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REPORT OF THE WORKING GROUP ON LONG-TERM MANAGEMENT MEASURES

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1.1 Participants

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1.2 Terms of reference

At the 80th Statutory Meeting, it was decided that the Working Group on Long-term Management Measures (Chairman: Mr T.K. Stokes, UK) would meet at ICES Headquarters from 19-28 January 1993 to:

a) consider how the data-set being compiled by the STCF Working Group on Improvements of the Exploitation Pattern of North Sea Fish Stocks might be most appropriately utilised and how the data-set should be expanded;

b) advise on how the above-mentioned data-set and associated models and MSVPA can be best integrated with the ICES assessment package (IFAP);

c) consider how the economic data and economic analyses associated with the above-mentioned data-set can best be maintained and developed through liaison with relevant scientific fora;

d) review existing technical measures to reduce the level of exploitation of young fish and shellfish;

e) consider the importance of, and strategies for, explicitly including spatial effects in multi-species/multi-fleet assessment models;

f) consider, from a stock conservation perspective, whether technical interactions between species allow for the setting of TACs for groups of species and what complementary measures would be needed, and to what extent a constant TAC can be maintained unchanged for several years and under what assumptions;

g) consider future terms of reference for the Working Group.

The Group will make its report available to the Working Group on Fishing Technology and Fish Behaviour.

2 LONG TERM MANAGEMENT

2.1 Introduction

2.1.1 History

The raison d'être and terms of reference of this Working Group had developed over the previous two years. Originally, the proposed Working Group had been seen as a group to evaluate "technical measures", i.e. largely those measures for the control of the exploitation pattern. These measures had tended in the past to be considered in a rather *ad hoc* fashion and it was felt that the species-based working groups had very little time to address the principles underlying technical measures. The view was taken by ACFM, however, that a working group devoted to this subject might not have the local knowledge required to answer detailed questions and that the need for such a group had in any case diminished with the change to area-based working groups. As a result, the remit of the proposed group was broadened and the name changed to the "Working Group on Long-term Management Measures" (LTMWG). The main reason for establishing the group was to bridge the gap between biological and technical interactions and to consider how spatial effects might be built into assessment models.

A specific question directed at the new working group was to be how the database of the European Communities (EC) Scientific and Technical Committee on Fisheries (STCF) might best be used. The problems this posed in the ICES context were not simply a matter of scale and complexity (the STCF database is spatially and temporally disaggregated on a fine scale), but also how to deal with the economic data included in the STCF database. In general, ICES has incorporated economic data (e.g. first sale values) in its analyses only for rather special purposes (e.g. to indicate the effects on different métiers of changing fishing effort etc. in the Southern Shelf area (Sub-areas VII and VIII)). It was also thought appropriate that this Group should consider how the Multispecies VPA (MSVPA) and STCF databases might be integrated with the ICES Fisheries Assessment Package (IFAP).

More recently, the need to re-evaluate long-term management measures has arisen as a result of the new form of ACFM advice. In this, ACFM recognises the need to provide advice on fisheries systems, not just single stocks or single fisheries (Serchuk and Grainger, 1992). The new working group was thus seen as an important complement to the new area-based working groups. To accomplish its tasks ACFM considered that the working group should involve fish capture specialists and economists.

The fourth term of reference - to review existing technical measures to reduce the level of exploitation of young fish and shellfish - originated in a request from the EC Commission to review the need for the "plaice box". This term of reference had been included in the remit of the North Sea Flatfish Working Group for several years. The intention was that the Long-term Management Measures Working Group should carry out a review of the types and variety of technical measures that already exist in legislation as a starting point for the development of a more conceptual framework for providing advice on measures to improve the exploitation pattern on fish and shellfish stocks. When the group's name was changed this term of reference was retained.

In 1992, STCF recommended (Anon., 1992a) that the Commission should ask ICES to carry out a detailed review of the effectiveness of:

1. The cod and plaice box in the North Sea with a view to a possible combination of these boxes;

2. The Norway pout box, and

3. All herring spawning boxes.

A request to review these measures was sent informally to ICES and included under the more general term of reference d).

Finally, in 1992, the Commission of the EC asked ICES to consider the implications of setting multi-species or multi-annual TACs taking into account technical interactions between fleets. This question was added to the terms of reference of this Group.

2.1.2 The purpose and scope of this meeting

It was suggested by ACFM that, at the first meeting of the LTMWG, priority should be given to methodological questions and planning, rather than to undertaking analyses. Nevertheless, the terms of reference (see Section 1.2) include specific requests for advice. One aim of the Working Group is to answer those requests as well as possible; the Working Group, however, is very much in a developmental phase and considers that it would be facilitative if it were given the opportunity to develop appropriate methods before being asked to advise on specific technical measures.

It was agreed that the Group should be able to formulate useful advice on the likely utility of management strategies and tools (technical measures and other rules). The Group should not be "just" a forum for evaluating "what if" questions, about the impact of specific technical measures, on an annual basis. Implicit in the term strategy is that long-term considerations are important. Nevertheless, implementing any long-term measure has short- and medium-term implications and methodologies to assess these implications will be needed.

As far as possible the Working Group has concentrated on developing a conceptual framework upon which future work can be based. There were two main thrusts at the meeting. The first was to agree a common ground in terminology and understanding of problems as an underpinning to future work. The second was to develop further the specifications for the models, database and computer program as used by the STCF Working Group on the improvement of exploitation patterns for North Sea fish stocks. Those models have been growing in complexity and future developments will continue this process. This should not, however, preclude the use of simple approaches where appropriate, and one task of the Working Group has been to consider the appropriate use of models in giving long-term management advice.

The Working Group, therefore, decided to attempt categorisations of various types (migration, fishery, biological system, technical measures and management rules, etc.). The aim was to derive, from first principles, case histories and simple models, a catalogue of the types of systems that the Working Group might need to provide advice on and the likely utility of certain strategies and rules applied to those systems. The exercise was an attempt to crystallise knowledge and experience which may serve as a guide to those asking questions, as well as providing the Working Group with a sound basis for appropriate modelling. The categorisation work was started with respect to migration at the present meeting (see Section 4).

The Working Group had to consider how best to work with gear technologists. It is clear that the selectivity models used in the past have not necessarily been a good representation of how gear regulations might really affect exploitation pattern. It is possible to construct increasingly elaborate models of fishery systems but, without good experiments and analyses of gear characteristics, assessing gear change effects will be difficult. The need for such work cannot be overemphasized. Similarly, the Working Group considered that the absence of discard data is a serious problem that needs to be addressed either by sampling or by inference.

There are at least two reasons for which the Working Group needs contact with economists. The first, price and cost formulation, is relatively simple from the biologists' perspective; it is a matter of ensuring that one can import and export appropriate quantities from the models. One of those quantities, however, is costs (or elements that are used to produce it). Data on costs are not readily available to most (or all) fishery scientists. A second reason that biologists and economists (amongst others) need to interact is to attempt to understand the problems of effort reallocation that are known to occur after any management tool is emplaced. This is a difficult area and the Working Group hopes to start discussions at the next meeting.

ICES has not previously had a great deal of contact with fisheries economists and there is no obvious framework in which to work together. There are likely to be difficulties in attracting economists to future meetings and funding may be required. One suggestion that arose out of the presentations in Section 3.5 was that it would be useful for an expert, or group of experts, to write a review (20-30 pages) of the international literature and experience in modelling fishermen's behaviour so as to identify the advantages, limits and disadvantages of different approaches to the problem. Such a review would help in developing a research strategy for the Working Group.

The motivation for the setting up of this Working Group undoubtedly came from Europe. Nevertheless, the types of questions that the Group will no doubt be asked to address in the future have relevance throughout the wider ICES community and further afield. The Working Group will certainly be developing the North Sea specific models started within the EC STCF; the Group felt, however, that wider contacts should be encouraged. To that end, the Group recommends that consideration be given to varying the venue of future meetings and soliciting appropriate participation.

The Working Group considered that January-February 1994 would be an appropriate time for its next meeting.

2.1.3 Brief review of other work/meetings etc.

The subjects of interest to this Working Group (e.g. management objectives, management strategies, management under uncertainty, technical interactions) have been well discussed in the last decade. The Working Group had available a number of references, many of which were used as background material (e.g.Horwood and Griffith, 1992; Hilborn and Walters, 1992; Mahon, 1985; Kirkwood, 1992; Anon.,1991).

The Working Group also recognised recent conferences of relevance [e.g. CAFSAC Workshop on Biological Reference Points and Risk Analysis in Fisheries Management (November 1991); International Symposium on Management Strategies for Exploited Fish Populations (October 1992)]. The reports of those meetings should be reviewed as soon as they become available.

2.1.4 Concerning prediction, short term, medium term and long term

Despite the long-standing interest of fisheries scientists, managers and economists in the various issues, many of the terms, definitions and concepts seem to have been loosely and interchangeably used at various times or not to have found a common acceptance. The Group, therefore, had extensive discussions in order to form a common terminology and understanding.

The term "prediction" is taken to mean a projection (in absolute terms or as statistical distributions) of the state of a stock as a function of time, starting with a given set of initial conditions.

It is extremely important to account for uncertainty in the parameters and assumptions used in predictions on any temporal scale. Important inputs include: stock abundance, recruitment, weights-at-age, exploitation patterns, biological interactions, effort distribution, stock identity and many more. The importance of the uncertainties will depend upon what is being predicted (catch, biomass, effort, absolute values in year X, average value over some period etc.), the time scale and the life-histories of the species involved. In performing predictions and in including uncertainties in stochastic processes, it is also very important to consider covariance among processes. These include stock x recruitment, growth x density, autocorrelation of recruitment etc.

The life span of a species should, of course, influence what is considered to be short, medium or long term. A prediction of more than one year might be short term for cod in the North Sea but would clearly be long term for short-lived squid species. In this report, we are primarily concerned with species with life spans of the order of ten years; the definitions of short term, medium term and long term are based on this.

The term "short term prediction" is taken to refer to a projection of a stock (or stocks) forward in time. The time span is typically taken to be just one, but sometimes two or three, years ahead. Such predictions need not account explicitly for biological interactions and need not take account of effort reallocation problems. The predictions may be deterministic as is common in TAC calculation but, ideally, uncertainties will be incorporated either analytically or numerically. An example of a model (used deterministically) to make short-term predictions for one or more fleets, in one or more areas, is the ABC model (see Section 3.1).

The term "medium-term prediction" is used in a similar way to "short-term prediction" but may cover an extended period over which the initial state of the stock is influential - typically, therefore, such a prediction may be of the order of the life span of a species. In such predictions, biological interactions may need to be included explicitly and the feedback between biological, economic and other factors may become important. Given the increased uncertainties in model structure and data, the need to deal with uncertainty is greater. An example of a model that might be developed to perform such predictions is given in Section 3.4. The MSFOR model (Section 3.3) has been used in such a way in the past [(Anon., 1989; Skagen, 1991 (see Section 4.2.1)].

There is general agreement that predicting the state of the stock beyond the time span of a medium-term prediction is not feasible.

The term "long-term analysis" is used to refer to at least two distinct types of analysis. Note that the term "long term" is itself misleading as it implies a prediction to some future point, as defined above.

The first type of "long-term analysis", as has been commonly used in fisheries work, involves evaluation of the steady state of a system for given inputs. A typical example is the procedure of evaluating the effect of the exploitation level on the yield-per-recruit and spawning stock biomass-per-recruit, keeping weights, maturity ogive, natural mortality and exploitation pattern constant. Typically, a baseline case will be run, a change will be made in the inputs and the results of the new analysis will be compared with the baseline (such as, perhaps, a percentage change). Such analyses are typically deterministic but sometimes include stochastic elements and rely on the system having a stable steady state.

The second type of "long-term analysis" involves Monte Carlo simulations of entire management procedures applied to generated data. The approach (as outlined in Section 2.2.4) can provide tools for evaluating the relative performance of management strategies that might be applied to particular systems and can test the robustness of those strategies to uncertainties (structural, data-related or even long-term climatic). Such an approach makes no assumption about the dynamic stability of the systems to be managed and takes into account any systematic monitoring function (e.g stock assessment) necessary to implement the management procedure.

An important background for the choice of this terminology is that each of the approaches has its own field of application. The main use of short-term predictions is to determine TACs or to evaluate immediate consequences of management actions. Medium-term predictions are needed for those who need to plan more than a year ahead (eg. fishermen, administrators, investors) but also, for example, to assess the likely performance of measures adopted to rebuild depleted stocks. At present, the main application of long-term analyses is to obtain biological reference points using steady state approaches. For this Working Group, the main application of long-term analysis should be to evaluate management strategies *per se*.

2.1.5 Notes on management procedures, tools, strategies and objectives

Sound fisheries "management procedures" require "objectives" which are to be achieved, "strategies" by which to achieve them, and "tools" to implement the strategies. A management procedure should be enforceable and cost-effective, and progress towards objectives should be monitored. A management procedure also includes the means by which resource status is assessed, and management tools evaluated and applied.

Objectives may be biological, social, economic, environmental and political in nature. Biological objectives often deal with resource conservation, such as avoiding recruitment and/or growth overfishing. These are rather simple when compared to the other objectives, and limit the role of fisheries biologists in establishing fisheries management objectives. Social objectives deal with resource access and distribution while economic objectives refer to the viability from a business perspective. Clearly, these objectives conflict and require trade-offs. Political objectives, while they undoubtedly exist, are often unstated and must be inferred from actions rather than read in public documents.

Management strategies define a general approach to determining fishery controls. Options include minimizing effort variation, minimizing catch or biomass variation. From a biological perspective, harvesting targets under various strategies are traditionally taken from a limited number of strategic models such as yield-per-recruit, spawning stock biomass-per-recruit, surplus production, or spawning escapement.

Following from the acceptance of a management strategy, a suite of tools may be applied to implement the strategy. These include TACs, national catch quotas, mesh size regulations to affect the age and size of capture, closed areas and seasons, and many more.

In principle, the tools chosen should be consistent with the adopted strategy, which should also be consistent with the objectives. The overall management procedure should be reviewed and evaluated on a regular basis, and could even be designed to obtain additional information on key areas for which uncertainties exist, in order to improve future management procedures. In practice, this is often not the case (see Section 2.1.6 below).

