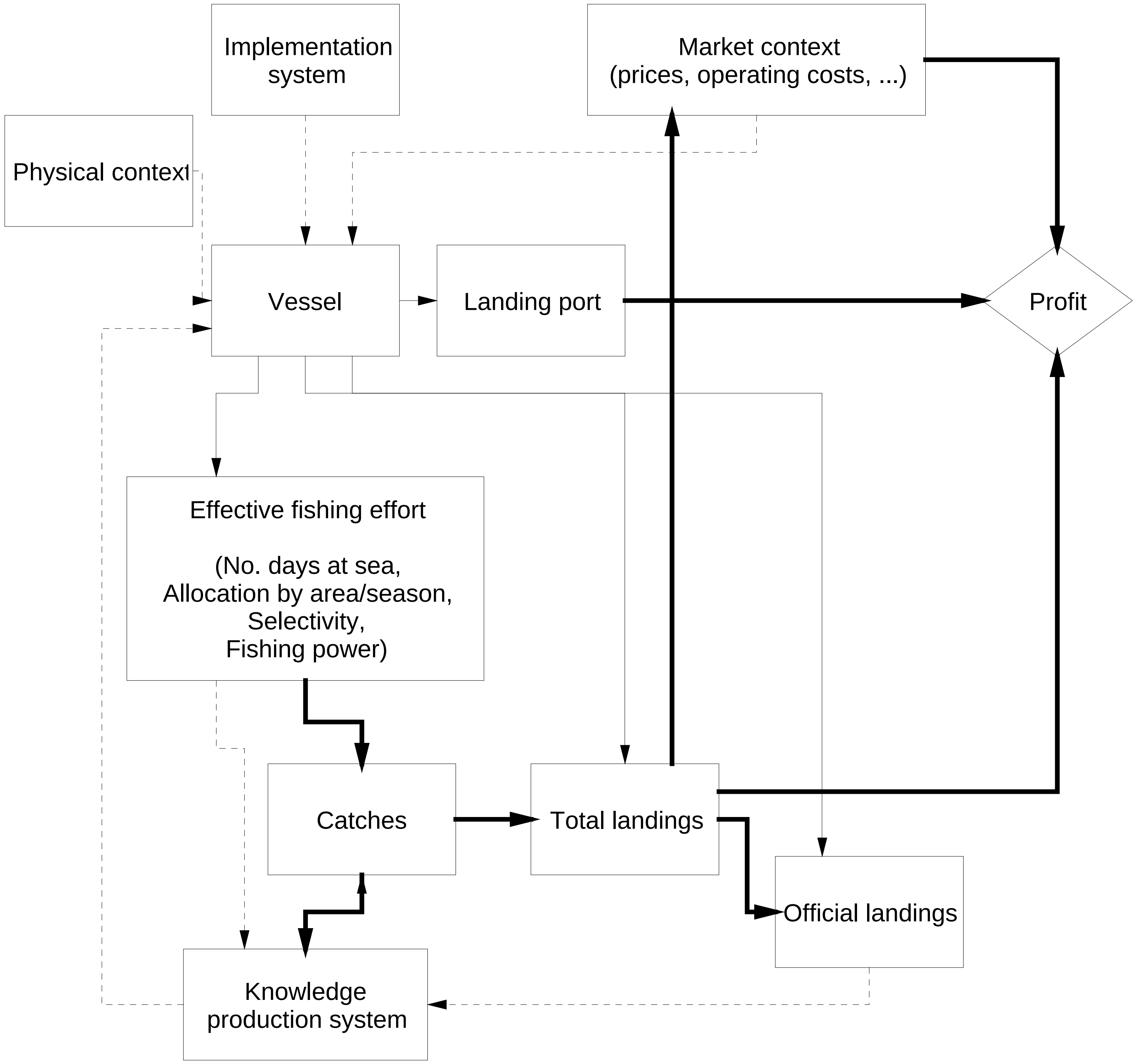


Figure 3.4 Chart diagram summarising processes to be included in the fishery adaptation system model. Dotted, plain and bold lines respectively refer to informational, decisional and influential links.

3.2.3 Management Decision System

Why analyze and assess Management Decision Systems?

As indicated above, fisheries in the North Atlantic have not been managed well by our fishery management institutions. There is increasing sentiment among fishermen, government authorities and the general public that our fishery management institutions are not working. They are saying that the management institutions are broke, and it is time to fix them. The key question then is how to repair these institutions? On that there is little agreement.

Like the proverbial blind men feeling different parts of an elephant, most observers see only part of the policy development and implementation process. Fishery scientists recommend increasing our knowledge of the fishery resource stocks. Social scientists recommend more research on the economic and social aspects of fisheries. Government authorities advocate more resources to administer and enforce fishery management regulations. But none of these recommendations is based on a comprehensive view of the entire system for developing and implementing fishery management policy. We believe that the lack of agreement and lack of substantive ideas for reforming our fishery management institutions are rooted in the lack of understanding of how fishery management policies are produced.

Framework for analysis of management decision systems in ICES Fisheries

The proposed framework involves two major steps: *description* of the management decision systems used in fisheries, and *analysis and evaluation* of the management decision systems.

Definition of the management decision system and processes to be analyzed

The Management Decision System (MDS) is defined to include institutional process by which fisheries management and other fisheries policies are produced. The products of the MDS include laws, regulations and policies intended to govern the use of fisheries resources.

The processes to be analyzed include the political and legally established processes for setting fishery management policy. The MDS processes usually occur in organizations such as fishery management councils or committees, where the members of the councils/committees collectively decide on policies to be implemented.

For example, in the United States the Magnuson-Stevens Fishery Conservation and Management Act authorizes eight Fishery Management Councils to develop plans to manage commercial and recreational fisheries. Fishery Management Plans specify management measures that regulate users of fishery resources in Federal waters. Fishery Management Council members include State and Federal government officials, as well as representatives of fishing, environmental and other interests (fig 3.5). The New England Fishery Management Council, for example, has 17 members: one Federal and five State government officials, 10 members representing commercial fishing interests and one member representing environmental interests. The Plans developed by the Councils must conform to elaborate guidelines for the preparation of fishery management plans – developed by the National Marine Fisheries Service has developed. The guidelines require, for example, that the plans include environmental impact statements and be subjected to public hearings.

The specific institutional arrangements for fishery management decision making vary by country and level of jurisdiction. For example, decision making may occur at the local level as well as at the provincial/state, national and international levels. Each is expected have a unique set of processes that comprise the MDS.

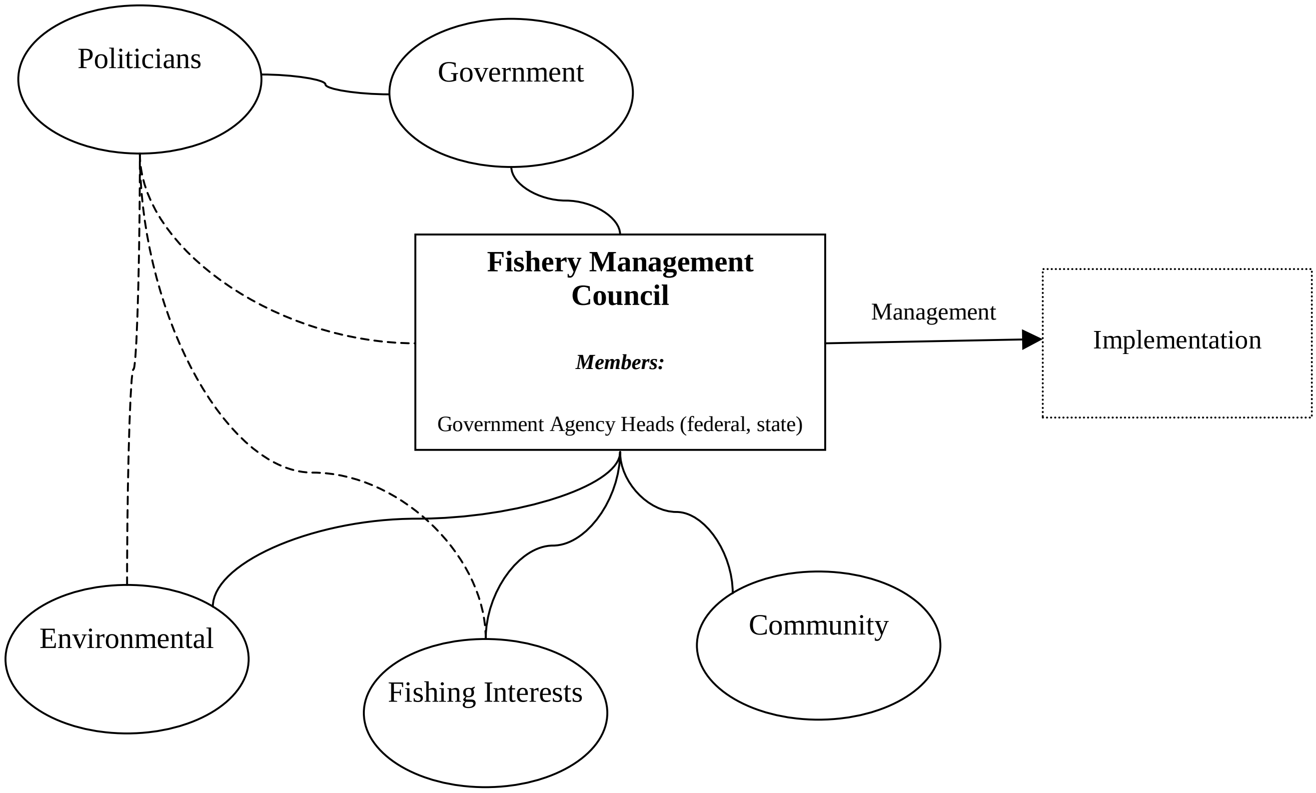


Figure 3.5 Management decision system, USA

Linkages to other subsystems

The MDS is closely linked to the Knowledge Production and Implementation Systems. Information produced by the Knowledge Production System influences decisions made by the MDS. In this sense, the products of the Knowledge Production System are inputs to the MDS.