2.1.6 Long-term management and the need for objectives (and the likelihood of getting them)

It is highly desirable to have clearly stated and quantifiable management objectives for establishing an effective management procedure and for evaluating that procedure. However, it is unlikely that this will occur, especially in politically complex fisheries such as in the North Sea (Horwood and Griffith, 1992, Appendix 4). Alternatively, it may be possible to infer management objectives from retrospective analyses of past management decisions and actions (Hilborn and Walters, 1992). While this may allow evaluation, it does little for developing the original management procedure.

In the context of long-term management measures, it is perhaps naive to believe that one could draw any guidance from existing management objectives, in the few instances where they may exist. The political climate is variable on this time scale; what may appear to be an objective today may not be so important in five years time. Given this reality, the Working Group should develop methods to evaluate alternative long-term measures by considering several different indicators relevant to possible biological, economic, social, and recreational objectives. At the same time, the Working Group will need to develop the tools to assess the specific short- and medium-term consequences of adopting any particular (long-term) strategy.

2.1.7 A note on métiers, fleets and fisheries

There has been some confusion in the use of the terms "métier", "fleet" and "fishery"; this section attempts to clarify the concepts.

Métier refers to the fishing activity characterised by similar vessels using similar gear and targeting the same species or group of species (e.g. bottom trawlers of length class X targeting mixed gadoids).

Fleet refers to a group of similar vessels using similar gear (e.g. bottom trawlers of length class X).

Fishery refers to a group of vessels targeting the same species or group of species and using similar gears (e.g. bottom trawlers targeting gadoids).

The following text table summarises these concepts.

There are three distinct métiers but only two fleets and two fisheries. Vessels A and B are the 20m bottom trawl fleet while vessels C are the 50m bottom trawl fleet. Vessels A and C are in the gadoid fishery but vessels B are in the plaice fishery.

Vessels	A	B	C
Length	20m	20m	50m
Gear	---Bottom Otter Trawl---		
Target Sp (P)	gadoids	plaice	gadoids
Métier 1	X		
Métier 2		X	
Métier 3			X
Fleet 1	X	X	
Fleet 2			X
Fishery 1	X		X
Fishery 2		X	

To evaluate the impact of a given technical measure, it is important to define the appropriate vessel grouping. Imagine, for instance, that the vessels described in the text table are all based in a harbour in northern France. Due to their size, vessels A and B fish only in the southern North Sea but vessels C can steam further north. If the southern North Sea were to be closed to fishing, fleet 1 would disappear from the area (North Sea) but fleet 2 would remain. To estimate the impact of the closure on fishery 1 it would be necessary to know the characteristics of each vessel - fleet 1 would be redistributed into other fisheries whilst fleet 2 would continue as before.

On the other hand, for example, if the minimum landing size of cod was to be increased, only fishery 1 would be affected and it would not be appropriate to evaluate the effects of that measure using the fleet definitions.

2.1.8 A short note on risk analysis

The Working Group on Methods of Fish Stock Assessment (MWG) is to investigate the use of risk analysis (especially with respect to its use in defining safe biological limits). The term "risk analysis" has been used extensively to refer to many things. The Working Group considered a communication by Conser circulated to members of the MWG. That communication gave a useful definition of risk analysis in the classical sense - i.e. that risk is the expected value of a loss function minimised with respect to a control variable over a given time period. The calculation of risk, therefore, involves calculating both the probability of a certain quantity (eg. SSB) or quantities, but also defining the loss function relating the quantity to the parameter(s) of interest (i.e. the control variable(s); eg. F). For single criterion risk analysis this might be straightforward. For multiple criterion analyses, however, it would be necessary formally to define objectives and their relative weighting.

Some of the approaches developed/advocated by the LTMWG will be probabilistic and account for uncertainties. This is only part of the required input to a risk analysis as described above. The models currently being considered by the LTMWG should not, therefore, be termed risk analysis. In particular, long-term analysis methods which make no attempt to predict through time cannot be used for the calculation of risk as defined above.

Advice from the MWG on terminology and the relationship between risk analysis and the models to be developed by this Working Group, would be welcome.

2.1.9 Use of statistical models

Many of the predictive models reviewed at this meeting use parameters for stock size, catchability, stock distribution, and feeding which are estimated in separate multispecies or single-species VPAs. It would be interesting to investigate combining the VPA tuning with forward predictions of catch and abundance by area. The tuning process could be the vehicle for parameter estimation. One could cast the predictions made currently by, for example, the ABC model, in terms of parameters of stock size in the prediction year, stock distribution, fishing effort distribution, and catchability but within one analytical framework. Using a statistical approach, one could estimate these parameters and investigate their variance, correlation, the feasibility of estimation, and use objective criteria for limiting the overall model structure (i.e. the number of parameters that may be estimated with the data available). Such an approach would require careful separation of observed data from predictions, variables from parameters. It would provide additional information on the variance of predictions that could be incorporated into the advice.

2.1.10 Coordination with other groups

An EC study group (Horwood and Griffith, 1992) recommended that another study group be established for a three year period to develop and evaluate strategies for medium- and long-term management of EC fisheries. At present it is unclear what the status of this study group is. The ICES MWG is also due to consider methods of using risk analysis to estimate safe biological limits for fish stocks. It is recommended that the chairman of the LTM WG liaise with the chairman of the MWG and members of the steering committee of the proposed EC study group, to formulate possible ways of developing methods to determine the performance of management procedures for fisheries systems such that work is facilitated but not repeated.

2.2 Presentations

This section is a collection of reports based on presentations given at the meeting. The presentations were solicited in an attempt to widen the scope of the meeting from only dealing with models developed by the STCF Working Group on Improvements of the Exploitation Pattern of North Sea Fish Stocks.

2.2.1 Reproductive capacity estimation based on population fecundity

A presentation on this subject was given by V. Serebryakov.

Population fecundity, or the total number of eggs spawned annually by a fish stock, is the equivalent of the original abundance of a year class and a more sensitive estimator of reproductive capacity than SSB (Serebryakov, 1990; Rothschild, 1986). Population fecundity was used to calculate the survival rate of Norwegian spring-spawning herring and North-East Arctic cod up to age 3 based on a long time series. The survival rate of each year class was estimated as the ratio of the number of 3-year-olds to the population fecundity. The mean and extreme values of survival rates were obtained in this way for abundant, moderate and poor year classes, based on an arbitrary classification. The figures obtained were considered as quantitative indicators of ecological conditions during the early life history stages. Based on the results, the total number of eggs required to produce an abundant or medium year class under three levels of survival was estimated.

Three levels of reproductive capacity were defined in terms of population fecundity:

a) a "safe level" which guarantees the emergence of a strong year class under moderate or better than moderate survival conditions in the early life history phase;

b) a "minimal required level" which secures the production of strong year classes under moderate conditions of early survival;

c) a "critical level" which allows a strong year class to be generated only in the best survival conditions.

A simplified though less accurate method was suggested when data on individual fecundity are not available and when reproductive capacity can only be expressed in terms of spawning stock biomass. Reproductive capacity levels for Norwegian spring-spawning herring and North-east Arctic cod were calculated using data on individual fecundity. The simplified method was used for calculating reproductive capacity levels in Icelandic herring, Barents Sea capelin, Icelandic, Labrador/North Newfoundland, Grand Bank, St.Pierre/Miquelon, Faroe Islands and West Greenland stocks of cod, North-east Arctic haddock, North-east Arctic saithe, and Greenland halibut.

Discussion

In most studies of the relationship between recruitment and spawning stock biomass it is implicitly assumed that fecundity per unit weight of spawning stock is constant from year to year. In at least some species, however, fecundity is a plastic parameter of individual reproductive capacity. If this is a general characteristic of fish stocks, then it is clearly desirable for stock recruitment studies to be based on population egg production rather than on the spawning stock biomass. While recognising the potential importance of annual variation in fecundity, the Working Group was uncertain how important this factor is in the population biology of many fish stocks, at least within the range of stock sizes encountered. They, therefore, considered that, in the first instance, a desk study should be undertaken of the annual variability in fecundity. This can be done either by considering the fecundity-length relationship or the relative fecundity, i.e. fecundity per unit weight of spawning stock.

Since it is clear that ecological conditions for the survival of the early life stages can be very variable, the Working Group considered that it is important to consider the variation in the form of the stock recruitment relationship under different survival conditions in the early life history rather than simply treating the relationship between recruitment and spawning stock size (or other parameters of population reproductive capacity) as a single invariant function.

While recognising the potential of the approach used in this presentation, the Working Group considered that a more sophisticated statistical approach is required to test the validity of the definitions of stock size categories described. They also considered that it is necessary to consider whether the gradations of stock size identified (i.e. abundant, medium and poor year classes) can be defined in a more objective way.

2.2.2 Stock prediction models using stochastic recruitment

In the new ACFM management strategy a Minimum Biological Acceptable Level (MBAL) has been introduced to classify the status of a stock. MBAL has been defined as a minimum acceptable level of SSB below which the stock should not be allowed to decrease, either because there are indications that average levels of recruitment are lower than normal at such levels, or because the stock is entering an unknown area where the risk that this may happen is high. The objective of the MBAL strategy is to prevent the SSB from decreasing below this level in the short, medium and long term, or, if it is below this level, to bring it above this level as soon possible.

Two prediction models which investigate the consequences of different exploitation scenarios on the status of the stock in the future in terms of probability were presented to the LTMWG.

SPLIR model

SPLIR is a model, developed and presented by Frans van Beek, to estimate a level of fishing mortality associated with a probability whereby the SSB will be above a certain level in the **long term**. The model, described in working document 18 submitted to the LTMWG (WD 18) and the MWG, is a standard prediction model which runs over a large number of years with the same constant input parameters as used for the long-term "equilibrium" yield and biomass curves. The only variable input parameter is recruitment, which is estimated from a distribution describing observed recruitment. In fact the model estimates the variability of the long-term yield and biomass due to recruitment variability. A comparable approach was developed earlier by Nielsen (1980). The output presents, for various levels of fishing mortality, the frequency (probability) that the stock will be below MBAL in any particular single year in the long term. The output allows a choice to be made of a level of fishing mortality to be applied in the long term, where the risk (probability) of the SSB being below MBAL in any year is acceptable.

In an extension of the model it is possible to include "management action" when the stock drops below or increases above defined levels of SSB. This action is implemented in the model as a reduction or increase of the level of fishing mortality.

STRC model (Skagen, 1991)

This model was presented by D. Skagen as a possible approach to the study of the consequences of management options. A medium-term stock projection was used, with initial data taken from recent assessments. The state of the stock over a time range of this magnitude will be highly dependent on the actual values of weight-at-age, maturity-at- age, mortalities and recruitment. These parameters are variable and to a large extent unpredictable. If, however, it can be assumed that their statistical properties can be inferred from historical observations, they can be introduced in a prediction as random numbers with specified distributions. By repeating this process a large number of times, the outcome of the prediction can be presented in the form of distributions. In such a prediction, rules for management action dependent on the current stock situation can be introduced, and the effect of different rules can be compared.

In the study presented here, only recruitment was considered as a stochastic variable. To construct a distribution for the recruitment, a kernel method was proposed. In this approach, the recruitment assumed for a prediction year is picked from a collection of historical recruitment values. The chance of each recruitment value being used is influenced by the difference (or ratio) between the present SSB and that generating the actual historical distribution. This is done by giving each recruitment a probability which is larger the closer the historical SSB is to the actual one. This gives a probability distribution for the recruitments given the present level of SSB, from which the recruitment to be used can be drawn. For a further discussion of the approach, the reader is referred to the original paper (Skagen, 1991).

Results were presented for North Sea sandeel and herring, and for the Western mackerel stock.

An important aspect of this kind of approach is how to present the results. In addition to expected values of catches and stock size, it may be useful to consider the variation, both within each prediction run and between runs. It may also be useful to present the probability that the stock size or catch will pass some critical value. Since this is a medium-term prediction in which the recruitment can depend on the SSB, the most important aspect in this respect is the probability that the critical value is passed at least once in the prediction period. In particular, this is so if the critical value represents an MBAL. Finally, some management rules, in particular keeping catches constant over a long period, may become impossible, and it will be useful to consider the probability that this may happen.

The management rules considered here were either to keep fishing mortality fixed, or to keep the catch fixed (if possible), or a regime aiming at stabilising the SSB. A general result seems to be that attempting to stabilise one variable will lead to increased variation in the others. Accordingly, stabilising SSB is not promising as a means of stabilising yearly catches, and stabilising either the catch or the SSB will induce large variations in the fishing mortality, and hence in the effort needed from year to year.

General comments

Both of the above models were developed as tools to evaluate the probability of a stock collapse (or the stock decreasing below a critical level). The STRC model does this using medium-term predictions starting from an observed population. SPLIR does this using long-term predictions. Both models are deterministic, except for the recruitment, which is a stochastic variable.

The STRC model takes account of the relationship between recruitment and spawning stock biomass, while the SPLIR model does not. The recruitment used in the SPLIR model appears randomly with good, average and poor year classes in the same frequency as observed the existing data-set. However, for some stocks there are indications that there are periods of consistently high or low recruitment levels suggesting auto-correlation or, maybe, stock/recruitment relationships.

As in yield-per-recruit models the other variables in both models are assumed to be constant. In reality this will never be the case. Some stocks have shown periods where changes in weight-at-age have occurred (either density dependent or density independent). There are also uncertainties in the estimate of the present exploitation pattern and it is likely that it will not be the same every year. It is desirable, therefore, that the robustness of the models to these possible trends, variations and errors, is tested.

From a statistical point of view it would be desirable to use the same set of random recruitment values for comparable runs with different levels of fishing mortality, which is not the case in the present implementation of SPLIR. Both in the STRC model and when using the extension of the SPLIR model it is assumed, when a decision for management action is taken, that the situation of the stock is exactly known. In reality this will not normally be the case.

Models of this kind have been presented from time to time, but have never gained widespread acceptability. However, in a management strategy aiming at keeping the spawning stock above a certain MBAL, such models may be a useful tool.

2.2.3 Management under uncertainty - the IWC approach

Presented by K. Stokes

Kirkwood (1992) outlines the background to the development of the Revised Management Procedure by the Scientific Committee (SC) of the International Whaling Commission (IWC); this section draws substantially from that source. The process started with the Scientific Committee asking the Commission (the political body) for objectives that it wished to have fulfilled by any revised management procedure. The Commission eventually accepted three objectives (suggested by the SC):

i) stability of catch limits, which would be desirable for the orderly development of the whaling industry;

ii) acceptable risk that a stock not be depleted (at a certain level of probability) below some chosen level (e.g. some fraction of its carrying capacity), so that the risk of extinction of the stock is not seriously increased by exploitation;

iii) making possible the highest continuing yield from the stock.