The products of the MDS are in turn inputs to the Implementation System, namely the management measures applied to the fishery. The management measures – and other policies – produced by MDS are implemented by enforcement and other authorities who comprise the Implementation System.

Analytical methods/approach

In this section we suggest a method for analyzing the dynamics of the collective decision making processes involved in the MDS.

One formal and rigorously developed framework for analyzing the MDS is outlined by Sutinen and Upton (1999). Fishery management policies in their model are the products of what can be thought of as a political marketplace. The principal actors that interact in the fishery political marketplace are politicians, officials of government agencies (including scientists), fishermen and those who depend on them, and environmental advocates. Some of these groups demand and others supply fishery policies and programs.

For example, in the US the eight Fishery Management Councils are the principal venues of this political marketplace. Other venues of the fishery political marketplace include the offices of elected representatives to Congress and State legislatures, and the offices of government agencies involved in fisheries. There is a multitude of actors and opportunities for the interplay among them that influence or determine the nature of fishery management policies. A schematic below illustrates some of the connections among these actors and their role in the fishery political marketplace.

The theory of collective choice (Buchanan and Tullock 1962, Olson 1964) hypothesizes that there are two fundamental characteristics of the principal actors and the products produced that strongly influence the incentive structure surrounding collective decision making and affect how well the political marketplace functions. The two fundamental characteristics are ‘shortsightedness’ and ‘decoupled’ costs and benefits (Wolf 1988).

Analysts use the term shortsightedness to describe the tendency by people to ignore, or give little weight to, future consequences, especially consequences in the medium to distant future. Politicians are active in the fishery political marketplace and they exhibit shortsightedness. They enact special legislation and appropriate tax revenues for fisheries policies and programs; and they periodically attempt to directly influence the contents of fishery management plans. Shortsightedness is a natural attribute of a politician. Politicians tend to be shortsighted because they face short reelection cycles (e.g., of 2, 4 or 6 years). They are concerned about the consequences of policies and programs before the next election. Long-term consequences tend to carry little weight in the calculus of the politician (Buchanan and Tullock 1962).

Fishermen in some circumstance are expected to be shortsighted about fishery management policy. In many managed fisheries those fishermen subject to management policies have no secure claim on future outcomes in their fishery. That is, they have no assurance that they will reap the benefits that might accrue from their short-term sacrifices. They also face great uncertainty regarding future fishery policies, fish stocks and markets. (Healey and Hennessey, 1999)

Not all actors in the fishery political marketplace are necessarily shortsighted. Environmental interest groups appear to embrace the long term, placing great weight on sustaining resources for future generations. Government bureaucrats also may not be shortsighted since they are civil servants and may concern themselves with programs and policies that last beyond the next election. But, bureaucrats are agents of elected politicians and must implement the shortsighted programs of politicians. They also tend to benefit from problems that grow in scale and scope by securing additional resources for their agency.

The second characteristic that strongly influences fishery policies and outcomes is decoupled benefits and costs. For many fishery products, those who benefit are different from those who pay the cost of a product. For other products, benefits accrue at a different point in time from the costs. For example, management policies that restrict fishing effort to rebuild fish stocks tend to impose short-term costs on commercial fishermen, with the benefits expected to accrue at best several years in the future.

Another example of decoupled benefits and costs are vessel/permit buyout programs. The beneficiaries are the fishermen whose vessels are purchased by the program and those remaining in the fishery. The costs, on the other hand, are borne by general taxpayers. The beneficiaries do not pay in proportion to the benefits they receive; and the payers do not benefit in proportion to what they pay.

This collective choice model of the fishery political marketplace yields some specific hypotheses about behavior and the types of policies adopted by fishery management councils and related institutions. One of the principal hypotheses is that the presence of shortsightedness and decoupled costs and benefits works against adoption of effective conservation policies. The incentive structure of the fishery management system tends to disfavor effective conservation policies because the policies impose short-term costs upon resource users in exchange for benefits in the future that would not necessarily accrue to those users who make the sacrifice.

There is some evidence in support of this hypothesis. For example, Fishery Management Councils in the United States have frequently either refused to adopt, or acted to weaken, strong conservation measures in response to pressure by fishing interests. In New England, politicians have intervened on behalf of fishing interests to pressure the National Marine Fisheries Service to approve weaker measures. Moreover, Hennessey and Healey (2000) identify a convergence of political and economic factors that in combination result in decisions leading to the depletion of fishery resources. The New England Fishery Management Council only began adopting stronger conservation measures after a 1991 law suit by an environmental interest group, the Conservation Law Foundation, that imposed deadlines for eliminating overfishing (Sutinen and Upton, 1999).

The theory of collective choice yields other important hypotheses about institutional performance. These other hypotheses involve ‘rent seeking’ (Buchanan 1980, Tollinson 1982), bureaucratic inefficiency (Niskanen 1971, Wolf 1988), ‘log-rolling’ (Buchanan and Tullock 1975, Olson 1964) and others. All of these behavioral hypotheses have significant implications for how well our fishery management institutions perform.

The model of fishery management policy making sketched by Sutinen and Upton is based on a sizable body of literature that has not been applied to fisheries heretofore. Nor have its hypotheses been systematically tested for fisheries MDS. The model is draw from, or based on, the extensive literature on collective decision making. This literature includes the seminal work of Buchanan and Tullock (1962), Olson (1964), Niskanen (1971), Stigler (1971), and Peltzman (1976), among others. It also includes numerous applications of the collective decision making paradigm to congressional voting, bureaucratic behavior and regulatory policy choice (e.g., Campos 1989, Fiorina 1982, Keohane, Revesz and Stavin 1998, MacCubbins 1985, Austen-Smith 1987, Hahn 1990, Magat, Krupnick and Harrington 1986, Spiller 1990, Zusman and Rausser 1994).

Expected outputs

This framework for analyzing and evaluating fisheries management decision making is intended to achieve the following specific objectives:

To develop a collective choice model of fishery management policy-making;

To test hypotheses derived from the collective choice model; and

To identify ways to improve the performance of Management Decision Systems.

The analysis is expected to produce peer-reviewed publications that improve our understanding of how and why actual the MDS in various fisheries works. These outputs will result in a more a comprehensive view of the entire system for developing and implementing fishery management policy.

Data Required/Anticipated

The first task of the analysis is to describe the MDS. The data and information needed for description is relatively straightforward. Descriptive information is needed on the laws, regulations, management measures, organizations, persons and groups, and processes involved in the MDS.

The analysis, which has the aim of explaining and evaluating how the MDS performs, will involve testing hypotheses derived from a well-formulated theory. Testing these hypotheses requires obtaining data from actual decision making by fishery management councils and agencies. These data may include votes and other activities related to making management decisions. Since this type of analysis has not yet been done in fisheries, it is not completely clear what data can and should be used for this purpose. Therefore, the specific data collection and analysis methods have yet to be developed for fisheries. Researchers will benefit from applied analyses of collective choice in other areas, such as those done for forestry, environmental and other regulatory policy decision making (Keohane, Revesz and Stavin 1998, Magat, Krupnick and Harrington 1986).

3.2.4 Implementation system

Definition of the management implementation system and processes to be analysed

The implementation system covers agencies and organisations that are concerned with implementing, monitoring and enforcing the various management measures that has been negotiated by the fishery management bodies.

The arrangements for implementing fishery management systems vary considerably across countries and fisheries. For some of the larger international fisheries, the implementation systems may be complex, involving agencies at both the supra national level (e.g. fishery commissions, EU) and at the national/regional level. The numbers and mixture of implementation tasks may vary considerably but will typically include compilation of catch and effort statistics and monitoring and enforcement of several fishing regulations (closed areas and seasons; by-catch, discard and legal landing size rules, gear and mesh-size restrictions etc).

National fishery laws typically establish the legal rules and principles that define the authority and structure of fishery management agencies, including the agencies designated to enforce management regulations. For example, US fishery law established and authorises fishery management councils to develop fishery management regulations to submit to the Secretary of Commerce for approval and implementation. Several agencies are typically charged with the many responsibilities of fishery management, including enforcement of management regulations. The National Marine Fisheries Service and Coast Guard in the US enforce the regulations, the Office of the General Counsel (part of the Department of Commerce) prosecutes, and a special administrative law court adjudicates federal fishery cases.

The primary functions of fishery management agencies encompass a wide range of tasks involved in the development and implementation of fishery management regulations. The regulations are commonly directed at fishers, though fish processors and dealers are also subjected to regulation in many fisheries.

Included in the many tasks of implementing a fishery management program are monitoring and enforcing regulations. The monitoring and enforcing tasks may be the sole responsibility of one agency or shared among agencies. Monitoring the regulated fishing activities is commonly done by the fisheries agency. Permits or licenses, if required, must be issued. If logbooks on fishing activity are required, they must be processed and analysed. Regulations which restrict fishing time (such as days at sea) or catches (quotas) must be monitored, either for individual fishers or for the fishery as a whole. Some fishery management plans require fishers to notify the agency in advance of their intent to embark on a trip and/or to land their catches, to use specific gear, etc. – all of which must be monitored.

A specialised enforcement division, within the fisheries agency, often bears the principal responsibility for enforcing fishery regulations. The enforcement division shares or co-ordinates its surveillance with other enforcement agencies, such as the coast guard, marine police and navy. But, enforcement of the regulations may also be carried out by an agency separate from the one formulating the regulations. And, too often, enforcement authorities play either no or a small role in setting such regulations. Similarly, managers typically play no or a small role in the policies and practices of enforcement.

In concrete fisheries there are numerous examples of significant violations of the fishing regulations but comprehensive evaluations on the efficiency of particular implementation schemes are generally lacking. There do however exist socio-economic works that has explored relations between effort levels in implementation, the juridical sanctions and the compliance behaviour. Game theory suggests that that there might be cases where the incentive does not exist for effective enforcement, in particular at the supra national level.

Linkages to other subsystems

The Implementation Subsystem is linked directly to both the Management Decision System and to the Adaptation System. The MDS determines the specific regulations and other measures that the Implementation System is tasked with implementing via monitoring and control of the fishery. The Implementation System, via its surveillance and sanctions it produces, attempts to control – or at least influence – users of the fishery resources in the Adaptation System.

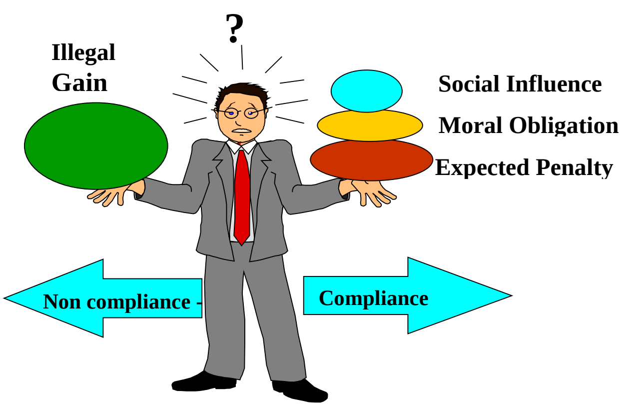
Analytical methods/approach

Theory of enforcement and compliance

The purpose of a fisheries compliance programme is to have fishers comply with conservation and management regulations. Therefore, we need to understand why people comply, and why they do not. We begin by reviewing the basic theory of compliance behaviour, first for the individual and then for fishers as a group.

Individuals generally tend to consider four factors when faced with a decision whether to comply with a law or regulation: the amount of illegal gain or benefit, the expected penalty, moral obligation, and social influence. This is illustrated by the cartoon in Figure 3.6.

Figure 3.6. The Compliance Decision



The illegal gain or benefit in a commercial fishery is the amount of added income that can be earned from violating a regulation. In a recreational fishery, the illegal benefit usually is the added value of fish taken illegally. It is this added illegal gain that usually temps people to violate a fishery regulation, though in some cases violations are inadvertent or due to ignorance.

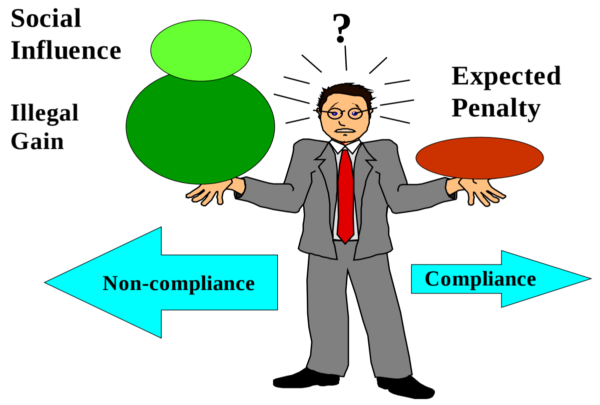
The expected penalty works to deter individuals from committing a violation. If large enough, the expected penalty can offset the illegal gain and remove the incentive to violate. Unfortunately, this is rarely the case. As explained below, the expected penalty usually is small relative to the illegal gain.

If the individual believes complying with the regulation is the ‘right thing to do,’ s/he will feel a moral obligation to comply. An individual disagreeing with the regulation, or management policy and procedures, may feel the opposite, and be obliged to violate the regulation. The basis of moral obligation is discussed in more depth below, as it is an important consideration when setting and implementing policy.

Most individuals also are influenced by their peers, or people who matter to them, when deciding whether to comply. Social influence is known to play a significant role in everyday social exchange, often taking subtle forms of ostracism or withholding of favours. A group of fishers can reward and punish its members, either by withholding or conferring signs of group status and respect, or more directly by threatening them with sanctions.

These four factors do not always influence individuals as portrayed in Figure 3.6. In some fisheries there is no moral obligation to comply and social influence is on the other side, encouraging individuals to violate (Figure 3.7). This was the case in the New England groundfish fishery during the late 1980s where the pressures from crews and competition with others drove captains of vessels to fish in closed areas and use illegal nets on most trips (Sutinen, et al., 1990). In such cases, compliance programs must not only strive to increase deterrence (i.e., the expected penalty), they also must strive to build a strong sense of moral obligation to comply among fishers and to shift social influence to the side of supporting compliance with the regulations.

Figure 3.7. Undesirable Compliance Context



Each of the four factors is discussed in more detail below, for each is influenced by fishery policy and each in turn influences the extent to which fishery policy is effective.

Illegal Gains

The amount of potential illegal gains in fisheries often is quite large. For example, in the New England groundfish fishery referred to above, Sutinen, *et al*. (1990) found a large percentage of fishers were earning illegal gains of about a quarter of million dollars per year. In some cases illegal fishing trips earned three times the revenue of legal trips. Not all fisheries offer such large potential illegal gains, of course. The important point, however, is that often the incentive to violate can be very powerful and difficult for fishers to resist.

Potential and actual illegal gains are dynamic, frequently changing, and are influenced by several conditions in the fishery. The regulations influence the extent of illegal gain. In general, the more restrictive the regulation, the greater the potential gain from violation. Biological conditions are a major factor determining illegal earnings relative to legal earnings. The size, location and composition of the fishery resource, which are constantly in flux, strongly influence where and how fishers can earn the most income. Prices and market conditions also affect the prospects for illegal gains and thereby influence the amount of compliance in a fishery.[2] A compliance programme must account for the nature and determinants of illegal gains and be prepared to adapt and adjust to these conditions as they change over time.

Expected Penalty

The expected penalty is equal to the size of the penalty times the probability of being caught and convicted of the violation. The magnitude and nature of the penalty or sanction is often constrained by law and determined by the judicial system. The average size of the penalty for any given violation usually is less than the maximum allowed by law. Even where not constrained by statute, the courts usually limit the size of the violation to reflect the amount of social harm done by, or amount of illegal gain realised from, the violation(s) for which the individual is convicted.

Penalties generally are not large relative to illegal gains. For example, in the groundfish fishery of the Northeast United States, Sutinen, et al. (1990) estimate flagrant violators grossed about $15,000 *per trip* from violating closed area and mesh size regulations, resulting in illegal earnings of $225,000 during 1987. Typical penalties, when caught and sanctioned for these violations, ranged from $3,000 to $15,000 in monetary fines.

---

[2] For more discussion of these conditions and how they influenced compliance in the New England groundfish fishery, see Sutinen, et al. (1990).

The probability of being caught and convicted is usually small, very small. The typical odds of being caught violating a fishery regulation are below one percent, and often at or near zero (Sutinen and Gauvin, 1989, Bean, 1990, Furlong, 1992, Kuperan, 1992).

When the small probability is multiplied by the modest penalty usually imposed, the expected penalty most fishers face is small. It is regarded by many fishers as a ‘cost of doing business.’ A similar pattern of the certainty and severity of sanctions relative to potential illegal gains tends to appear in most fisheries. Raising penalties to the point where the expected penalty offsets illegal gain generally is not feasible. The courts are not willing to mete out sanctions perceived as excessively severe. Rather, courts tend to impose sanctions that fit the crime, as measured by the illegal gains realised or the social harm caused by the *detected and proven* violation.