The objectives, as stated, are not very precise and contain terms that require to be defined operationally. Additionally, no time frame was specified and the three objectives cannot all be met at once - they are at least partly incompatible.

Despite these apparent difficulties, the SC proceeded to develop five management procedures for the management of baleen whale stocks. The individual developers adopted different approaches to the problem but co-operated throughout the development process such that many of the ideas and implementations displayed a degree of convergence. Note that in the IWC SC terminology, a "management procedure" consists of both an assessment procedure and a harvesting strategy (set of rules).

The process for developing and testing various management procedures in the IWC SC has been quite different from anything used in the ICES community. Ideally, any management procedure would be tested experimentally. There are, however, compelling reasons that rule this possibility out for most resources. The reasons include the length of time that would be required for the experiment(s), the fact that it is difficult in reality to maintain any particular management strategy for a long period and, not least, that getting it wrong could have disastrous consequences for real resources (Punt, 1992; Hilborn and Walters, 1992). Because of these difficulties, the IWC SC determined the appropriateness/utility/performance of various management procedures using Monte-Carlo simulation.

Essentially, each management procedure was subjected to a screening process consisting of a series of computer-based trials. Each trial examined the management of a simulated whale stock over a 100 year period. This was repeated 100 times (at least) for each trial with different simulated data. The simulated data were generated from an "operating model" which produced population abundance data (absolute and relative). Summary statistics monitoring the performance of the procedures in relation to the three management objectives were collected for each trial. The trials adopted tested the management procedures against a range of problems arising from failures made in the assumptions concerning the true stock dynamics (i.e. model structure) and the data (e.g. availability, precision, bias) and from plausible long-term environmental changes. The summary statistics, collected from the application of the management procedures to the simulated data-sets, permitted comparison of how well each procedure met the management objectives and formed the basis for recommendations to the IWC as to which management procedure to adopt. Appendix 1 explains the process and terminology in detail.

In the IWC, the purpose of the development process was to produce a management procedure (assessment procedure plus harvesting strategy) that could be applied to all baleen whale stocks meeting certain criteria. The adopted procedure, tested severely on the computer, is not necessarily the best possible model but it should give acceptable performance in terms of the stated objectives and be robust to a wide range of plausible but uncertain factors. The same process, however, can be used to discriminate between the utility/performance of any management procedures (the assessment procedures and/or the application of management tools) that might be considered as a long-term management option. That discrimination depends upon deriving meaningful and interpretable performance statistics; in the IWC SC statistics were refined through time and developed away from simple quantities such as averages and variances.

Clearly, in the case of the IWC work, the problem concerned (and hence the operating model) had relatively few stocks (a maximum of about 10), no direct multi-species effects and no more than two "fleets" . Migration, however, was included and multi-species effects were addressed indirectly through variations in certain parameters. If such an approach were to be adopted by the ICES Working Group on Long-term Management Measures, then the size and complexity of the operating models and management procedures could be very large indeed. In certain ICES regions, the dimensions of the problem are relatively small but in the North Sea, for instance, there are multiple areas, approximately 10 commercially important species and innumerable fleets. The theoretical difficulties for such a system may not be substantially larger, but the computational problems could become enormous if attempts were made to consider everything. Nevertheless, an approach of this kind provides a rigorous method for calculating, in terms of probability, the relative performance of different management options. As such, it could provide an invaluable tool for assessing questions of the kind regularly asked of ICES working groups either for specific or generalised systems.

The approach has been used to develop management procedures in a number of areas on diverse fisheries [e.g. for Cape hake stocks (Punt, 1992)] and has been suggested as a means of investigating seal-fishery interactions in the Benguela ecosystem (Anon., 1991b).

2.2.4 Changes in stock size in Northwest Atlantic groundfish fisheries

Presented by A. Sinclair

A summary of trends in catch, biomass and fishing mortality for 11 stocks in the NAFO area was presented. The stocks were cod in 2J3KL, 3Pn4RS, 4TVn (J-A), 4VsW, 4X, and 5Zjm (Gascon *et al.*, 1990); haddock in 4TVW, 4X, and 5Zjm; and pollock in 4VWX5Zc.

Since the early 1960s there have been two large cycles in the biomass. The range of the fluctuations in biomass is in the order of 2.5x. The early to mid-1960s was a period of high biomass. In the latter part of the decade biomasses declined rapidly to a minimum in the mid-1970s. Biomass then increased and peaked again in the mid-1980s. Subsequent to this peak in biomass, stocks have again declined and several large reductions in TAC have recently been announced for cod and haddock stocks.

Fishing mortalities also varied during the period, but to a lesser extent than the biomass. The average F varied between 0.40 and 0.55 with no temporal trend in the 1960s. F then increased in the 1970s to a peak of 0.70 just prior to the extension of fisheries jurisdiction by Canada in 1977. The average F then declined to about 0.45 and was stable for a few years, but then increased again to around 0.60. In general, F tended to peak when biomass was at a minimum.

The presentation suggested that the cycles in population biomass seen in this area have been influenced to a greater extent by environmental forcing than by fishing alone. The range in biomass is greater than the range in F. It is likely that increases in F in the 1970s and again in recent years were more a result of attempts to maintain catches in the presence of declining biomass. While this probably reduced biomass to a larger extent than would have occurred if F had remained constant and at a lower level, it was not the main cause of changes in biomass.

One of the often-stated objectives of fisheries management is to minimize variation in catches and abundance. However, it is inevitable that stock sizes will vary because of factors outside the influence of fishing. Management procedures should be robust to these changes and any long term advice should account for these.

2.2.5 Plaicebox approach

In 1987 the ICES North Sea Flatfish Working Group addressed the problem of evaluating quantitatively technical measures to reduce the level of discarding of flatfish in the North Sea. Although discard data were available for plaice and sole, these were considered to be inappropriate for the estimation of the level of discarding given the large seasonal, annual and spatial differences in the rate of discarding. As a result, an alternative approach was chosen, in which the number of discards is estimated from the spatial distribution of fishing effort and fish. Quarterly distribution patterns of the fish by age were based on survey data and commercial CPUE data. Effort data were derived from national statistics and combined to give overall effort distribution by quarter in the North Sea flatfish fisheries. The approach was then used to explore the effects of box closures on the level of recruitment of North Sea plaice and sole (Anon., 1987a; Rijnsdorp and van Beek, 1991).

Method

If the spatial distribution of fish is known by age group on a rectangle basis, the catch can be calculated according to:

$$C_i = q_i \, f_i \, N_i$$

where C is the catch number, q is the catchability coefficient, f is the effort, N is the number of fish, and i denotes the rectangle.

Summed over all rectangles and assuming that q is constant, the total catch is

$$C = \Sigma \, C_i = q \, \Sigma(f_i \, N_i) \qquad (1)$$

$$\text{Also } C = F/Z \, (1\text{-}\exp(\text{-}Zt)) \, N \qquad (2)$$

From (1) and (2)

$$F/Z \, (1\text{-}\exp(\text{-}Zt)) = q \, \Sigma \, (f_i \, N_i/N) \qquad (3)$$

and F can be solved by iteration. Note that the N_i/N represents the proportional distribution pattern of an age group over the rectangles.

These calculations are carried out for each quarter, after which the surviving fish are redistributed over the age- and quarter-specific distribution pattern.

In order to use the model q should be calibrated. This can be done if an independent estimate of the exploitation pattern is available that is representative of the level and pattern of fishing effort used in the simulation. Figure 2.2.1a and b show the observed and simulated exploitation patterns for the final choice of q. For plaice there is a reasonable correspondence, but for sole the deviation between the observed and simulated values of F tends to increase, suggesting that the assumption of a constant q does not hold.

Figure 2.2.1 Observed and simulated exploitation patterns for North Sea plaice and sole.

Figure 2.2.1a

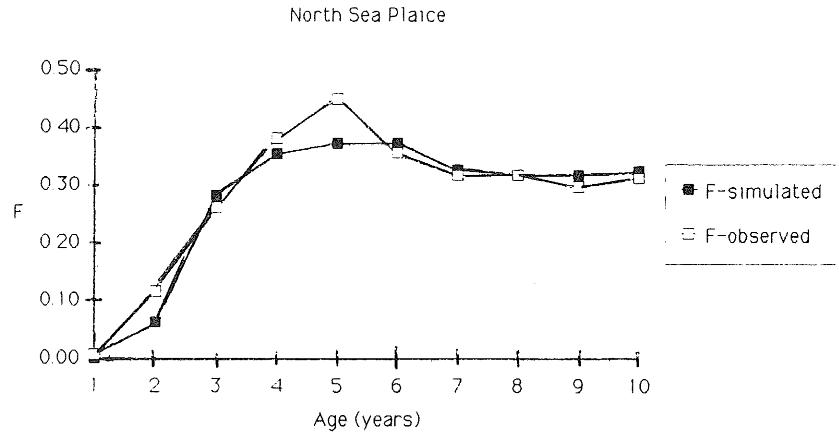
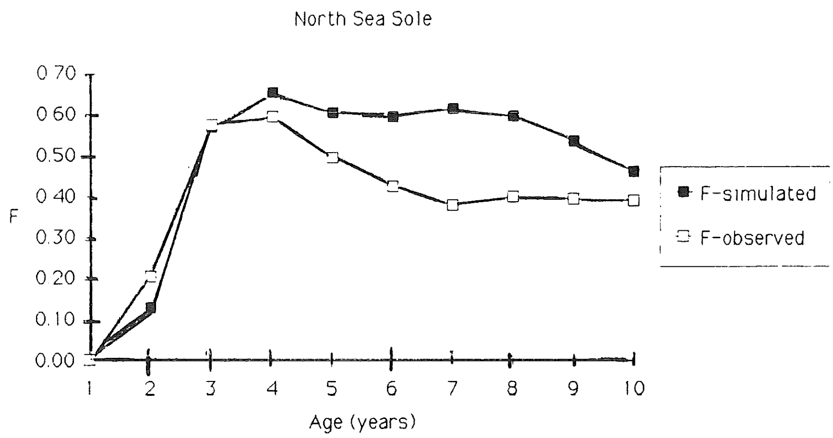


Figure 2.2.1b



The input data for the model are tabulated in Table 2.2.1.In addition to the distribution of fish, effort and percentage discards, it also gives the percentage of fish that escape through the meshes, and the proportion of fish recruited to the fishing grounds. These parameters can be incorporated in the right hand term of equation (1).

The simulated catches by rectangle in the baseline run are split into a number landed (fish above the minimum landing size, excluding discards) and the number of discards. The results of this baseline run can then be compared to the simulated landings and discards when specified rectangles are closed for the fishery.

The best way to present the results of the simulated box closure is not immediately obvious. As a tabulation of the number of discards cannot be linked directly to the effects on the yield and spawning stock biomass, the Flatfish Working Group chose to carry out a VPA analysis of the simulated catch-at-age and landings-at-age matrices in order to reconstruct the population numbers-at-age and obtain an estimate of the apparent number of fish that recruits to the fisheries. As an example, Table 2.2.2 reproduces the results of the baseline simulation for sole. The VPA analysis of the simulated landings estimates the recruitment at age 1 as 71,000 fish, whereas the VPA analysis of landings+discards estimates a recruitment of 100,000. Discard mortality thus reduces the number of recruits to the fishery by 29%.

Utility of the model

The model may be seen as a first step to evaluate quantitatively the effects of box closures, or, more generally, the effects of changes in effort distribution patterns on the level of discarding. One of the drawbacks of the model is that the survivors are redistributed according to a fixed distribution pattern. This redistribution takes implicit account of migration resulting from the changes in the spatial distributions between quarters and age groups. However, since the spatial distribution patterns are assumed to be fixed, and thus not affected by the changes in intensity and spatial pattern in fishing effort, the model should be used with caution. The assumption may not hold in the case of a relatively small box closure, or when the level or spatial pattern of fishing effort is changed substantially.

Table 2.2.1 Input data for the box-closure model exploited by the ICES North Sea Flatfish Working Group (Anon., 1987).

Relative distribution pattern by age group, quarter and rectangle.
Percentage discards by age group, quarter, and rectangle.
Percentage of fish that escape through the meshes by age group, quarter and rectangle
Effort distribution by quarter.
Proportion of fish recruited to the fishing grounds by age group.

Table 2.2.2 Output of the simulation. The table gives the estimated numbers of sole caught (including discards) and landed and the fishing mortality (F) and stock numbers as estimated by a VPA analysis of the total catch (landings + discards) and of landings only (from Rijnsdorp and van Beek, 1991).

	VPA analysis of landings + discards				VPA analysis of landings only	
Age	F	Total catch	Landings	Numbers	F	Numbers
			Baseline run, no box-closures			
1	0.044	4,140	60	100,000	0.001	70,543
2	0.361	25,006	7,364	86,549	0.129	63,773
3	0.641	24,709	21,068	54,607	0.570	50,727
4	0.657	11,999	11,923	26,040	0.654	25,961
5	0.604	5,299	5,299	12,214	0.604	12,214
6	0.594	2,587	2,587	6,039	0.594	6,039
7	0.614	1,325	1,325	3,017	0.614	3,017
8	0.596	634	634	1,477	0.596	1,477
9	0.535	291	291	736	0.535	736
10	0.461	138	138	390	0.461	390

3 THE STCF WORKING GROUP ON IMPROVEMENTS OF THE EXPLOITATION PATTERN OF NORTH SEA FISH STOCKS (MSVPA/IFAP/ECONOMICS)

3.1 The STCF North Sea Subgroup

3.1.1 Background

Increasing problems in assessing the demersal North Sea fish stocks were one of the reasons for establishing the EC STCF Working Group on improvements of the exploitation pattern of the North Sea fish stocks. A main task of that Working Group was to create a database to address questions concerning the effects on individual fleets of specific technical measures.

The new management tools should - apart from the traditional TACs and mesh assessments - account for technical interaction effects. Furthermore, it should be possible to evaluate consequences of box closures in time and space. In order to do that it was decided to establish a detailed fishery database for the North Sea and to develop new prediction models. The database should include spatial and fleet-disaggregated catch and effort data. Economic data should be included as well.

The STCF database system and the associated models are described in detail by Lewy *et al.* (1992), Anon. (1989) and Anon. (1990).