The implications of this evidence are clear. Compliance policy cannot depend exclusively on deterrence to insure a high degree of compliance among most fishers.

Moral Obligation

Despite the strong incentive to violate (high potential illegal gain relative to the expected penalty), a high proportion (half to 90 percent) of fishers normally comply with regulations (Sutinen, et al 1990, Sutinen and Gauvin 1988, Bean 1990). This pattern is typical is regulated fisheries.

Asked why they persist complying when illegal gains are much larger than the expected penalties, many fishers refer to the need to ‘do the right thing.’ That is, they express an obligation to obey a set of rules (either their own or an authority’s). The sense of moral obligation is common throughout society and may be a significant motivation explaining much of the evidence on compliance behaviour.

An individual’s moral obligation to comply is the result of two forces: the individual’s moral development and standards of personal morality, and the individual’s perceptions of how just and moral are the rules and regulations. That is, the moral obligation to comply is based on individuals’ perceptions of the fairness and appropriateness of the law and its institutions. These are factors that policy formulation and implementation can and should influence to build compliance.

Social Influence

Social influence in fisheries is often manifested in forms of verbal and physical abuse (e.g., fist fights, destruction of gear and vessels). In the Massachusetts lobster fishery strong forms of social influence, commonly called ‘self enforcement,’ is estimated to account for the bulk of enforcement in the fishery (Sutinen and Gauvin, 1988). Fisheries with which I am familiar where social influence to comply with management regulations is prevalent, and appears highly forceful, include American lobster (Massachusetts and Maine), clam (Rhode Island), herring roe (Alaska, British Columbia, Oregon, San Francisco Bay), sakuri ebe (Japan). There probably are many other fisheries where this phenomenon is operative.

Social influence and moral obligation are closely linked. The standards an individual uses to judge his/her own behaviour are used to judge others’ behaviour. Therefore, the moral principles on which individuals base their own behaviour are also the basis for the social influence they exercise. The more widespread a common moral obligation is in the fishing population, the stronger social influence is expected to be. An important implication of this linkage is that policies which strengthen the moral obligation to comply also strengthen social influence.

Aggregate Compliance Behaviour

All fishers are not alike in their compliance behaviour. Some are more compliant than others, reflecting variations in the size and nature of the four forces of compliance. For example, some fishers invest in methods to avoid detection and face lower probabilities of detection than other fishers (Anderson and Lee, 1986, Bean, 1990). Others have a stronger moral obligation and face more social pressure to comply (Gauvin, 1988).

The available evidence suggests that within the typical population of fishers there is a small core subgroup, of about 5 to 10 percent of fishers, which tends to violate chronically and flagrantly. They are motivated largely by the tangible (usually financial) gains from illegal fishing. Moral obligation and social influence have little or no effect on their behaviour. Only by changing the economic incentives, by reducing the potential illegal gains or by increasing the expected penalty, can their illegal fishing be controlled. In the absence of incentive programs, the only control mechanism for this subgroup is enforcement.

The remainder of the population consists of a small fraction (5-10 percent) that is strongly influenced by moral obligation and comply most, if not all, of the time, and a large portion that normally complies, depending largely on the degree of social influence they face. This latter group typically consists of about 80 to 90 percent of the fishing population.

The result is that most of the non-compliance, and most of the risk to conservation and management of a fishery, is usually perpetrated by a relatively small number of fishers. These fishers can only be controlled by enforcement and other tangible incentives. The non-compliance by the vast majority of fishers is on a small scale, is often inadvertent or opportunistic, and can be controlled by non-coercive methods.

Enforcement

We can define enforcement as the set of policies and actions that compel fishermen to comply with fishery regulations. Many enforcement authorities would agree that their principal job is to deter fishermen from violating regulations. In other words, they focus on producing deterrence as their principal task. Progressive enforcement programs view the role and tasks of enforcement authorities more broadly. In our view, compliance can be best achieved by a 'carrot-and-stick' approach, where enforcement authorities aim to both deter non-compliance and also to induce voluntary compliance using non-coercive methods. Therefore, we choose to divide the services that produce compliance into two major categories: enforcement and compliance-building services. Enforcement, as the name suggests, involves using the coercive powers of the state to produce compliance. Compliance-building services include actions and programs that encourage people to comply voluntarily without the threat of sanctions.

Enforcement tasks include detecting violations, prosecuting alleged violators and, sanctioning violators. As explained above, enforcement authorities use a variety of methods to detect violations, including patrols at-sea and dockside to inspect fishing vessels and monitor fishing activity. Observers, electronic monitoring and audits also are used to detect violations. Prosecutors assemble the evidence collected, officially charge the individual(s) with the violation(s), and present the case to a court of law (or similar adjudication process) or settle the case out of court. The court hears the case and decide whether to convict the alleged offender and, if so, designate the sanction to be imposed. Most fisheries offences are sanctioned with civil penalties, which include monetary fines. and the authorities, usually the prosecuting authorities, are responsible for collecting or carrying out the designated sanction.

Enforcement produces deterrence by threatening sanctions against fishers that are violating the regulations. Enforcement is a process involving several steps and actions by governmental authorities that, together, form the 'chain of deterrence.' We use the term 'chain' to denote the critical linkage between the steps of the enforcement process and to emphasise that the potency of the deterrence produced is no greater than its weakest link.

To enforce management regulations, authorities must detect a violation, prosecute the alleged violator and, if found guilty, sanction the violator. A typical chain of deterrence has the following steps and actions, each with an associated probability:

Step 1: The first and essential step is detection of the violation. A fishery enforcement officer obtains evidence that one or more regulation has been violated by a fisher.

Step 2: The officer files the evidence and other specifics of the violation with a governmental prosecuting office. Prosecuting officials review the evidence and decide whether to issue a notice of violation to the fisher alleged to have violated the fisheries law. If the evidence is sufficient, a notice of violation (NOV) is issued and sent to the parties involved. If the evidence is insufficient, the case is dropped or dismissed.

Step 3: In response to the NOV, the fisher can either attempt to settle out-of-court with the prosecuting office or proceed to an administrative hearing, which can take the form of a trial before a court.

Step 4: When settling out-of-court, the fisher may be able to negotiate a partial penalty less than the full penalty set by law or the penalty schedule.

Step 5: If the fisher either chooses not to, or cannot, settle out-of-court, he stands trial in court where he faces the chance of being convicted.

Step 6: Under some circumstance, the fisher may appeal his conviction by the court and have his conviction upheld or overturned.

The processes and steps described here are not intended to apply to all fisheries enforcement programs. Each program has unique processes and steps. But all programs tend to involve a sequence of steps that together form the chain of deterrence, some with more steps and more complicated processes than others.

The processes and activities involved in each of these steps can be described and their efficacy can, in principle, be measured (e.g., see Sutinen, Rieser and Gauvin 1990).

Scope for analysis

Thorough descriptions of the structural set ups and analysis of the functional behaviour is needed to allow evaluations of the efficiencies of the implementations schemes in use. Potential analysis may include:

- Analysis of the successfulness of implementation, i.e. evaluating whether the ex ante benefits anticipated have actually been achieved
- The enforceability of various management measures given the economical and logistical constraints embedded in concrete implementation schemes
- Cost efficiency of different regulation types and implementing schemes to achieve stipulated goals
- Compliance attitudes and adaptive responses towards different regulation s and implementations
- Importance of sanctions (or rewards) for compliance and adaptive behaviour
- Concordance between the implementation scheme and the incentive structures, including the involvement of stakeholders in the implementation process.

Approaches and methods

The majority of available work on management measures and their implementation are based on several disciplinary approaches, e.g. cost-benefit analysis, econometric analyses of compliance behaviour, game theory, normative economic models, simulation studies and in depth interviews to determine important factors influencing compliance behaviour using sociological and criminological methods. The Working Group notes that comprehensive knowledge of the overall efficiency is generally not available and suggests that detailed empirical studies are carried out. Such studies may require multidisciplinary approaches. As the implementation schemes differs considerable and as the issues of potential interests are diverse the group did not attempt to short list appropriate approaches. For compliance studies the methodology has been developed, but need to be modified for specific studies. There appears to be a need to develop a thorough method to cover all relevant aspect of the implementation process, in particular, on how to collect and measure the cost of implementation.

Examples of the methods that have been used to assess the performance of compliance and enforcement systems in fisheries include Sutinen (1996), Sutinen and Gauvin (1988), and Sutinen, Rieser and Gauvin (1990). Researchers in Europe, North America and Asia currently are further testing and refining methods for this purpose. The Working Group suggests that some of these research analysts become involved in conducting implementation evaluation studies for ICES member country fisheries.

Expected Outputs

The results of research on the Implementation System is expected to provide more information on how implementation is conducted in practice, the overall performance of implementation programs and detailed insights into how the Implementation System may be improved.