3.1.2 The STCF database system

The database, STCFBASE, is an interactive menu-driven system with a context-sensitive help facility. The system consists of the database and a wide range of data modification and presentation facilities. The STCFBASE also handles communication with the associated ABC prediction model, the required aggregation of data and the production of input files to the model. Finally, the STCFBASE reads the output files and gives facilities for data manipulations and presentations. The system was developed with the SAS software system and works on platforms using DOS, OS/2 and UNIX.

The STCF North Sea database contains spatially disaggregated landings data by national fleets, gear selection data and some economic data for the commercially important species in the North Sea. Data for 58 fleets from eight countries are included. Table 3.1.1 gives a short description of the contents of the database.

Table 3.1.1 Contents of the STCF North Sea database.

1. Fleet specification by country and year.
2. Gear selection parameters by country, year, fleet and species.
3. Effort data by country, year, quarter, fleet and ICES rectangles.
4. Total catch data (catch weight and value) by country, year, quarter, fleet, category and species.
5. Catch weights by country, year, quarter, fleet, category, ICES rectangles and species.
6. Catch-at-age data (catch numbers, mean weight and mean length) by country, year, quarter, fleet, category, ICES rectangles, species and age.
7. Price data by country, year, quarter, fleet, category, species and age.
8. Price flexibility data by country, year and species.
9. Landings distribution by country, year, quarter, fleet, category and destination country.
10. Whole fish/gutted fish weight ratio by country and species.

"Category" denotes human consumption landings, industrial landings and discards.

At the moment the database contains data for 1989. Data for 1991 are being collected and should be available by May 1993 (see Section 3.4.3).

3.1.3 The STCF prediction model ABC (assessments of bioeconomic consequences of technical measures)

The ABC model is a development of the model previously used by the STCF Working Group, the so-called MSFBOX model made by Benois Mesnil (Anon., 1989 and Anon., 1990)

The MSFBOX model is a multi-fleet technical interaction prediction model for the whole North Sea, which enables estimation of catches inside and outside a predescribed management box. This model was considered to be a first attempt to utilize the STCF database.

During its work the STCD Working Group became aware of some weaknesses of MSFBOX, for example that fish "released" by a box closure in the northern part of the North Sea would immediately be available to a fishery in the southern part. The natural solution to this problem is to perform predictions separately for specified sub-areas, below called "spatially disaggregated prediction models". At the same time the Group realized that fish migration and reallocation of effort in connection with spatially disaggregated models may seriously affect the predicted effects of box closures. As a consequence fish migration and reallocation of effort should be taken into account in a spatially disaggregated model.

The ABC model is an example of a spatially disaggregated prediction model. An optional number of box closures in time and space can be treated by the model. Effects of mesh size changes introduced inside and outside the predescribed boxes may also be evaluated. Furthermore, technical interactions are taken into account as well.

The sub-areas which constitute the basis for predictions are assumed to be the same for all species in question. However, the division of the area into sub-areas may easily be selected or reselected for estimating the sensitivity of the choice of sub-areas. The MSFBOX model is a special case of the ABC model, in which no subdivision of the total area takes place.

The model runs on a quarterly basis. The quarterly, spatial stock size distribution by age group required for spatially disaggregated predictions may be obtained for some stocks for 1991 and onwards from the International Bottom Trawl Survey (IBTS).

Migration is implemented in the model in a very simple way. Migration is assumed to take place at one time at the end of each quarter. The model assumes that the migration matrix describing migration rates between the sub-areas selected in the model is externally known for each species and age group. This information needs to be estimated (see Section 4 on migration).

The ABC model does not contain a formal description of the fleet activity dynamics in relation to changes in regulations. Instead some standard options are available in the case of box closures. These options are of interest only when considering spatially disaggregated predictions. The reallocation algorithm implemented, which has no scientific justification, should only be considered as a preliminary trial.

As available knowledge on migration and reallocation of effort is rather limited, further research on these topics is important.

The ABC model contains an economic model describing the relationship between prices and quantity landed, and from which the future price modifications can be predicted. This can be done using ex-vessel prices by fleet and age group and economic parameters included in the database. No account, however, is taken of costs.

The effect of the following management measures may be evaluated in the model:

- Box closures by fleet and quarter
- Effort reallocation options following box closure
- Mesh size changes by fleet and box
- Relative change of effort by fleet

3.1.4 Experiences with the STCF ABC model and database

Catch data in the database have been compared with ICES Working Group data and the model has been tested by the STCF North Sea Working Group (Anon., 1991c). The Working Group concluded that summary STCF catch data were in good agreement with ICES Working Group catch data for the demersal species. The ABC model was tested for these species and was found to produce results which were in accordance with the results of the ICES Flatfish and Roundfish Working Groups. For the pelagic species the STCF database was incomplete.

As used so far, the model has only been run on the assumption that the fish are completely mixed.

3.1.5 Data requirements

Making predictions based on the total North Sea requires the STCF database, recent stock size, mean weight-at-age and maturity data.

In the case of spatially disaggregated predictions the spatial distribution of stock size by age is needed, as are migration matrices. The spatial distribution of the stocks may be obtained by quarter from the IBTS data.

3.2 MSVPA and MSFOR Models

3.2.1 An overview of the ICES MSVPA and MSFOR models, programs and data-sets

A manual containing a comprehensive description of the model and a user's manual for the program package are being prepared by the Danish Institute of Fisheries and Marine Research (DIFMAR) (WD 1). This work is not yet completed. It has been decided at DIFMAR to stop further development of the present computer package.

The current MSVPA-program was developed some 10 years ago. It was written in FORTRAN for a mainframe computer, and a certain expertise is required to operate it. The MS-forecast program was developed a few years later, and has the same deficiencies as the MSVPA program. The programs are not user-friendly and they do not live up to modern software standards. It is difficult to modify and extend the current programs because of the program structure. The core of the current MS-programs has the same structure as the original program. The program has been extended with several new computation routines, but no facilities to improve the user-friendliness have been implemented. The current version is, therefore, even less user-friendly than the original version. It will become increasingly difficult to extend the current program further. The only (draft) user's manual for the MSVPA program was prepared in 1984 (Sparre, 1984).

The set of MS-models comprises two models, that is a retrospective model (**MSVPA**, Multi-Species Virtual Population Analysis) and a forecast model (**MSFOR**, Multi-Species **FOR**ecast).

The MSVPA is used to estimate parameters, so it deals with past events. It takes (basically) as **input**:

1. Total numbers caught by all fishing fleets
2. Relative stomach content and food consumption rates of predatory fish

from which it produces the **output**:

1. Past stock numbers in the sea
2. Past predation mortality coefficients and the parameters to compute them
3. Past fishing mortality coefficients

MSFOR is used to predict what will happen in the future. The output (or parameters) 1 and 2 from MSVPA is used as input to MSFOR. The fishing mortalities are the parameters which can be controlled by man, and they are, therefore, the input to the forecast program, which thus takes the **input**:

1. VPA-output (stock numbers and predation parameters, fixed parameters)
2. Assumed future fishing mortalities

and MSFOR produces the **output**:

1. Future stock numbers in the sea
2. Future predation mortality coefficients

MSVPA and MSFOR do not account for spatial aspects, in that they consider the area covered as one homogeneous area, in which all species are evenly distributed.

The Multispecies VPA computes a part of the natural mortality, namely the natural mortality caused by predation. The natural mortality is partitioned into M = M1 + M2, where M1 is called the residual natural mortality and M2 the predation mortality (i.e., the mortality created by the predators specifically included in the model). M2 is calculated as the sum of the partial M2s created by each predator species. The predation created by a predator stock depends on the annual food consumption, the number of predators and the so-called "suitability" of the prey species in question. The biomass of prey weighted by its suitability is called "available food". Suitabilities are computed from observed stomach contents, using the equation:

suitability of prey s as food for predator p =

$$\frac{\text{(observed stomach content in predator p of prey s)}}{\text{(total biomass of prey s in the sea)}}$$

which can be shown to be equivalent to the equation

(Fraction of predator p's food coming from prey s) =

$$\frac{\text{Biomass of prey s "available" to predator p =}}{\text{Total food biomass "available" to predator p}}$$

One major problem in this approach is that only some of the prey stocks are assessed by ICES working groups. The remaining part of the food, called "other food", is not assessed, and its handling has to be based on questionable assumptions. Predators not assessed regularly by ICES assessment Working Groups, however, can be accounted for if some information on their biomass and food consumption is available.

Recently, the MSVPA has been extended with a "tuning module" developed at the MAFF Fisheries Laboratory, Lowestoft.

The forecast, MSFOR, computes internally the predation mortalities, using the suitability coefficients estimated in MSVPA. Results are expressed relative to a "baseline simulation", which is usually chosen to be the "present situation" computed by MSVPA. MSFOR predicts catches by fleet, and separates catches into landings and discards. It also computes the value of the catch, when prices are given as input.

MSFOR may be used for either short-term prediction or long-term equilibrium simulations.

MSFOR contains options for sensitivity analysis and stochastic simulation of recruitment. The stochastic simulation takes correlation between stocks into account (Gislason, 1991).

The computer programs are written in FORTRAN, and run under UNIX and DOS/WINDOWS.

A summary of the current MSVPA and MSFOR models is given in Appendix 2, in the form of a comprehensive list of input and output.

Further information on multi-species modelling is given in Anon., 1984a,b; 1986; 1987b; Andersen and Ursin, 1977; Beyer and Sparre, 1983; Daan, 1973 and 1975; Gislason, 1991; Gislason and Sparre, 1987; Helgason and Gislason, 1979; Pope, 1979; Sparre, 1980, 1984, 1986, 1991; Sparre and Gislason, 1986.

3.3 IFAP: The ICES Fisheries Assessment Package

IFAP is an integrated system for data storage, data documentation and documentation of runs made by the ICES Assessment Working Groups. The data handling, run documentation and prediction/yield-per-recruit facilities are programmed in SAS (Statistical Analysis System), and IFAP provides facilities for data exchange with the Lowestoft VPA program (a stand-alone FORTRAN program). The system is still under development.

The basic storage unit is a **stock**, that is a species in a certain area. At present there are 140 stocks, allocated to 13 Working Groups. For all stocks, the system keeps the standard FAD data (FAD: Fisheries Assessment Data), comprising total international catch and landings, mean weights and parameters for natural mortality and maturity. Apart from landings, all data are given by age group. The data period can be a year, half-year or quarter, and the data may be split by sex (total, males, females) and category (total, human consumption, industrial fisheries and discards). Fleet data can be handled by the system, but at present only catch and effort data for tuning VPA are fully implemented.

The system is designed as a hierarchical menu system. It provides the basic facilities for data administration, e.g. data entry, data update, printing and plotting. Data may be entered interactively or imported from ASCII files, and facilities are also provided for exporting data via ASCII files. Parameters and data for all VPA runs, prediction runs and standard assessment plots made by the users, are kept and documented by the system. Hence, all runs may be reproduced, updated or used as a starting point for new runs. It is the intention that all data flows between permanently stored data, VPA runs, and prediction runs should be made internal and automatic; as yet this has only been achieved to a limited extent.

At present the system is running in a DOS environment on PCs. The PCs are connected in a LAN Manager network in the ICES Secretariat, where all data files are kept on a central server. However, work is ongoing for transfer of the system to a UNIX environment on a work station in the ICES Secretariat.

3.4 Integration of the STCF and ICES Multi-species work

3.4.1 An extended multi-species, multi-fleet and multi-area model

The following suggested model and computer program (Lewy *et al.*, WD 1) is part of an EC-funded project. As the LTM WG may be one of the main customers for this work, it should be considered as an introduction, open to new ideas and changes.

The aim of the extended program is to include both historical analyses (VPA) and predictions in one program for which output from VPA automatically goes into predictions. The model should include both biological and technical interactions and spatial effects. The STCF database system and the economic aspects of the STCF ABC model will be included as well.

The VPA will be more or less the same as the ICES MS-VPA. The program will include an option to estimate spatially disaggregated suitability coefficients for 1991 using spatial information on landings (from the STCF database), stock size (from IBTS) and stomach contents. If historical, spatially disaggregated catch and stomach content data exist it will be possible to make multi-species VPAs for specified subdivisions of the total area. Such catch data will not be available for the North Sea until STCF data have been collected for several years.

The prediction program will in principle be the same as the ABC model described above but including the effects of species interaction. Predation mortality will be estimated in the same way as in the ICES MSFOR program using suitability coefficients from VPA.

As in the ABC model it will also be possible to make predictions based on, for instance, roundfish areas or any other sub-division of the North Sea using spatially-disaggregated suitability coefficients for estimation of predation mortality. Options for different kinds of migration patterns will also be included. Reasons for inclusion of spatial effects are treated in Section 4.

Furthermore, there will be options for stochastic recruitment and sensitivity analyses. The prediction model can be run without considering the VPA, but taking the input from other Working Groups.

It will be possible to evaluate the effect of the same management measures as in the ABC model:

- Box closures by fleet and quarter
- Effort reallocation options following box closures
- Mesh size changes by fleet and box
- Relative change of effort by fleet

Furthermore, the model structure should accommodate possibilities for implementation of for instance tuning modules, multi-annual/multi-species TACs and dynamic fleet reactions.

Data requirements

The VPA requires the quarterly catch-at-age data and stomach content data used by the Multispecies Working

Group, natural mortality and parameters for estimating food intake are also needed.

For predictions based on the total North Sea catch at age data by fleet, recent stock size and mean weight-at-age and maturity data are required. Furthermore, estimates of suitability from the VPA should be available.

In the case of spatially disaggregated predictions the spatial distribution of stock size by age and migration matrices are needed. At present the spatial distribution of the stocks for 1991 may be obtained by quarter from the IBTS data.

3.4.2 Data requirements

Discards data

For many assessments no estimates of discards are available. If it can be assumed that discarding is proportional to year-class strength, the lack of discard data may not matter when estimating the relative trends in recruitment and SSB or when making catch forecasts. However, including discards in assessments becomes essential when estimating the absolute stock size. Discards are also essential in assessing the effects of technical measures such as mesh size increases and closed areas, since these measures are aimed also to protect the "unseen" fish. If discarding is substantial, the main benefit may come from protecting the "unseen" fish which will appear in the fishery and the stock as increased recruitment.

Estimates of discards, either obtained by observations in the fishery or estimated by model using various sources of data, are, therefore, essential in the evaluation of the effects of mesh size changes and box-closures. Also important is information on the survival of fish escaping through the meshes. If there is no survival, there would also be no benefit of mesh size regulations and calculations.