Data requirements

The information requirements will differ according to the management measures evaluated and the actual scope of analysis. It may include data traditional available (e.g. catch and effort statistics) supplemented with economic data and attitude information gathered through interviews. Good examples of the type of data that can be used to study Implementation Systems include Sutinen and Gauvin (1988), and Sutinen, Rieser and Gauvin (1990).

3.3 Interdependencies between subsystems

The four subsystems are closely interlinked. Linkages are both direct links between subsystems along the chain and indirect links such as the significance of user accept of the stock assessment process for the legitimacy of management measures in the implementation process.

Examples of linkages are:

The Knowledge production system is influenced by:

- management measures – the knowledge about the system to be produced depends on management measures for which advice are requested
- requirements for acceptability among stakeholders

The knowledge production system influences:

- the management decision process – ability to address issues and present to stakeholders
- the implementation process – user accept of the validity of stock assessments will influence the legitimacy of management measures

The management decision system is influenced by:

- the relevance and presentation of knowledge products
- the acceptability of knowledge products
- information about implementation system performance (implementation possibilities)

The management decision system influences:

- the knowledge production system – requests for advice
- the knowledge productions system – direct and indirect pressures
- the implementation systems – defining what to implement
- the implementation process – participation in management decisions increases compliance ?

The implementation system is influenced by:

- the products of the management decision process
- the procedure (participation) of the knowledge and management decision systems
- the adaptability of the fleets

The implementation system influences:

- the management decisions to the extent they are based on understanding the efficiency of implementation
- the knowledge production system – data availability and quality
- adaptation

The adaptation system is influenced by:

- the efficacy of implementation

The adaptation system influences:

- management decisions
- the knowledge production system – data availability and quality
- the knowledge production system – can prognoses catch adaptations

3.4 Criteria for performance evaluation

This section discusses the concept and the use of the concept "Performance criterion", rather than attempting to give an exhaustive list of performance criteria. One point made below is that a complete final list of performance criteria cannot be made.

By a "performance criteria" or a "measure of performance" is understood, a "key-indicator" showing something essential about the present status of the fisheries system or the marine ecosystem. What the word "essential" means is related to groups of stakeholders, as stakeholders have different and sometimes conflicting objectives. Only a few global performance criteria are accepted as essential by all stakeholders, although the different stakeholders will give different emphasis to them. Therefore, performance criteria can conveniently be defined relative to stakeholders. The four main groups of stakeholders identified were:

The fishing industry (Harvesting and Processing sectors)
The government treasury
Society in general
Society concerned with nature conservation

More stakeholder groups can be defined, and the above four groups can be further divided.

Performance criteria was grouped by "dimensions", such as "Economic", "Social", "Ecological" and "Governance", in the "FAO guidelines for development of indicators". This grouping, however, is not very much different from the grouping according to stakeholders, as stakeholders somewhat reflects the dimensions. Grouping according to stakeholders should secure that all major requests from society can be met, and it furthermore facilitate the justification of using the performance criteria in question.

All performance measures, however, should to some degree be accepted by all stakeholders. The allocation of a performance criterion to a stakeholder means that the stakeholder in question give highest priority the criterion in question.

A performance criterion may or may not be an objective in itself. Combinations of performance criteria can lead to objectives (for example: The performance criteria: Costs of fishing and revenue from fishing provides the objective: Cash flow = Revenue – costs, which we may also consider a performance criterion).

The performance criteria should reflect the average status of the system during a certain time period (say 1 year, 2 years or a decade depending on the use of the criteria), it should not reflect a "snapshot" of the situation. For example, one year of accidental very low recruitment to a fish stock should not be reflected in the performance criteria, but a longer sequence of low recruitment years should.

Whenever possible and/or meaningful, the performance criteria and derived objectives should be given in relative terms (scaled to some reference point) to allow for comparisons of different fisheries/ecosystems.

Reference points should be defined for all performance criteria which are also objectives, indicating the status of the system relative to the performance criteria in question. Reference points may be categorised according to success, such as "poor", "average" and "good". It should be recognised that the definition of reference points often cannot be made on scientific grounds. Only when clear objectives have been defined by decision-makers may it be possible to derive reference points on a scientific basis.

Performance criteria should be selected not only because of their capability to describe the status of the system, but should also be selected so that they are easily understood and accepted by the stakeholders and by the public in general.

The combination of performance measures to an overall objective for the entire system is a political process. The scientist's contribution is the provision of a suite of management measures, which can meet the requests from all groups of stakeholders, and which allows the managers to make decisions on a rational basis. The list of performance measures will therefore be under continuous revision and development. It is thus better to have one performance criteria "too many", than missing one, although a large number of performance criterion is not a goal in itself.

Performance criteria may be measured in financial units, economic units, biomass units, mortality rates, employment units, units of variability (or risk) and in units of benefit (or damage) to society in general.

Performance criteria may be presented as a single figure, or as a probability distribution. It may be given for each time period in a dynamic presentation, or as a value combined for all time periods (For example, financial performance criteria of a time period may be combined in one criteria-value by the Net Present Value)

Performance criteria should be defined according to well established and generally accepted methodologies, possibly with the endorsement of recognised international organisations. Application of controversial theories should be avoided when defining performance criteria.

This working group will undertake the task of defining a minimum set of performance criteria, which can be applied to any case study. This task will be completed in meetings following the present meeting.

3.5 Summary of research needs

As chapter 2 shows, there are some recent initiatives on developing frameworks for evaluating fishery system performance. However, fishery systems are complex and vary extensively, thus vast, inter-disciplinary knowledge is needed in order to evaluate fishery system performances. So far, only a few fishery systems are evaluated. To achieve a broader understanding in this field, it is necessary to:

- Develop methods and analytic approaches to subsystems of fishery systems (see Fig. 3.2)
- Develop methods and analytic approaches for synthesising subsystem models
- Implement the points above on case studies.

Traditionally, ICES has concentrated on resource issues, which only covers the box on the right in Fig. 3.2. This WG finds it necessary that ICES starts focusing on the other processes in the fishery system. *Examples* of research issues that need to be addressed are:

- Study fishers behaviour with special focus on the response to the implementation of regulations
- Investigate effort allocation given economic and management constraints.
- Develop political-economics models of fishery management decisions
- Evaluate efficiency of enforcement of e.g. closed areas
- Evaluate the ownership to the knowledge base for fisheries management and the implications of this ownership for compliance

The aim is to put more effort into research issues related to those mentioned above to make the picture of processes in Fig. 3.2 more complete. To achieve this, ICES needs to attract scientists from disciplines that traditionally have not been connected to the ICES system. In chapter 5 some suggestions are pointed out on how to do this.

4 CASE STUDIES

4.1 Selection criteria

In order to find suitable case studies to further explore and develop the framework given in section 3 we have listed a few selection criteria.

1. The case studies should cover all 4 subsystems including:

   - Models of the management decision system
   - Models of the implementation and enforcement process
   - Models of the industry’s adaptation to the enforcement
   - Models of the resource system

2. The different subsystems should also be related through information and decision processes in addition to the direct influence. Special focus should be made on the management systems (decision and implementation/enforcement) in order to enable the evaluation of alternative systems (robust, cost-effective and sustainable).

3. The different case studies should cover a broad range of fishery systems starting with the most simple ones and then move into more complex systems. Complexity should be viewed in relation to the different subsystems, but also in relation to the level of knowledge within each subsystem. This could include:

   - One nation, one fleet, one species systems
   - Multination, multifleet, mixed species systems
   - Systems managed by TAC control or by technical measures (e.g. effort control, licensing)
   - Data intensive knowledge production systems (e.g. age based) or simpler systems (e.g. production models)

4. The overall criteria for selecting any case will depend on the logistics eg availability of data, expertise, funding and institutional interest and participation, in order to deliver a product.

4.2 Candidates

The following case studies were suggested (details in Table 4.1):

The 'simple' cases (one nation, one fleet, one species) - one or two may be developed into a research project or they could be covered based on existing info under a concerted action:

- Scallops fisheries France
- Mussel fisheries Wadden Sea Denmark
- Channel Island fisheries
- Faroese fisheries
- Iceland cod

NS flatfish - 'classical' human consumption demersal fisheries - multiple fleets, multinations, mainly TAC controlled but tech measures important. Decommission programme analysed here. Good data for assessment, some data for bioeconomics exist.

NS industrial fisheries - mainly managed by technical measures (by-catch, gear restrictions, closed areas), 'green' considerations important in management. Biological data and data on compliance exist.

Barents Sea cod fisheries - international management, multifleets.

New England Groundfish fisheries. Data for parts of the 'left hand' models exist.

A range of fisheries/studies could be pulled into a concerted action to apply the framework based on existing data: Australian shark, Bay of Fundy herring, Pelmodel, Iceland cod.