The STCF database has included discards data of haddock and whiting for the Scottish fleets. Estimates of discards of haddock and whiting for other fleets has been made by extrapolation of the Scottish data-set. For the other species (cod, saithe, plaice, sole, herring, mackerel, Norway pout, sandeel and sprat) discards data have not been included in the database.

At the last STCF WG meeting (Anon., 1991c) Denmark presented discard data for cod, whiting, saithe, haddock, plaice and sole for some of their human consumption fleets. These data have not yet been included in the database.

This rather limited and, for some fleets inaccurate, discards estimate data-set for discards, should be improved and extended to all species and fleets considered.

The results from the STCF WG (Anon., 1991c) indicated that the effects of box-closures for protection of juveniles were underestimated using the present data-set (see Section 6).

Discards data for assessment purposes may be obtained by monitoring programmes on the commercial fleets. Such programmes would be quite extensive and expensive, since the discards rate is dependent on gear, fishing ground and period. It is, therefore, unlikely to that such data can be obtained on a regular basis in the future for most fleets.

Priority should also be given to developing models which can estimate the discards rate and the spatial and temporal distribution of these, using information on stock distribution, distribution of fleets and their gear performance and empirical data obtained in the fisheries. Such models could be tested, for example, against data from the extensive Scottish discards sampling programme.

It should be realised that discards models in principle estimate catch-rates of fish below a certain size, which is not necessarily the same as discards. Undersized fish, which are not recorded, may be landed and also legal-sized fish may be discarded as a consequence of market saturation or quota restrictions.

The Working Group recognised that the potential of the STCF database cannot at present be fully employed because of the lack of completeness of discard data and, therefore, **recommends** that discard estimates of commercial demersal species be obtained.

Expanding the year range for the North Sea STCF database

The North Sea STCF database has includes data from 1989 and data from 1991 will be provided by the national institutes to DIFMAR in April 1993 (EC-contract).

At present, the North Sea STCF data are available with a time lag of 1 - 1.5 years. This lag might be reduced, but the complexity of the data makes it impossible for some countries to produce STCF data as fast as data for the standard annual ICES assessments. The STCF data are, therefore, not the appropriate source for the annual short-term advice used by ACFM.

If short-term effects are also to be evaluated by this group it is important to update the database every year.

For only long-term considerations the database could be augmented less frequently.

The STCF database could be updated annually to create time series for investigatory purposes. Data from the period 1991-95 seem to be especially important, as the quarterly IBTS will be conducted in these years. The combined stock (IBTS) and fleet and catch (STCF) distribution data-set might be a valuable source for the description of stock and fleet distributions and variability.

The Working Group on Long-Term Management Measures **recommends** an annual update of the North Sea STCF base for at least one more year. The Group recognises that production of such a database requires a lot of extra work for the national institutes and that such a work needs external funding.

Gear selection data

The gear selection model and parameters used in the ABC model were inspired by Scottish selectivity experiments and results (Armstrong *et al.*, 1989). All parameters for this selection model could be given only for the Scottish fleets. For the non-Scottish fleets, it was assumed that the selection curve depends only on species and mesh-size in the cod-end. The gear selection parameters used in this simple model were obtained from a review by Wileman (1988) and are very similar to those specified by the Roundfish Working Group of 1974 which were themselves derived from work carried out in the 1960s and early 1970s.

The STCF Working Group on Improvements of the Exploitation Pattern of the North Sea Fish Stocks evaluated a scenario in which legal minimum mesh size was increased to 120 mm (Anon., 1991c). The STCF Working Group concluded that there is an urgent requirement for up-to-date estimates of selectivity parameters for all major demersal towed gears.

STCF recently made an inventory of existing selectivity data relevant to the present fisheries in EC waters (21st Report of STCF, 1992). It identified gaps in the information and indicates present priorities in obtaining information, in the future, with respect to species, gears and areas.

Economic data

The STCF database includes ex-vessel prices by fleet, species and age and price modification factors.

Value and quantity data are normally available using the national catch statistics and the price data can, therefore, be produced without undue effort. Other economic data, such as cost information, are not available through data sources normally accessed by biologists.

The Group recognised that the description and model development of effort reallocation would require an active role from fishery economists and that both catch values and costs seem to be important variables in such a model.

3.4.3 Expanding and maintaining the data-sets

Integration of data with IFAP

Inclusion of the STCF database and the multi-species data-set into the IFAP system would make it possible to avoid discrepancies in the catch statistics used in the different models. The ideal solution would be that data should only be provided once in the most disaggregated form. The format could be the STCF exchange format with an additional management stock identifier. Data for single and multi-species assessments would then simply involve aggregation of these data. However, at present this solution seems to be too ambitious as some countries do not have facilities to produce this set as a normal routine.

The IFAP system does not include possibilities for storing spatially disaggregated data. This system can, therefore, not handle the spatially disaggregated data in the STCF base without heavy modifications.

The very disaggregated storage formats used in IFAP give a high degree of flexibility for data manipulation related to standard single species assessments, but seem inconvenient for operations including more than one stock. The IFAP data structure, using one file for one variable for one stock and fleet would, for example, produce about 2,000 separate files for storage of total catch weight, catch numbers and catch mean weight from the STCF database (this example ignores the fact that IFAP cannot store spatially distributed data). It seems, therefore, at least for practical reasons, impossible to use IFAP to store STCF data. However, both IFAP and the STCF system has been developed using SAS. The two systems can, therefore, be combined in one package.

The data-sets for multi-species assessment can be stored in IFAP for most of the types of data used. IFAP, however, has no facilities for the storage of stomach data.

The problems using IFAP as a multi-stock, multi-fleet database will be the same as for storage of the STCF database. It does not seem fruitful, therefore, to put effort into modifying IFAP to include the full multi-species data-set.

Maintaining the data-set

DIFMAR will in 1993 continue the development of the database system for storage and presentation of the STCF database (EC-contract). Facilities for storage of the additional data required for the extended "ABC-MSVPA-MSFOR" model will also be developed. These data include stomach content data, stock distribution data (IBTS data) and migration data. Furthermore, STCF data for 1991 will be checked and included in the database system.

DIFMAR will distribute data from the extended database on request. The confidentiality of catch and price data requires that each country has to give its agreement before its national data are distributed.

From 1994 ICES will take over the maintenance of the database and computer programs. The transfer of the STCF database to the ICES Secretariat would need some guidance to the Secretariat about how it should be done and about what service should be provided to the users. The Working Group **recommends** that a Steering Group should be set up oversee the transfer of the STCF database and in particular, to determine:

- hardware and software facilities needed
- maintenance requirements
- checking procedures
- error corrections
- updating procedures
- extraction procedures
- confidentiality rules
- access rights
- etc.

Experience from the IYFS database and the development of the IFAP system have shown the need for steering groups or the like for these kinds of tasks.

Confidentiality of the STCF base

The North Sea STCF database has included catch information in a very disaggregated form. The STCF Working Group expressed reservations about the access to the international data contained in this database (Anon., 1990). For using the international data, the user has to obtain permission from the chairman of the STCF Working Group on Improvement of the Exploitation Pattern of the North Sea Fish Stocks. The chairman has then to seek permission from the individual national authorities.

The LTMWG **recommends** that the STCF database should be made available to the ICES working groups relevant to the management of the North Sea fish stocks. The Working Group asks for guidance from ACFM and national and EC representatives on what conditions need to be attached to the use of this database by this and other ICES working groups.

3.5 Economics data and models

The Working Group does not consider itself expert in bio-economics; because of the need for an economics input and liaison, however, a fisheries economist attended the meeting. This section contains papers based on presentations by Sparre (Section 3.5.1) and Cunningham (Section 3.5.2). There was some discussion on the difficulties of understanding fishermen's behaviour and on fleet reallocation models. These discussions are not reported here, but see Section 2.1.2 and Section 8.

3.5.1 The links between the ICES forecast model (MSFOR) and economic models

In order to combine the biological assessment carried out by ICES with an economic analysis, some sort of collaboration between ICES biologists and a group of fisheries economists must be established. Currently there is no expertise on fisheries economics available in ICES. This section assumes that a collaboration between ICES biologists and a group of economists has been established.

The biological analysis will precede the economic analysis. The ICES biologists supply the economists with a "production function", which in principle is the same as the traditional yield curves. However, to combine the ICES yield prediction methodology with an economic fisheries model, some extensions and modifications will be required. By "economic model" we shall here only consider a costs and earnings analysis, that is calculation of profit by:

Profit = Revenue — Costs

This calculation has to be made for each fleet (here defined as a group of fairly uniform vessels). The definition of "fleets" or "métiers" will not be discussed here. However, it is noted that the inclusion of economic aspects in the analysis may have implications for fleet definition, which is crucial for an economic analysis.

Any economic analysis will be centred around the fleet units and will take its starting point in the above basis costs and earnings analysis (a comprehensive description of the procedures described below is given in, for example, Sparre and Willmann, 1992, 1993).

Input/output to ICES catch prediction

The traditional format of the principal input/output to ICES forecast models are:

INPUT: Fishing mortality by fleet and age group

OUTPUT: Numbers caught by fleet by and by age group

Both input and output to the biological analysis will become input to the economic analysis. Input becomes costs and output becomes revenue. Costs are separated into variable and fixed costs. Basically, variable costs depend on the fishing effort and the value of the catch. Fixed costs depend on the number of boats within each fleet. Thus the task is to convert fishing mortality into costs of fishing and number of boats, and numbers caught into value of the landings.

Value of the catch

The price per kg of a given species can vary between fleets and it can vary within the fleet, depending on who buys the landings. It is assumed that the economists supply the prices or define procedures for calculation of prices. Prices per kg are not given by age group but by commercial size category. Thus, the first thing to do is convert the array of numbers caught by age group into units of weight by commercial size category. The second step is to split each weight in the array of commercial size categories into components according to the buyer (fish auction, exporter, processing plant, etc). The third step is to multiply each weight component by the buyer-specific price. If the prices and the distribution on buyers are supplied to the biologist by the economist, the actual calculations can conveniently be made as part of the biological forecast program. Economists may require values in terms of different prices, typically in "Ex-vessel prices" and "Whole sale prices".

Variable costs of fishing depending on the number of effort units

Fishing mortality is not useful for calculation of variable costs (such as fuel, lubrication, crew's wages and food, maintenance of gears, etc.) and has to be converted into fishing effort for each fleet. The measure of effort suitable for calculation of costs may not necessarily be the same as the effort measure suitable for conversion of effort into fishing mortality. Thus, when making a biological prediction, input should include both fishing mortality by fleet and the corresponding effort. The effort is also used to compute the employment in the harvesting sector. The development of suitable definitions of effort should emerge as the result of collaboration between, biologists, gear technologists and economists.

Variable costs of fishing depending on the value of the catch

These costs comprise, for example, the crew's share of the revenue and auction commission fee. As the value of the catch will be calculated for the purpose of profit calculation, these costs will not give any additional work.

Fixed costs of fishing

Fixed costs depends on the number of vessels, and include depreciation, insurance, licence fee, etc, that is costs which occur irrespective of the fishing activity.

The number of boats is related to the effort exerted. With a certain number of vessels there is an upper limit to the effort per unit time the fleet can exert. Thus, for each fleet, the maximum number of effort units which can be exerted per unit time should be defined.

Integration of economic elements in the biological model

As is demonstrated in BEAM 4 (Bio-Economic Analytical Model, Sparre and Willmann, 1993), it is convenient to make some of the economic computations while doing the biological computations. The economic quantities to be calculated within the biological model are:

Conversion of landings into commercial size categories
Value of the landings
Number of effort units exerted
Number of boats
Distribution of the landings to buyers

The biological model behind BEAM 4 is essentially the same as the ICES forecast model, MSFOR, and consequently the same methodology for merging biology and economics should be applicable for MSFOR. The economic part of BEAM 4, however, was developed for penaeid shrimp fisheries in developing countries, and cannot be readily transferred to, for example, the North Sea.

3.5.2 Economic aspects of the EC model

Price formation

Simulation models often take prices as constant. The usual justification for this is that the fishery under consideration is part of a world market for the target species and that catches from that particular fishery influence the world price. Another reason is that, in most cases, the shape of the revenue curve is such that even if price is variable the optimal level of exploitation is not very sensitive to price changes.

In practice, however, the price situation tends to be complicated in various ways. Firstly, landed prices received by fishermen may vary according to the quantity landed, first because of the quantity itself and second because the quality of fish may be inversely related to quantity. Secondly, in many cases a price structure may exist for the species such that larger individuals command higher prices than smaller ones. In some cases, e.g octopus, the number of price categories may be substantial.

An improvement in the level of catches and/or in their structure may be negated at the economic level by price changes. The fishermen could even find themselves worse off if price is sufficiently sensitive to landings.

Economists have modelled demand in fisheries in various ways. One area that seems deserving of future research would be to try to integrate a demand model, as a separate module, into a general simulation framework for a fishery (such as BEAM IV). Otherwise arrays of prices need to be output from economic models and input into simulation models (depending on the purpose of the model).

Prices are important for another reason: they are an important determinant of the level of resource rents available from the fishery. Resource rents are important for two major reasons. First, they are the reason that there is a fishery problem at all and, second, they are the major benefit that will flow from fishery management. They are the reason that there is a problem because the rents give misleading economic signals to the fishermen to which they respond very efficiently. An estimate of resource rents is needed, therefore, to enable predictions to be made concerning the likely levels of fishing effort and to enable the costs to be assessed of a failure to manage fisheries effectively. The fact that prices do not affect the optimal level of exploitation is acceptable if all that is required is some estimate of this level; but is irrelevant if what is required is an estimate of how far away from it the fishery will be.

Demand must, therefore, be taken into consideration, and ideally prices should be endogenous to the model. However, the difficulty of achieving such a result should not be underestimated. Demand is a multi-variate function. The price of the species is important, but so are other factors. Economic theory suggests that, in general, the most important of these will be the prices of other species, the prices of competitive foodstuffs (eg chicken), and real consumer incomes. However, in any particular case, a whole range of factors may be important ranging from the Pope to the weather. A demand study is an iterative process whereby likely variables are identified on the basis of theory and knowledge of the particular circumstances. Data are collated on relevant variables (or proxies (instruments) if the original variable is unobservable or data are unavailable). Empirical estimation is undertaken. The relevant variables list may then be modified. The model is then maintained by the regular collection of data and re-estimation. Generally regression techniques are used as the basis for demand estimation.

Fishermen's behaviour

Probably the most difficult aspect of forecasting and simulation concerns predicting the behaviour of fishermen in response to economic (and other) stimuli and hence in response to management measures.