Case **Potential partner institutions** **Potential funding source**	**Management decision system** **Objectives (F based, stability), multiple objectives (shared resources)** **Existing data, information on or background for changes?**	**Implementation/enforcement** **TAC, effort control, licensing, mesh size regulations, area closure etc.** **Existing data, implementation costs etc.?**	**Fishery adaptation** **Different fleets, access to other fisheries, single or mixed species fishery** **Existing data or studies, economic studies, fishermen behaviour, data on discards/highgrading?**	**Perceived production system** **Age based, VPA family, production models**
NS demersal fisheries (flatfish and cod)	Multinational, discards and ecosystem effects are considered important. Data on the decision system is needed	TAC controlled, tech measures, decommissioning program Data on the implementation strategy is needed	Multiple fleets	Good data for assessment
NS Industrial fisheries	Multinational, no overall management strategy, but some ecosystem considerations (availability of sandeels to sea-birds and seals)	By-catch regulations, gear restrictions, closed area, recently also TAC	Danish and Norwegian trawlers. Both sandeel and Norway pout caught by the same fleets.	Catch data and detailed biological data are available
Scallop fisheries, France	Management consists in a combination of catch quotas, effort restrictions and technical measures.	Nominal fishing effort is directly restricted by a system of fishing licences, and limitations on the number of fishing hours per day. The authorised number of fishing hours is updated during the fishing season in relation to the informative catch quota. Technical measures include season closure, minimum landing size, gear and horsepower restrictions. The implementation of management is controlled under aerial og coastal surveillance.	Scallops of the Bay of St-Brieuc (France) are exploited by one directed fleet (dredge) belonging to one nation (France). Fishermen have reacted to the restrictions on fishing inputs as follows: In case of good recruitment, the fishery has concentrated intensively on fishing grounds known for their high scallops density. In case of bad recruitment, fishermen spread out in quest of other fishing grounds.	Annual catch quotas are calculated every year through cohort analysis by IFREMER, and submitted to local fisheries committees

Mussel fisheries, Wadden Sea Denmark	National. Formalized co-operation between fisheries and environmental authorities (ecosystem considerations mainly to allow availability of mussels to birds).	Licenses, TAC, gear restriction, min. landing size, closed areas (to protect habitats).	Small local fleet exclusively engaged in Wadden Sea mussel fishing.	Mussel assessment based on stratified survey (strata defined from air photography, sampling by dredge or frames within strata). Bird abundance assessed by environmental agency.
Barents Sea cod The Directorate of fisheries, Fiskebåtredernes forbund, Norges fiskarlag, University of Tromsø Norwegian Research Council	2 nations, fish at F=0.42 or below, keep SSB at or above 500 000 tonnes. Strategy not used for 2000. No clear formulation of management objectives	TAC (not following the strategy), mesh size and sorting grid regulations, minimum landing size, area closures, onboard inspections.	Mainly Russian and Norwegian trawler fleets, traditional coastal longlining, gillnetting and Danish seine (Norway) and increasing high intensive longlining with ocean going vessels (Norway).	XSA including cannibalism, tuned with 4 surveys and 1 commercial CPUE-series. Bad retrospective pattern, 20 % underestimation of F in the assessment year.
New England groundfish fisheries				
Canadian 4WX (Bay of Fundy) herring (ref: Stephenson *et al* 1999. ICES JMS)	Single nation jurisdiction. Considerable industry involvement in in-season management. Specific biological objectives	TAC, ITQ, in-season management including time-area closures and sub-allocation of TAC	Canadian purse seine, gillnet and weir (trap) fisheries with good documentation	Industry acoustic surveys. Historical SPA using research (larval abundance) survey. Good sampling and fishery information
Canadian 4X/5 groundfish fisheries (ref: Sinclair *et al* 1999. ICES JMS)	Single nation and bilateral jurisdiction. Multiple objectives. Considerable industry involvement in management (community management boards)	TAC's, EA's, ITQ's, community quotas	Canadian trawl, longline, gillnet fleets. Some stocks transboundary with US fleets	Most stocks have age-based assessments calibrated with research surveys (bottom trawl) and CPUE

Pelmodel Bio-economic evaluation of management options for NS herring and small-mesh fisheries Potential partnership: As for the PELMODEL project EU Shared-Cost project No.97/SE/002	International	TAC's, bycatch regulations and technical management measures	International, multi area and multispecies fisheries.	Well studied fisheries and stocks

5 A WORKPLAN FOR DEVELOPMENT OF FRAMEWORK AND METHODOLOGY

5.1 Overall workplan

The working group will proceed by refining and testing the framework on designated case studied as discussed in section 4. However, there are two conditions for a successful outcome:

- Social scientists covering relevant disciplines must be attracted to take part in case studies and in working group meetings
- Work on case studies must be done intersessionally, working group meetings can only synthesize and evaluate results which basically have been produced in research work done outside working group meetings.

Both conditions are contingent on identification of funding sources.

The low representation of social scientists in the present WG meeting (two out of 14 participants of which one only participating in half of the duration of the meeting) is due to 1) the fact that social sciences are absent or only marginally present in the institutions normally participating in the ICES work and 2) that other academic institutions do not have access to funding to send staff members to ICES working groups. Before the present meeting several social scientists with a record in fisheries management research were approached and there was definitely interest in participating. However, it was not possible for any of the interested social scientists to identify funds to attend the meeting and other sources were not available. The work programme of the WG cannot be implemented without a considerably larger input from the social sciences. It is therefore necessary to identify funding for such participation.

The institutions involved in ICES work do not have resources to take on the case studies within their existing budgets. This is even more the case because new disciplines must be covered which are not available within the existing staff profiles of the biological research institutions. Intersession work on cases is therefore dependent on new funding being identified.

The work plan for the working group must therefore include a funding plan.

The working group proposes the process to proceed as follows:

Autumn 2000:

- Proposals are developed and submitted to the EU 5th framework programme and to North American research funds covering (see details in section 5.3) :

    - Networking costs including travel of participants from institutions not normally participating in ICES WG's and research components to supplement and synthesize existing case studies in relation to the framework proposed

    - A number of case studies

Summer 2001:

- the first case studies are initiated dependent on funding

- 2nd WG meeting to refine framework in relation to case studies, to synthesize work on existing case studies and to develop performance evaluation criteria

Autumn 2001 – spring 2004:

- work on case studies

Autumn 2001:

- Presentation of framework and cases, Theme session ICES ASC

Summer 2002, 2003:

- 3^{rd} and 4^{th} WG meeting to follow up on case studies and develop approach to synthesis and evaluation. Finish work on minor case studies

Summer 2004:

- 5^{th} WG meeting to finalise case studies and synthesize framework development

The WG meetings will – especially in the initial stages – comprise a considerable element of cross-education between social and biological sciences as has also taken place on the first WG meeting. Specific workshops in connection with WG meeting may be arranged if funding is identified.

5.2 Terms of Reference for future work of the Working Group

The core TOR for the future work of the Working Group remains:

a) develop a framework and methodology for the analysis of fishery system performance;

At its meeting in 2001 the WG should address the needs for methodological refinement in the initial stages of case studies:

b) refine and specify methods to be used in case studies

Furthermore, the present meeting has demonstrated that there is a need to develop performance criteria on basis of literature, but specific to the needs of the WG objectives:

c) develop criteria for performance evaluations of fisheries management

Finally, there will be an ongoing need for the duration of the case studies to follow up:

d) discuss progress in implementation of case studies and adapt work plan

Specific TOR's for individual meetings will depend on the case studies to be undertaken.

By developing the framework and testing and refining it on case studies as described in the present report the WG should contribute to the priorities 3c of the Strategic Plan of ICES and the objectives of the RMC relating to priority 3c: to establish and maintain links and dialogues with other disciplines, agencies and interested parties and to establish a framework for evaluation of management regimes and alternative management strategies

5.3 Funding plan

The working group discussed the need to acquire funding to support progress in this initiative. There is a need for new work and for workshops in which the framework and methodology can be developed and tested. The initiative will require the input of some researchers who have not traditionally been part of the ICES system. Several of the most desirable contributors are in academic or other institutes which will require funding in order to attend. The Working Group therefore proposed:

1) the development of a concerted action application to fund networking costs including participation in meetings and studies on existing cases, and
2) the development of a proposal for case studies in the Eastern Atlantic
3) the development of a comparable proposal for funding of case studies in the western Atlantic.

These proposals would be cross referenced so that there was the explicit opportunity for travel to meet and compare case studies. ICES will be asked to support both funding proposals by letter or resolution as appropriate.

The proposals will be submitted by October 2000 for the 5^{th} framework programme and to North American funding sources. Meeting costs can also be applied for in NATO.[3]

---

[3] During the proposal preparation period after the WG meeting it was decided to merge the networking (concerted action) and North Sea case study proposals into one proposal – the EFIS.

5.3.1 Concerted action

A proposal for a concerted action will cover:

- WG participation of social scientists from institutions not normally participating in ICES WG's

- Workshops and intersessional work to supplement and implement framework on cases for which data are available

Partners will include RIVO, DIFRES, MRI, CEFAS, Univ Rhodes Island and IFM

A range of institutions will be approached for participation: LEI, Rutgers University, Univ. of Oregon, Univ of Tromsø, Univ Hull etc. (see footnote 3).