One approach is to argue that fishermen are fishing for profit and that this is the key variable. In simulation models the usual approach is to argue that if profits are positive then entry to the fishery will occur and if they are negative exit will occur. However, this approach suffers the drawback that bang-bang solutions generally emerge and so constraints are usually imposed on the fishery to prevent this happening. For instance, it might be argued that it takes two years to commission a new fishing vessel so that profits now will lead to an influx of vessels in two years time. On the exit side, it might be argued that entry and exit conditions are asymmetrical so that if losses occur fishermen will nonetheless carry on fishing providing they cover their variable costs since their assets are fixed in the fishing industry.

In the case of a particular fishery, however, numerous complications have to be considered. First, a bang-bang solution may be the most accurate if vessels can switch their effort from fishery to fishery in response to profits. Second, the profits available from alternative fisheries and even alternative occupations are clearly important, so that even with accurate predictions of profits for a particular fishery it may be difficult to predict the behaviour of fishermen.

There is also a need to consider different time periods since the reaction of fishermen may be very different in the short run, when they simply inherit the consequences of yesterday's investment decisions, and in the long run, when they decide the level of investment in various economic activities of which fishing may be only one. The importance of an understanding of behaviour cannot be overemphasized in the context of designing management measures. Some anecdotal evidence may help to give a flavour of the kind of problem being faced.

Suppose that an open-access fishery is currently in bioeconomic equilibrium and that fishermen are aiming to maximise profits. If a tax is imposed on landings then the price to fishermen is effectively lowered. Some of the least efficient firms are likely to leave the fishery immediately, others over the long run. Those that remain will find it profitable to use a smaller level of effort. Overall, therefore, fishing effort can be expected to fall as a result of the tax.

If, however, the target of fishermen is simply to achieve a satisfactory level of profits then imposing a tax will encourage them to increase their effort in an attempt to re-establish their previous profit level. In this case a tax might have the unintended side effect of increasing fishing effort simply because fishermen's objectives are misunderstood.

In the Moroccan pelagic fishery, installation of power blocks had no noticeable effect on employment. Although difficult to understand to begin with, this result is easily explained once it is realised that many vessels are (effectively) owned by the crew, whose major concern is employment. Unless features such as this are understood, it will be impossible to predict the impact of management measures.

The problem in this area is not simply one of data collection but of investigations to determine the factors underlying fishermen's tactics and behaviour.

Exploitation level versus regulatory framework

Much of the discussion between biologists and economists concerning fisheries management has been a rather sterile debate about the merits of one "optimal" exploitation level compared with another (the MSY vs MEY debate). Recently, fisheries economics has been much more concerned with finding an optimal regulatory framework - the opinion being that it matters less what the target level of exploitation is than how it is achieved.

Fisheries economics currently lays great stress on the issue of ownership of resources. The reason is simple. The problem of fisheries management arises because a valuable resource (the fishery) belongs to no one. The fishermen, therefore, confuse returns which should accrue to the resource owner with those that should accrue to the resource exploiter. If the fishermen both own and exploit the resource then their reaction is different (the problem is not of overexploitation of Scottish salmon farms - although even in aquaculture some element of overexploitation may occur due to lack of ownership of the marine/brackish environment). Once ownership of the resource is allocated to a person/company/body then that entity should extract the returns due to the owner (resource rents) and the attraction of exploiting the resource will be correspondingly diminished. As a result many of the fisheries problems which are common at present will be resolved (most notably the issue of overexploitation) although other problems may appear (eg in New Zealand, there have been disputes over ownership which have finished with the Maoris pursuing their case through the courts).

Bio-economic models for the North Sea

Having discussed the difficulties of bioeconomic modelling in general, the Working Group considered an approach to the problem developed in connection with the North Sea fisheries.

The model framework

The basic structure of the model was established at an STCF sub-group meeting held at Nantes, France in September 1989 (Anon., 1989). The model calculates a do-nothing baseline simulation to which the impact of proposed management measures are compared using the relationship between catches, prices and costs of fishing. This relationship enables one to calculate total revenues and profits. The model then considers the way that fishing effort might be expected to develop in response to such profits.

The structure of the model is quite simple but it brings out very clearly the inter-relationships between biological and economic variables that make forecasting the impact of management measures so difficult. The inter-relationship between the variables also makes it difficult to know where to break in to the cycle.

The model begins with four definitional equations.

[1] $\pi = TR - TC$ (profits)

[2] $VA = \pi + w$ (value added)

[3] $w = \alpha.TR$ (wages)

[4] $TR = p.q$ (total revenue)

where π = profits, TR = total revenue, TC = total costs, VA = value added, w = wages, α = share rate, p = price, q = quantity landed.

It then specifies a series of functions to be estimated:

[5] $p = p(q,n)$ (demand)

[6] $q = q(f \ldots)$ (ICES multi-species model) (output)

[7] $TC = c(f,s,q)$ (costs)

where n = a set of other variables influencing demand, f = effort, s = stock size.

Some simplification of equation [7] is possible since both s and q depend on f, so that ultimately TC depends solely on f, for a given level of technology, this being a standard assumption of fisheries economics.

The important part of the model is the correct specification and estimation of equations 5-7. Equation 6 should flow from the biological side of the model, although if the biological model is specified in terms of mortality (or multipliers of effort) some way has to be found to translate the results into nominal fishing effort so that equation 7 becomes meaningful. Equation 5 is the demand relationship and this will flow from the economic side of the model. The precise specification of the equation will depend on the fishery or fisheries being studied.

The link with fishermen's behaviour (and the element of circularity) is then introduced by equation 8 which attempts to specify how fishing effort is determined.

[8] $f = f(\pi^*, o, w)$ (effort)

where f = effort, π^* = target profit level, o = other objectives, w = weather.

An equation such as [8] is clearly required. Models where the impact of management measures is investigated by simulating the operation of the fishery over a large number of periods on the assumption that effort is exogenous are likely to give very misleading results. Generally, in such models, measures such as mesh size increases and seasonal closures look very attractive because only the impact of these measures on profitability is considered. This might be called the first round impact of the measure.

However, changes in profitability will affect effort levels which will affect the long-run profitability of such management measures; this being the second round impact. The result is that a fishery can easily be driven into a situation similar to that of the US part of the Pacific Halibut fishery where the fish stock itself is, apparently, in good condition but the fishing fleet operates two days per annum with vastly excessive levels of fishing effort.

Each time the fishery is simulated a reduction in open season length looks attractive if only its first round impact is taken into account but the second round impact is to encourage more effort into the fishery requiring another reduction in season length. This cycle may then repeat itself, apparently until the season length tends to zero.

Fisheries economics expects that due to the very competitive nature of fishing, those enterprises that fail to maximise their profits will be driven out of business in the long run. Fisheries economic models frequently assume therefore that the goal of enterprises will be profit maximisation and that π^* will be the principal determinant of fishing effort. However, it is very important to verify this hypothesis since if fishermen are following different goals predicting their response to management measures will be impossible.

During the study some modifications were made to the model. In particular the effort function was broken into an effort allocation function (equation [9]) representing short-run effort decisions and an investment function (equation [10]) representing the long run.

[9] $f = f(\pi_{t-1}, I_{t-1}, o, q)$ (effort allocation)

[10] $I = I(\pi, r, T)$ (investment)

where r = real interest rates and T = technology.

Empirical Results

The empirical results obtained tend to confirm the general observations made above, although it is regrettable that, due to the very ambitious nature of the project, not all elements of the research strategy could be completed.

An important result of the project was to develop a variety of economic time-series data-sets, each for around a ten-year period. The project also demonstrated that modifications of biological, technical or economic parameters may have different effects on short and long-run fishing strategies. In the short run it is usually the parameters determining the composition and distribution of effort that are changed (fishing time, target species, fishing gear). Structural changes in the level of capital and labour employed tend to occur in the longer run.

Costs and earnings functions were estimated at the métier level using standard econometric techniques. The verification of the economic data was done by comparison of various sources (Ministries and other management agencies, fishermen, banks).

Finally, a case study of price formation and market interrelationships in the French sole fishery showed that the price structure of the fishery was stable so that there was no need to proliferate equations in order to model price effects. Instead it was possible to identify a key price to which other prices were linked in a predictable way.

4 FISH MOVEMENT AND SPATIAL EFFECTS IN MODELS

4.1 Terminology

Active migration refers to systematic and regular transfer of fish, either horizontally between areas or vertically. Passive migration refers to the transport, mostly of eggs and larvae, with the currents. It was recognized that the non-systematic movement within an area should be distinguished from migration. An attempt was made during the meeting to classify movements of fish having in mind the effect of technical measures given the impact of various types of movement.

Classification of movement

1. Seasonal migrations by adult fish. This typically occurs between spawning, feeding and overwintering areas. Although this kind of migration is in many cases repeated year after year, it may show large variations in some stocks due to climatic factors, stock size, or other causes. Situations where fish of different age or size appear at the spawning grounds, feeding grounds etc. at different times are included in this type of migration.

2. Juvenile migrations. This is introduced to emphasize that juveniles usually do not have the adult migration pattern. It includes the gradual shift in distribution, e.g. towards deeper water, as the juveniles get older.

3. Age and size dependent distribution. This refers to the tendency for larger and older fish to be distributed differently from smaller or younger fish, within the age groups described in 1 and 2 above.

4. Diel migrations, typically in the form of vertical migrations, but in some cases also horizontal migrations, including the fact that some fish use vertical migrations to take advantage of the tidal currents.

5. Non-systematic movement within an area. Fish are usually not completely sedentary, but moves around in a more or less random fashion. This implies that fish mix within the area.

6. Passive migration of eggs and larvae. This may be relevant to the understanding of recruitment processes, but will not be considered further here.

4.2 Behavioural Mechanisms of Movement

Known mechanisms for transport can be utilized as a basis for modelling the spatial dynamics. For example, fish may move between two areas by active swimming or use particular water currents for transport. The latter behaviour, in the form of selective tidal stream transport, is well documented for plaice (Arnold *et al.*, 19...??).

4.3 The Impact of Mixing on the Effect of Local Technical Measures

Basically, the link between technical measures and a model of the dynamics of a stock is the fishing mortality. The modelling problem, therefore, essentially is to describe the effects of technical measures in terms of fishing mortalities.

The effect of technical measures applied to a restricted area depends strongly on how well fish inside and outside the area in question mix. The general aspects of this can be illustrated by considering the effect of a box closure (as defined in Section 6).

One extreme situation is when the fish inside and outside the box mix completely. Then, the area distribution of the stock will not be affected by local changes in mortality. In the case of a box closure, the overall fishing mortality will be reduced by the partial F in the box if there is no effort redistribution. However, if the TAC is maintained at the original level, there will be no effect on the population at all.

The other extreme is when fish within a given area is isolated from the rest of the stock, i.e. no mixing takes place. In this case, closure of the box will not affect the fishing mortality outside the box if there is no effort redistribution. The overall spatial distribution of the stock will change, with the relative density inside the box increasing. If the TAC is maintained, the fishing mortality outside the box will increase, thus increasing the change in relative densities.

A more common situation than in the two extremes mentioned above will probably be a partial mixing, i.e. a gradual exchange of fish between the areas, but not so effectively that changes in the fishery have no effect on the future area distribution.

4.4 Examples of the Impact of Migration on the Effect of Technical Interactions

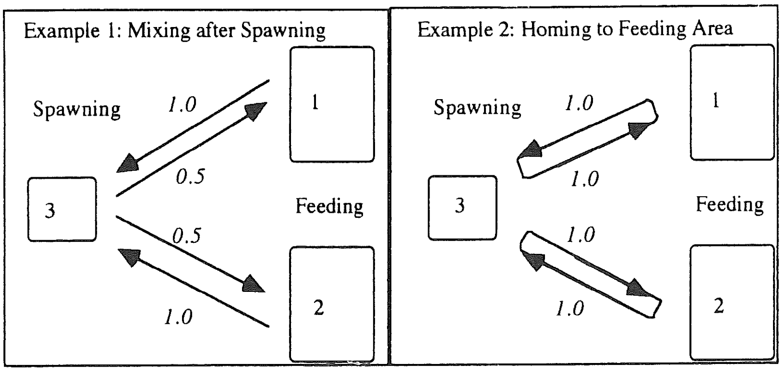
A common motive for closing a box is the protection of juveniles. The migration in question is unidirectional. Reduction of F on the juveniles will increase the chance that they become adults. This will also change the exploitation pattern of the fishery. If there is no reduction of TAC, this will result in an increased F on the adults. No information on juvenile abundance will be available from the fishery. It follows from the considerations above that closing only part of the juvenile area will be less effective if mixing takes place within the juvenile area.

Closure of spawning grounds has also been used in some areas. There are possibly two motives, to enhance recruitment, and to prevent fishing when the fish are concentrated in order to prolong the fishing season. One can assume a high level of mixing following the spawning period. If there is no reduction in TAC, there will be no reduction in fishing mortality, and no effect on the spatial distribution.

While area closures are usually directed at protecting a specific species, there could also be effects on the other species fished in the closed area. For example, the Norway pout closures are meant to protect haddock juveniles. Do the closures also isolate a portion of the Norway pout population from fishing and thus affect the assessment estimates?

Two types of annual regular adult migrations are illustrated below (see Figure 4.1). In both, the fish move between a spawning area, where they are aggregated, to summer feeding areas where they are disaggregated into two separate areas. In the first example the fish mix completely during spawning and redistribute themselves equally to the two feeding areas. In the second, the fish home to the feeding areas. Migration rates are indicated in italics.

Figure 4.1 Two types of adult migration showing in each case the proportion of the stock migrating between spawning and feeding areas.



The consequences of closing one of the feeding areas onthe spatial distribution of the fish would differ according to whether there was homing or not. In example 1, closure of one of the feeding areas would isolate half of the stock from fishing during the feeding period. The stock would mix in the spawning season and redistribute itself equally to the feeding areas in the following summer. Thus the closure would not affect the pattern of stock distribution. The second example in effect represents two stocks that are mixed in the spawning season. Closure of one feeding area would reduce fishing effort on one of the stocks and thus change the spatial pattern of distribution; fish in the closed area would be more abundant than in the open area.

There would also be important implications on the stock assessment. It is unlikely that the two stocks in example 2 could be assessed separately given that they are mixed during spawning. However, the closure would result in differential exploitation of the two stocks and the Fs estimated with VPA would represent local F rather than F on the two stocks. The problem would be exacerbated in a tuned assessment. If the abundance index used for calibration was drawn from only a survey during spawning, more fish would be available to the survey than to the total fishery. If CPUE data for the entire fishery were used, then the local abundance in the closed area would not be sampled. This issue may warrant further study using examples of current closed areas.

Example 2 above is not unlike cod in the northern Gulf of St. Lawrence. In winter the stock aggregates at the mouth of the gulf as ice forms, and remains there until the ice disappears in April. Recent tagging studies have shown a certain degree of fidelity of cod to summer feeding grounds (Gascon *et al.*. 1989).

4.5 Modelling of Migration

Inclusion of migration in age-based fish stock assessment has been suggested for many years, but there are few examples of practical use of the methodology. For a theoretical discussion of migration in connection with age based fish stock assessment the reader is referred to Quinn *et al.* (1990). These authors also discuss the estimation of migration parameters. Sparre and Venema (1992) discuss the assessment of migratory stocks at a somewhat lower mathematical level. A summary of the mathematical aspects of migration was presented as a working paper to the group (Webb 1993, WD 8). As an example of how migration can be modelled, a summary of the model of migration in BEAM 4 (Sparre and Willmann, 1993) is given below. A similar approach is used in the ABC model.

The migration is modelled in a time-discrete manner for any number of areas and any migration route between the areas. Migration only takes place at the end of each (species-dependent) time period. Within each time period the fish are assumed to be homogeneously distributed within the area.

The "Migration Coefficient", T_{BA}, from area A to area B is defined as the fraction of the animals in area A which moves to area B. In this definition, the "movements" include the "move" from area A to area A, i.e., the event that the animal does not move. The migration coefficient depends on (or has the indices):

ar: Starting area j: Destination area
s: Species a: Age group

Note that the sum of migration coefficients over destination areas always becomes 1.0, as the starting area is also considered a destination area, i.e. for each starting area i:

$$\sum_{j\ \text{(destination)}} T_{ji}[s,a] = 1.0$$

To illustrate the concept, an example is considered in the text table below with three areas, A, B and C. A unidirectional migration from A to B and from B to C is assumed. If the migration from A to B takes place gradually over age groups 2 to 4 and no fish return to area A the migration coefficients for movement out of A could be those shown in the upper part of the table. If the migration from B to C takes place gradually over age groups 6 to 8 and no fish return to area A or B the migration coefficients for movement out of B could be those shown in the middle part of the table. If the fish stay in C the migration coefficients for movement out of C are those shown in the lower part of the table.

		T_{BA} (s,a) Age group										
From	to	0	1	2	3	4	5	6	7	8	9	10
A	A	1	1	0.8	0.5	0.2	0	0	0	0	0	0
	B	0	0	0.2	0.5	0.8	1	1	1	1	1	1
	C	0	0	0	0	0	0	0	0	0	0	0
B	A	0	0	0	0	0	0	0	0	0	0	0
	B	1	1	1	1	1	1	0.8	0.5	0.2	0	0
	C	0	0	0	0	0	0	0.2	0.5	0.8	1	1
C	A	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0
	C	1	1	1	1	1	1	1	1	1	1	1

In some cases, in particular where there is a fishery in an area in which the fish abundance varies rapidly due to migration, the assumption that fish only move at the end of each period may cause problems. A first alternative is to use the continuous analogue (Beverton and Holt, 1957). Here, the rate of change of the stock in each area is described as the loss due to mortality, the loss due to emigration, and the gain due to immigration:

For each area i and each cohort,

$$dN_i/dt = -(M_i+F_i)N_i - \sum_j N_i T_{ji} + \sum_j T_{ij} N_j$$

This will increase the computational burden considerably, since a set of differential equations has to be solved each time.

Estimation of migration coefficients

Whatever migration model is applied, the coefficients describing the migrations have to be estimated. In some cases this is rather obvious, eg. when the whole adult stock moves to a spawning ground. In other cases, it may be possible to infer realistic migration coefficients from known biological properties of the stock, as noted previously.

If only the area distribution is known by season, the number of unknown coefficients will excede the number of possible equations in the general case, and the problem has innumerable solutions. A solution can be found which is optimal in some sense, eg. the one which requires a minimum of transport effort. It may be questionable, however, how realistic such solutions are.

If adequate tagging data are available, migration coefficients can be estimated. This seems to be the best approach to the problem. This also seems to be the natural approach to estimating the extent of mixing due to non-systematic movement.

4.6 Spatial Aspects of MSVPA

In the MSVPA the consumption of a prey species by a predator is assumed to be a function of the preference of the predator for the prey (i.e. suitability) and the abundance of predator and prey. A problem with the current application of the model is that spatial overlap is not accounted for in the estimation of suitability and the prediction of consumption. This may be overcome by using a spatially disaggregated model. A discussion of this topic can be found in the 1992 Multispecies Working Group report (Anon., 1992b)

4.7 Conclusions and Recommendations

There are several reasons for considering area distributions in relation to the work of this Working Group. Many technical measures are restricted to certain areas and their evaluation requires area-disaggregated models. Modelling the migration *per se* becomes more important when mixing is less extensive. Only when mixing is complete, can the area distribution be used as it is.

In long-term considerations, the possibility of changes in migration routes and distribution, either density dependent or environmentally-induced, may have to be considered. Migration that is not accounted for may cause bias in assessments, either through sampling errors or because CPUE is referred to the whole stock even though it should apply only to a local fishery.

In the MSVPA, inclusion of spatial distribution in the model may reduce the variations in the suitabilities over time due to variations in spatial overlap. It may also remove inconsistencies in the predictions which appear because predators are allowed to eat prey outside the area where the predator is found.

It should be noted that the number of migration coefficients grows very rapidly as the number of areas is increased. The number of areas in a model should, therefore, be kept as low as possible.

For the future work of the Working Group, it is recommended that an overview of existing sources of data on migrations, in particular tagging data and area distributions of stocks and catches, is made.

For a further understanding of the dynamic consequences of the various types of fish movement, simulation studies are encouraged. These may be studies with simple models of general aspects of the problem, or direct studies of particular stocks and technical measures. In the latter case, the ABC model should be a useful tool.

5 FLEET, GEAR SELECTIVITY AND EFFORT MODEL

5.1 The Need for Fleet-disaggregated Catch Data

Disaggregation of catch data on fleets in predictions is necessary if technical interaction effects are to be taken into account. Technical interactions are connected to the fact that a specified fleet may catch several species besides the target species. All these species may be affected by management regulations and these overall changes are defined as technical interaction effects. These may be expressed in terms of fishing mortality matrices indicating the exploitation pattern by species. Assuming that no changes in the spatial distribution of stocks and effort occurs, future catches may be predicted by assuming that the fishing mortality matrix remains constant. This assumption seems to be valid in the case of the short-term, and maybe also for medium-term, predictions.

However, if the spatial allocation of effort or the stock size distribution changes during time the fishing mortality matrix will probably change. If such changes are to be understood and predicted then the concept of métiers needs to be introduced. The reason for this is that the choice of métiers is probably crucial for the behaviour of the fishermen and, therefore, for the allocation of effort.

In order to make prediction models, including effort reallocation models, the métiers have to be identified such that effort by fleet can be split into various métier components. For management purposes a large number of métiers may not be operational. It, therefore, seems to be necessary to combine the métiers into manageable fleets. Furthermore, the mechanisms of effort reallocation have to be analysed.

In order to estimate suitabilities, fleet data are not needed in the MSVPA, but only total international catch by age.

5.2 Identifying Métiers

Lewy and Vinther (1992) have suggested how métiers might be identified using data on a single vessel trip level. They used the cluster analysis technique to identify the métiers of the Danish human consumption bottom trawlers by classifying the species composition of the trip landings. The value and not the weight of the species was considered.

Some warnings were expressed by the Working Group regarding the procedure used, because the clusters identified might not be real métiers but just represent catch compositions originating from random noise. Furthermore, decisions about the number of clusters and their delimitation can be done in several ways and always contain an element of subjectivity (Gabriel and Murawski, 1985).

It was suggested that, if data from more than one year are available, the métiers identified could be evaluated, for instance by applying the procedure to each year separately and comparing the fisheries identified and the 'exploitation pattern' matrices.

Whether data are available in all countries around the North Sea to allowing similar studies is uncertain.

A related approach using principal component analysis (but based on commercial catch weight compositions) was used to look at English bottom trawl data (by trip) from 1982 to 1987 (Rocha *et al.*, 1991). This work suggested that definitions of métiers could be derived which were complicated (with vessels entering métiers at different times and from different home ports) but which were stable through time.

It was argued that objective criteria for defining métiers, such as combinations of vessel types, vessel size, gear used, home harbour, time of year etc. on a trip basis, might be safer than the above procedure. Some doubted whether this would define métiers because it has often been observed that a given vessel can use the same gear in completely different fisheries. It might be worthwhile investigating whether this is happening sufficiently often to prevent the use of objective criteria in defining métiers.

5.3 Effort Reallocation

To analyse the short-term reaction of fishermen to any new technical measure it is necessary to know how they reallocate effort. Assuming that the situation remains stable after the establishment of the measure (short-term change) it will then be possible to run medium-term predictions and long-term analyses. However, very little is known at present about fishermen's behaviour and the Working Group strongly recommends that existing data are analysed in this respect. There are plans to have an EC workshop with the following terms of reference (Horwood and Griffith, 1992):

a) evaluate the different methodologies developed for identification of fisheries units (métiers),

b) advice on how métiers should be defined for management purposes,

c) advice on appropriate units or measures of fleet and vessel capacity,

d) advice on data requirements and methods for describing the dynamic behaviour of fishing fleets.

This Working Group strongly supports these plans, and recommends the involvement of sociologists and economists in this kind of work.

5.4 Gear Selectivity Models

In order to estimate the effect of mesh size changes models of gear selectivity are needed.

However, investigations have shown that gear selectivity is not just a matter of mesh size used. The selectivity of a given mesh size can be changed substantially by special rigging and design of a gear. The fishermen have, so to say, ways of circumventing mesh size regulations without actually breaking them. This would indicate that selectivity measures must deal with more aspects than just the mesh size. Both the rigging and the design have to be considered. At present it is not quite obvious how this should be done in the regulations and, therefore, it is difficult to see how it should be modelled.

Another problem with gear selectivity models is that it is not always certain whether the fish escaping the gear will survive. Some experiments suggest that almost all the fish die and others that most of them survive. This survival rate will probably depend on both species and gear. The Study Group on Ecosystem Effects of Fishing Activities has discussed this matter at their meeting in 1992 (Anon., 1992c).

Both the above questions would require the involvement of gear technologists and ways of liaising with them should be considered. The EC project described below will deal with (among other things) the problem of gear selectivity.

5.5 Effort Modelling

Dick Ferro (gear technologist) presented an EC-funded project which aims at analysing fishing power of individual vessels. The variables which may affect fishing power can be grouped under the headings: vessel characteristics (e.g. Hp, length), gear design (e.g. mesh size, number of meshes round the cod-end, net size) and gear performance (e.g. net spread, towing speed).

In the present context fishing effort is defined as the product of the fishing power of a fishing unit and the fishing time.

Traditional management analysis evaluates fishing effort for a particular gear category as the fishing time (e.g. number of days absent), assuming that the fishing power is constant for all fishing units in that category. Sometimes the fishing time is scaled by some arbitrary indicator of vessel fishing power (e.g. horsepower).

Because the gear categories recorded in fisheries statistics databases are very broad (pelagic and demersal trawling may not even be distinguished), the constant average fishing power assumption is unlikely to be accurate.

For ICES Divisions IVb and IVc and a limited range of species the major métiers (groups of similar vessels working similar gears targeting the same species) will be identified for each of four countries (Denmark, Belgium, England and Scotland). A comprehensive survey of gear and equipment used by fishing vessels will be undertaken by interviewing the skippers. Catch per unit effort over a complete year will be used as a dependent variable and its relation to the vessel parameters and measured gear parameters for a typical fishing unit in each métier will be explored. This may involve a similar analysis to that outlined by Pope (WD 14), using the STCF database to provide quarterly distribution charts for the North Sea. The vessels in each métier will be chosen specifically to ensure that they form a homogeneous group which can be represented by one typical vessel whose gear performance will be measured at sea. Gear performance (engineering, not catching performance) is not thought to change markedly within the time scale of one year. Variance due to spatial and time effects will be estimated.

The Working Group considered that this work would be useful in shedding light on the significant parameters defining fishing power. The Working Group felt that the analyses relating CPUE and vessel parameters need to be approached in more detail. The work also aims to make comparisons of the fishing power exerted by different gears and different vessel sizes. There were suggestions that discards needed to be taken into account if possible and that the derivation of fishing mortality from CPUE would be helpful, e.g. to allow comparisons between years.

The Working Group suggested that factors affecting catch rates of towed demersal gears could also be estimated by the use of generalized linear models. By relating catch to effort it will be possible to investigate the relative fishing power of different classes of vessels. Classification of vessels can be made on the basis of vessel type, gear characteristics or target species, e.g.:

ln catch (species, year, area, fleet) =

ln effort (year, area, fleet) + fleet + area + year + error.

The fleet factor will provide a coefficient that will enable measures of effort to be compared between vessel groupings. It will be possible to test how homogeneous particular groupings are and, by adding extra terms or making effort a function of additional variables, to investigate factors affecting catch rates. Gavaris (1980) has followed these lines when estimating catch and effort from commercial data, and this paper might be worth consulting for more details.

It was, furthermore, considered that it would be interesting if the skippers in the interview survey could be asked what gear they have used in the past, say, 10 years in order to get not only a snap shot of the present situation but also indications about the variation over time.

The terminology among gear technologists and biologists seems to differ somewhat. An effort should be made to standardise it.

5.6 Considerations of Differences in Exploitation Patterns among Fleets

A methodology was presented by A Sinclair for investigating the interactions between fishing fleets that exploit different age-groups of the same resource population (Sinclair, 1993). The term "partial recruitment" (PR) was used to describe the age-specific exploitation pattern experienced by a population, which is the combined effect of the relative fishing effort of the fleets. In the following discussion F and effort ware assumed to be equivalent, i.e. catchability is constant.

The yield-per-recruit implications of different levels of effort by the two gears were described. Methods were presented to calculate catch quotas for the individual fleets if the management objective is to keep fleet effort constant, or alternatively to predict catch rates and fishing effort by fleet if the allocation rules are based on a percentage sharing of the TAC among fleets. Simulations based on a cod fishery on the Nova Scotian Shelf were used to illustrate the effect of recruitment variation on fleet-specific catch and effort under the two allocation regimes.