5.3.2 North Sea fisheries case study

A research proposal will be submitted to the second call of the EU 5th framework programme (11 October 2000) under the title: **E**valuation of **FI**sheries **S**ystems in relation to knowledge production, political decision making, management implementation, fleet adaptation and resource abundance (EFIS**.**

The project will aim to develop methodologies to evaluate fisheries systems and to apply these methods for the evaluation of the North Sea demersal and industrial fisheries in response to resource abundance, political decision making processes, management implementation and enforcement and fleet dynamics (adaptation) including compliance behaviour.

The North Sea demersal fishery is understood to cover the fisheries for flatfish and cod in the southern North Sea. The main characteristics of the fisheries are that they are mixed fisheries and that the resource base is relatively simple and well studies. The major countries active in this fishery are Denmark, the Netherlands, Germany, Belgium, France, England and Scotland. Management of these fisheries is by TAC regulations, technical measures and vessel buy-back programs. Discarding and ecosystem effects are considered important collaries of these fisheries. Data is currently being made available on the resource basis for this fishery and work has also been done on the adaptation system (both the compliance behaviour and the effort allocation behaviour).

The North Sea industrial fishery is mainly carried by Norway and Denmark. The fishery has only recently been managed by means of TAC's. Closed areas and effort regulations have also been applied. Furthermore, this fishery would provide an interesting case study because the management system is for an important part influenced by environmental concerns, e.g. availability of sandeels to sea-birds and seals. Detailed biological information is available.

The project will depend on the availability of data on the Management decision system and the Implementation system. This information should preferably be derived from direct observations of political or managerial meetings. Alternatively information could also be derived from direct interviews with key-players.

Potential partners in the research include social scientists, economists and biologists from institutes in Tromsø, Bergen, Aberdeen, Lowestoft, Portsmouth, Hull, York, IJmuiden, Oostende, Nantes, Rennes, Brest, Copenhagen and Hirtshals.

The project is envisaged to last for three years and to focus on method development, data collection and collation, and analysis.

5.3.3 Case study proposal: New England Scotian Shelf fisheries

Possibilities to develop a North American case study on the New England Scotian Shelf fisheries will be pursued.

6 REFERENCES

6.1 References cited

Austen-Smith D. 1987. Interest Group, Campaign Contributions, and Probabilistic Voting. Pub Choice 54:123-134.

Bailey, P. D. and S. Yearley (1999). Discourse in fisheries: constructing vessel monitoring systems and overfishing.

Biseau, A. and Gondeaux, E., 1988. Apport des méthodes d'ordination en typologie des flottilles. Journal du Conseil International pour l'Exploration de la Mer, 44, 286-296.

Buchanan J. and G Tullock. 1975. Polluters, Profit and Political Response: Direct Control versus Taxes. Am. Econ. Rev. 65:139-140.

Buchanan, J. and G. Tullock. 1962. The Calculus of Consent. Ann Arbor: University of Michigan Press, 1972.

Buchanan, J.M. 1980. Rent-seeking under external diseconomies. In Toward a Theory of the Rent-Seeking Society, ed JM Buchanan, RD Tollinson, and G Tullock. College Station:Texas A&M Press.

Campos J.E. 1989. Legislative Institutions, Lobbying and the Endogenous Choice of Regulatory Instrument: A political Economy Approach to Instrument Choice. J.L. Econ & Org 5: 333-348.

Doulman, D.J.(1995). Structure and Process of the 1993-1995 United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. FAO Fisheries Circular No.898. Rome, FAO.

FAO 2000. FAO Technical Guidelines for Responsible Fisheries No.8. Indicators for sustainable development of marine capture fisheries. Internet site: www.fao.org/fi/agreem/codecond/gdlines/guide8/guide8.asp..

Finlayson, A. C. (1994). Fishing for truth; a sociological analysis of Northern cod stock assessments from 1977-1990.

Fiorina M. 1982. Legislative Choice of Regulatory Forms: Legal Process or Administrative Process?. Pub. Choice 39:33-

Francis, R.I.C.C.(1992). Use of risk analysis to assess fishery management strategies: a case study using orange roughy (*Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. Canadian Journal of Fisheries and Aquatic Science, 49:922-930.

Garcia, S.M., 1997. Indicators for sustainable development of fisheries. In FAO: Land quality indicators and their use in sustainable agriculture and rural development, pp.131-162.

Garcia S.M, Staples, D.J and J. Chesson. 1999.The FAO Guidelines for the development and use of indicators for sustainable development of marine capture fisheries and an Australian example of their application. ICES CM 1999/P:05.

Hahn K. 1990. The political Economy of Environmental Regulation: Towards a Unifying Framework. Pub. Choice 65: 21-

Hammond, T.R. and O'Brien, C.M., 1999. An application of the Bayesian approach to stock assessment uncertainty. ICES CM1999, T:3.

Healey, M. and T. Hennessey. 1999. The Paradox of Fairness; The Impact of Escalating Complexity on Fishery Managment.Marine Policy. 22.109-118.

Hennessey, T. and M. Healey. 2000. "Ludwig's Ratchet" and the Demise of New England Groundfish. Coastal Management (Forthcoming)

Holland, D.S. and Sutinen, J.G., 1999. An empirical model of fleet dynamics in New England trawl fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 56, 253-264.

Hiis Hauge, K. (1998). The use of personal knowledge in stock assessment.

ICES (1994a). Report of the Working Group on Long-term Management Measures. ICES CM 1994/Assess:11.

ICES (1994b). Report of the Comprehensive Fishery Evaluation Working Group. ICES CM 1999/D:1

ICES (1995). Report of the Working Group on Long-term Management Measures. ICES CM 1995/Assess:15.

ICES (1996). Report of the Comprehensive Fishery Evaluation Working Group. ICES CM 1996/Assess:20.

ICES (1997a). Report of the Comprehensive Fishery Evaluation Working Group. ICES CM 1997/Assess:15.

ICES (1997b). Report of the Study Group on the Precautionary Approach to Fisheries Management. ICES CM 1997/Assess:7.

ICES (1999). Report of the Comprehensive Fishery Evaluation Working Group. ICES CM 1999/D:1

IWC(1993). Report of the Scientific Committee. Rep. Int. Whal. Commn., 43:57-64.

Jasanoff, S. (1990). The fifth branch; science advisers as policymakers.

Keohane N., Revesz R. and R Stavin. 1998. The Choice of Regulatory Instruments in Environmental Policy. Harvard Environmental Law Review, 22:313-367.

Lane, D.E. & Stephenson, R.L.(1998). A framework for risk analysis in fisheries decision-making. ICES Journal of Marine Science, 55:1-13.

Lauritzen, S.L. & D.G. Spiegelhalter, 1988. Local computations with probabilities on graphical structures and their applications to expert systems. *Journal of the Royal Statistical Society* 50: 157-224.

Lewy, P. and Vinther, M. 1994. Identification of Danish North Sea trawl fisheries. ICES Journal of Marine Science, 51, 263-272.

MacCubbins, M. 1985. The legislative design of regulatory structure. American Journal of Political Science. 29:721-738.

Magat, W., Kruspnick, A. and Harrington, W. 1986. Rules in the making: A statistical analysis of regulatory agency behavior. Washington, DC: Resources for the future.

de la Mare, W.K.(1985). Simulation studies on management procedures. Rep. Int. Whal. Commn., 36:421-450.

de la Mare, W.K.(1986). On the management of exploited whale populations. D.Phil thesis, University of York.

Maury, O. and Gascuel, D., 199?. Aquatic Living Resources.

Niskanen, W. 1971. Bureaucracy and Representative Government. Chicago, IL:Aldine Press.

OECD. 1997. Towards Sustainable Fisheries: Economic Aspects of the Management of Living Marine Resources. Paris: Organization for Economic Co-operation and Development (268 pp.).

Olson, M. 1964. The logic of Collective Action. Harvard University Press, Cambridge MA.

Peltzman, S. 1976. Toward a more general theory of Regulation. Journal of Law and Economics 19:211-240.

Pelletier, D. and Ferraris, J., 2000. A multivariate approach for defining fishing tactics from commercial catch and effort data. Canadian Journal of Fisheries and Aquatic Sciences, 57, 51-65.

Powers, J.E. & Restrepo, V.R.(1993). Evaluation of stock assessment research for Gulf of Mexico king mackerel: benefits and costs to management. North American Journal of Fisheries Management, 13:15-26.

Punt, A.E.(1995). The performance of a production-model management procedure. Fisheries Research, 21:349-374.

Punt, A.E. & Butterworth, D.S. (1995). The effects of future consumption by the cape fur seal on catches and catch rates of the cape hakes. 4. Modelling the biological interaction between Cape fur seals *Arctocephalus pusillus pusillus* and the Cape hake *Merluccius capensis* and *Merluccius paradoxus*. South African Journal of Marine Science, 16:255-285.

Restrepo, V.R., Hoenig, J.M., Powers, J.E., Baird, J.W. & Turner, S.C.(1992). A simple simulation approach to risk and cost analysis with applications to swordfish and cod fisheries. Fish. Bull. U.S., 90:736-748.

Spiller, P. 1990. Politicians, interest groups and regulators: A multi-principals agency theory of regulation (or "let them bribed"). Journal of Law and Economics 33:65-101.

Stephenson, R.L. and D.E. Lane (1995). Fisheries Management Science: a plea for conceptual change. Can. J. Fish. Aquat. Sci 52: 2051-2056.

Stigler, G. 1971. The Economy theory of Regulation. Bell Journal of Economics 2:3-21.

Sutinen, J. G. 1999. What works well and why: evidence from fishery-management experiences in OECD Countries, *ICES Journal of Marine Science*, 56: 1051-1058.

Sutinen, Jon G. and Harold F. Upton. Forthcoming. 'Economic Perspectives on New England Fisheries Management,' *Northeast Naturalist*.

Tari, F., 1996. A Bayesian Network for predicting yield reponse of winter wheat to fungicide programmes. *Computers and Electronics in Agriculture* 15: 111-121.

Tollinson, R.D. 1982. Rent-Seeking: A survey, Kyklos 35:575-602.

United Nations (1995a). Structure and Process of the 1993-1995 United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. FAO Fisheries Circular No.898.

United Nations (1995b). Code of Conduct for Responsible Fisheries. Rome, FAO. 41pp.

United Nations (1995c). Precautionary Approach to Fisheries. FAO Technical Paper 350/1.

WCED, 1987. Our common future. World Conference on Environment and Development. Oxford University Press: 400 p.

Wolf, C. Jr. 1988. Markets or Governments: Choosing between Imperfect Alternatives. The MIT Press, Cambridge, MA.

Zusman, A. and G. Rausser. 1994. Intraorganizational Influence relations and the optimality of collective action. J. of Econ. Behavior and Org. 24:1-17.

6.2 Related References

Baron, D. 1989. Service-induced campaign contributions and the electoral equilibrium. Quarterly Journal of Economics. 104: 45-72

Becker, G. 1983. A theory of competition among pressure groups for political influence. Quarterly Journal of Economics. 98: 371-400.

Bental B. and U Benzion. 1975. Political Contributions and Policy: Some Extensions. Pub.Choice 24:1-14.

Ben-Zin U. and Z. Eytan. 1974. On Money, Votes and Policy in a Democratic Society. Pub Choice,17:

Denzau, A. and M Munger. 1986. Legislators and Interest Groups: How Unorganized Interest Gets Represented. Am. J. Pol Sci. 80:89

Fullerton, E. 1987. Regional Fishery Management Councils: The Federal Perspective. Coastal Management 15(4) : 124-142.

Grier K and M. Munger. 1993. Comparing Interest Group Contributions to House and Senate Incumbents 1980-1986. J.Pol. 55:615-640

Jentoft, S. and B. McCay. 1995. User Participation in Fisheries Management: Lessons Drawn from International Experience. Marine Policy 19:227-246.

Kiser, L. and E. Ostrom. 1982. The three worlds of action: A Metatheoretical Synthesis of Institutional Approaches. In Elinor Ostrom (ed). Strategies for Political Inquiry. Beverly Hills, CA Sage pp 179-222.

Komesar, N. 1994. Imperfect Alternatives: Choosing Institutions in Law Economics, and Public Policy. Chicago, IL: The University of Chicago Press.

Laffont J., and J. Tirole. 1993. The theory of incentives in procurement and regulation. MIT Press, Cambridge, MA.

McLain, R. and R. Lee. Adaptive Management: Promises and Pitfalls. Environmental Management 20(4) : 437-448.

Ostrom, E., L Schroeder and S. Wynne. 1993. Institutional Incentives and Sustainable Development: Infraestructure Policies in Perspectives. Boulder, CO: Westview Press.

Ostrom, E., R. Gardner and J. Walker. 1994. Rules, Games & Common-Pool Resources. Ann-Arbor, MI. University of Michigan.

Peltzman, S. 1984. Constituent Interest and Congress Voting. J.L and Econ 27:181

Schlager, E and E. Ostrom. 1992. Property Rights Regimes and Natural Resouces: A Conceptual Analysis. Land Economics 68(3) : 249-62.

Schlager, E. 1990. Model Specification and Policy Analysis: The Governance of Coastal Fisheries. Bloomington, IN: Indiana University Dissertation.

Sproule-Jones, M. 1982. Public Choice and Natural Resources: Methodological Explanation and Critique. American Political Science Review. 790-802.

Weingast, B. and M. Moren. 1983. Bureaucratic discretion on congressional control: Regulatory policymaking by the Federal Trade Commission. JPE 91:765-800.

Young, M. and B. McCay. 1995. Building equity, stewardship, and resilience into market-based property right systems. In Susan Hanna, and M Munasingle (eds). Property Rights and the Environment: Social and Ecological Issues. Washington, DC: The World Bank.

References on Regulatory Compliance & Enforcement in Fisheries

Descriptive

OECD. 1994. *Fisheries Enforcement Issues*, Paris: Organization for Economic Co-operation and Development.

Sutinen, J. G. 1987. "Enforcement of the MFMCA: An Economist's Perspective," *Marine Fisheries Review*, 49(3):36-43.

Sutinen, J. G. and T. M. Hennessey (eds.), 1987. *Fisheries Law Enforcement: Programs, Problems and Evaluation*, Marine Technical Report 93, University of Rhode Island, Kingston, RI.

Sutinen, J. G. and T. M. Hennessey. 1986. "Enforcement: The Neglected Element in Fisheries Management." E. Miles, R. Pealy and R. Stokes (eds.), *Natural Resource Policy and Management: Essays in Honor of James A. Crutchfield*. Seattle: University of Washington Press.

Wang, S. and A. Rosenberg. 1997. 'Thalassorama: US New England Groundfish Management Under the Magnuson-Stevens Fishery Conservation and Management Act,' *Marine Resource Economics 12*: 361-66.

Theory

Akers, R. L. 1985. *Deviant Behavior: A Social Learning Approach,* Third Edition. Wadsworth, Belmont, Calif.

Aronfreed, J. 1968. *Conduct and Conscience*. Academic Press, New York.

Becker, Gary. 1968. "Crime and Punishment: An Economic Approach," *J. Political Economy* 76(2): 169-217.

Kohlberg, L. 1969. “Stage and Sequence: the Cognitive-Development Approach to Socialization,” in D. A. Goslin (ed.) *Handbook of Socialization Theory and Research*. Rand McNally, New York.

Kohlberg, L. 1981. *Essays on Moral Development. Vol. 1.The Philosophy of Moral Development: Moral Stages and the Idea of Justice*. San Francisco: Harper and Row.

Kohlberg, L. 1984. *Essays on Moral Development: Vol. II*. Harper and Row, San Francisco.

Milliman, Scot. R. 1986. "Optimal Fishery Management in the Presence of Illegal Activity". *J. Environ. Econ. and Manage*. 13(4):363-381.

Sutinen, J. G. and P. Andersen. 1985. "The Economics of Fisheries Law Enforcement." *Land Economics*, 6l(4):387-397.

Sutinen, J.G. 1993 "Recreational and Commercial Fisheries Allocation with Costly Enforcement." *Amer. J. Agricultural Econ*. 75(5): 1183-1187.

Tyler, T. 1990. *Why People Obey the Law*. New Haven & London: Yale University Press, 273p.

Evidence

Bean, C. 1990. An Economic Analysis of Compliance and Enforcement in the Quahaug Fishery of Narrangansett Bay, unpublished Masters thesis, University of Rhode Island.

Furlong, W. J. 1991. “The Deterrent Effect of Regulatory Enforcement in the Fishery,” *Land Econ*. 67(1): 116-129.

Gauvin, John R. 1988. An Econometric Estimation of Compliance Behavior in the Massachusetts Inshore Lobster Fishery, an unpublished M.S. thesis, Department of Resource Economics, University of Rhode Island.

Kuperan, K., and J. G. Sutinen. 1998. ‘Blue Water Crime: Legitimacy, Deterrence and Compliance in Fisheries,’ *Law and Society Review* 32(2):309-338.

Sutinen, J. G. and J. R. Gauvin. 1988. A Study of Law Enforcement and Compliance in the Commercial Inshore Lobster Fishery of Massachusetts. Volumes I and II. An unpublished Report to the Environmental Enforcement Division, State of Massachusetts.

Sutinen, J. G., A. Rieser, and J. R. Gauvin. 1990. "Measuring and Explaining Noncompliance in Federally Managed Fisheries," *Ocean Development and International Law*, 21:335-372.

Policy Analysis, Prescriptions

Sutinen, J. G. 1996. *Fisheries Compliance and Management: Assessing Performance*. Australian Fisheries Management Authority, Canberra, ACT (August).