The relative effort exerted by the fleets will affect target fishing mortalities under a yield-per-recruit management strategy. Fishing success (CPUE) by the fleet which catches older fish will be more sensitive to increases in effort by the fleet catching younger fish than the reverse situation. Since the fleets exploit different age groups, changes in fishable biomass due to recruitment variation are lagged, and trends in annual catch rates will vary among fleets. If the management strategy is to maintain population F constant, variations in recruitment will lead to variations in fleet F, and thus effort, if catch quotas are allocated as a percentage of the total TAC. This will also lead to slight variations in population F due to errors in PR used in predictions.

The results indicate the importance of considering differences in PR among competing fishing fleets when setting catch quotas.

6 REVIEW OF TECHNICAL MEASURES

6.1 General

Following a request from the Commission of the European Communities to consider the methodology and data which could be used to evaluate the effects of a number of boxes which have been implemented in Community waters, the Working Group considered these for the following boxes: Norway pout box, cod box, plaice box and the herring boxes.

Boxes are technical measures which are used as a management tool to assist with other tools in the management of the stocks and the fisheries. They may be used for various reasons such as protecting juvenile fish in the act of spawning, (spawning) biomass, specific fisheries, environment or a combination of these.

Boxes can be defined as specified subareas in a management area where other specific conditions for the fishery apply regarding fishing gear, fishing vessel characteristics, catch composition or combinations of these, during the whole year or parts of the year. The implementation of a box can be permanent or temporary.

A number of boxes are at present in operation to control the fisheries in EC waters. They are included in either the EC TAC regulation, in which case they are reviewed every year, or the EC technical measures regulation, in which case they continue until they are rescinded or changed.

The introduction or removal of a box may cause changes in both stocks and fisheries. It may affect the distribution of fish (see Section 4), the distribution of effort, the (S)SB, the level and age of recruitment, the catch levels and size distribution and its distribution over various fleets. It may, therefore, introduce changes in the economics and consequently may have social effects as well. The potential effects a box may have can be small or large, depending also on other alternative or additional restrictions to the fishery which might apply if the box did not exist.

An evaluation of the effect of the boxes in the ICES framework would have to be restricted to the conservation effects on the stocks [in other words short- and long-term changes, i.e. steady state in (S)SB and catch]. When appropriate disaggregated data exist, short-term changes in catch levels on a fleet basis can be estimated.

Given the different nature of the various boxes and the different nature of the potential available data for evaluation, a similar approach for all these boxes does not seem possible.

Assessing the effects of the implementation of a box (expectation) and the evaluation of the effects of an existing box (realised effects) requires different methodologies and different data. Generally, after the introduction of a box, no research or monitoring programmes have been established to measure the effects of the box. Given the fact that in general the implementation of a box is a rather severe measure, effort should always be made after its implementation to measure its effect.

As a first step in the estimation of the effect of the possible implementation of a box, preference could be given to relatively simple methods using aggregated data in order to test whether the box will achieve what it aims for. The results of this first evaluation will indicate whether it is necessary to obtain more detailed information from models using disaggregated data.

6.2 Methodology

In the evaluation of the effects of a box it is necessary to distinguish between (i) the expected effect based on some theoretical model and (ii) the realised effect based on empirical data collected when the box is in operation.

Expected effects

In evaluating the expected effect of a box which is aimed to protect particular age groups of fish the following information is needed:

1. exploitation pattern of the relevant fisheries inside the box;
2. exploitation pattern of the relevant fisheries outside the box;
3. redistribution of effort of the relevant fisheries due to the box-closure;
4. redistribution of fish.

In the case of a "mesh size" box, selectivity parameters of the fishing gear of the fleets fishing inside the box are also required.

In practice not all information will be available, so reasonable assumptions have to be made, e.g on the redistribution of fishing effort and fish. In addition, the evaluation of the introduction of a new box differs from the evaluation of an existing box. In the latter case, which can be cast in terms of simulating the effects of removing the box, the exploitation pattern inside the box may be unknown and may have to be estimated from experimental fishing inside the box, or from survey data.

Survey data can in principle be used to infer catch levels and age compositions of a commercial fishery from the relationship between survey data and commercial fleet CPUE data in adjacent areas. However, these relationships might be poor since a commercial fishery is targeting on particular species while a survey is not, and because the commercial CPUE data might be biased as a result of discarding and management constraints (such as maximum by-catch levels).

Models that are at present available are the ABC-model (Section 3.1.3) and the plaice box model (Section 2.2.5), which can, if the relevant input data are available, be used for short-term and long-term (steady state) predictions, respectively.

Realised effects

The effects of a box to protect particular age groups can be evaluated once the box is in operation by sampling the relevant age groups inside and outside the box, and comparing these with data obtained prior to the establishment of the box. Estimates of the abundance of cohorts at successive ages may be used to obtain estimates of apparent mortality which can then be compared for the period prior to and after the box closure (see Section 2.2.5).

6.3 Norway Pout Box

The Norway pout box is in fact a closed area in the North Sea for the industrial fishery directed at Norway pout to prevent by-catches of haddock and whiting by this fishery. The box was introduced in 1977.

An attempt to estimate the effect of the introduction of the box was carried out in 1979 (Anon., 1979) using Y/R analysis. However, since then estimates of the values of M for various species have been revised.

Assessing the effects of the box by comparing the present exploitation patterns with a situation where the box is removed is uncertain, since the effect will depend on the assumed attractiveness of the area and the decision of the industrial fishery whether to start fishing in the area or not. The possible effect of the box could be estimated in a similar way to that used with the simulation of the introduction of the directed whiting fishery in the North Sea, introducing an industrial fishery in the area by shifting some effort outside the box into the box. Such calculations should be carried out for various levels of effort. At present, a major problem would be to get reliable estimates of the expected by-catch levels and age compositions in the closed area of the various species caught by this fleet in the area.

The effects of the Norway pout box depend also on the technical conditions which would have been in force if the box did not exist, and the enforcement of these conditions. There is a by-catch limit in the Norway pout fishery of 15% protected species and not more than 5% of the catch may consist of cod and haddock. If these conditions cannot be fulfilled in the box, fishing for Norway pout in that area by an industrial fleet would not be legitimate. In that case, in principle, it does not matter whether there is a box or not. However, the reason for the box was that it was not possible to enforce the by-catch regulation. In this consideration it is assumed that by-catch levels are true catches and that discarding does not occur.

6.4 Plaice Box

In 1989 the EC established a closed area in the south-eastern North Sea in the 2nd and 3rd quarters to protect young flatfish. In the plaice box the same management regulations apply as in the 12 mile zone, thus excluding beam trawl fisheries in vessels with a motor power of >300 Hp. The plaice box is included in the EC technical measures regulation.

Expected effect

The biological basis of the plaice box was laid in 1987 by the ICES Flatfish Working Group, which expected an increase in plaice recruitment by 25%. In a later study, Rijnsdorp and van Beek (1991) estimated the effect on sole to be between 11 and 27% and further showed that spatial and temporal extension of the box would enhance the recruitment of flatfish, in particular sole, even further. These calculations, employing the method described in Section 2.2.5, referred to the level of distribution of effort in the period 1974-1977 and assumed that fishing effort was redistributed in proportion to the observed effort distribution outside the box.

In 1991, the subgroup of the STCF on the Improvement of the Exploitation Pattern on North Sea Fish Stocks tested the ABC-model for plaice and found that the effect of the plaice box was insignificant. However, since no discard data were included in the model and the effort data referred to a year when the plaice box was already in operation, these results were considered to be unrealistic.

As the management regulations for the plaice box allow for beam trawling with vessels of ≤ 300 Hp, the discarding of flatfish inside the box will not have been reduced to zero, as was assumed in calculating the expected effect. In addition, the level and distribution of fishing effort in recent years has been different from that in the period 1974-1977. Therefore, the expected gains will be different from those calculated. An update of the expected gains is feasible from the recent effort distributions obtained after establishment of the box and available in the STCF database for 1989 and 1991.

Measured effect

The ICES North Sea Demersal Working Group provided indications of a reduced mortality in juvenile plaice since the introduction of the plaice box. Survey data on the abundance of 0-, 1-, 2- and 3-group plaice in the plaice box were available from 1970 onwards. The survey data were collected at the end of the closed period in September-October. The ratio of the log-abundance estimate of age groups 3 over 2 was significantly larger in the years of the plaice box than in the previous years. No significant difference was observed for the ratio of age group 1 over 0 or 2 over 1. Since the 0- and 1-group were not fully recruited to the fishing grounds prior to the establishment of the box, the largest effect is expected for the decline in abundance between age 2 and 3. Further support for the effect of the plaice box was obtained from the inspection of the estimated F values for the youngest age groups in the VPA. These were lower since the plaice box was established.

6.5 Cod Box

The cod box was introduced in 1987 in a number of rectangles with a traditionally high abundance of juvenile cod in the German Bight in order to protect the abundant 1985 year class and has been continued in the following years until 1993. The implementation, in the 1st and 4th quarter was a year later than proposed and, instead of the recommended 120 mm mesh size, a 100 mm mesh size was applied in the box. The latter mesh size was considered as inappropriate (too low) by ACFM and STCF. Given the successive poor year classes following the 1985 year class, and the incentive of the fisheries to avoid the effects of a mesh increase, it is considered that the implementation of the box has had no, or very little, effect. It should, therefore, not be further evaluated.

An attempt to quantify the expected effect of the box on the stock and the catches of the various roundfish fleets has been carried out by the STCF Subgroup for the Improvement of the Exploitation Pattern on North Sea Fish Stocks in 1991, in order to test the ABC-model. The predicted effects were small, even when assuming recruitment of a very strong year class, but no discard data were available for use in the model.

Under certain assumptions it is possible to estimate the effects of a proper implementation of a cod box using the plaice box model. Such implementation might be a closure of the area or the introduction of a larger mesh size. The simulation of the introduction of a closure using this model would not take into account fleet and species interactions. Data on effort distribution and CPUE could be made available from the STCF database. Essential in the simulation is the estimation of the spatial and temporal distribution of discard rates by age group from discard trips and from the distribution of undersized fish in surveys.

6.6 Herring and Sprat Boxes

A number of box closures are at present in place to control fishing for herring or sprat. Since these boxes can be allocated into definable categories, they are considered in groups according to their main purpose, as identified by the Working Group.

Any of the boxes listed below which include areas outside the EC zone apply only to vessels from EC countries.

The herring and sprat boxes can be sub-divided as follows:

I. Herring boxes

1. **Nursery area closures**

a) **Division IVb.** Annual closure from 1 July-31 October in an area off the Danish coast. Included in TAC regulation.

b) **Division VIIa.** Closure throughout the year of most of the area adjacent to the east coast of the Irish Sea. Included in TAC regulation. An additional small bay to the north of this area is closed throughout the year under a different regulation also included in the TAC regulation (see 2c below).

2. **Spawning area closures**

a) **Division VIa.** Annual closure of an area adjacent to the Outer Hebrides from 15 August-30 September every year. Included in technical measures regulation.

b) **Division IVb.** Annual closure of two areas off the northeast coast of England from 15 August to 30 September and 15 September, respectively. Included in TAC regulation.

c) **Division VIIa.** Annual closure from 21 September-31 December of spawning areas around the Isle of Man and close to the coast of Northern Ireland. By derogation, small vessels from local ports may fish for herring by drift-net in the spawning area off the coast of Northern Ireland. Included in TAC regulation (see also 1b above).

d) **Division VIa (Clyde).** Annual closure of the entire Firth from 1 January-30 April every year. Included in TAC regulation.

e) **Divisions VIIg-k.** Three different spawning areas are closed in rotation, one each year, over different dates. Included in TAC regulation.

3. **Specified gear closures**

a) **Divisions VIIg-k and the southern part of Division VIIa.** Closure to fishing by purse seine. Included in technical measures regulation.

II. Sprat boxes

a) **Division IIIa.** Closure throughout the year for trawling for sprat using a mesh size of less than 32 mm. Included in technical measures regulation. No information was available to the Working Group to indicate the basis for this regulation.

b) **Divisions IVa and b.**Sprat fishing is closed in a number of areas of the North Sea. Off the Danish coast, the closed period and area are exactly the same as in I.1 (a) above, but in this case the box is included in the technical measures regulation. In addition, the same regulation includes closures of three areas off the east coast of the UK from 1 October-31 March each year.

General comments

In the case of all the above herring and sprat boxes, the reasons for which they were introduced are not explicitly included in the preamble to the relevant regulation. They can thus only be viewed against the scientific advice provided by ICES in the past. There are basically two ways in which their effectiveness can be judged. In the first place their effectiveness in meeting the proximate requirements of the regulation can be evaluated, i.e. whether or not they succeed in preventing the fishing at which they are aimed or whether some variation of the timing or area of the regulation would be more effective. In the second place, one can evaluate the effectiveness of the measure in terms of the exploitation pattern or the fishing mortality on, or recruitment to, the stock concerned. In the case of none of the herring or sprat boxes, however, were quantitative predictions made of the expected effects before the boxes were introduced. It is thus not possible to evaluate the effects of the boxes against expectation. It should, however, be noted that most of the boxes included in this review were made during a period when most of the herring stocks in the northeast Atlantic were at a very low level as a result of overfishing and poor recruitment. At the time, therefore, any measure that could reduce exploitation on juveniles or protect spawning fish was thought to be likely to enhance the possibility of stock recovery. It is more difficult to evaluate the continuing need for each of these measures except in the very general sense of whether they result in a better exploitation pattern or a lower fishing mortality than would be the case if they did not exist.

From information available to the Group, the sprat boxes in the North Sea are aimed, not at protecting sprats, but at protecting juvenile herring which in the past were caught in large quantities as a by-catch in the sprat fisheries in some areas.

Since their aims are very different, the nursery area and spawning area closures are discussed separately below.

Nursery area closures

The prime objective of the nursery area closures for herring and of the sprat boxes in the North Sea is to protect juvenile herring and thereby improve the exploitation pattern of herring. It should, therefore, in principle be possible to compare the exploitation pattern before and after the introduction of the box. Such a comparison, however, is only likely to be meaningful if other aspects of the exploitation and the distribution of the stock concerned have remained the same. Also, in no cases do the areas closed cover the entire range of distribution of juveniles of the stocks concerned. The boxes may thus not necessarily be expected to show major changes in the overall exploitation pattern on the stock. In general, they were designed to protect juvenile herring in areas where significant catches or by-catches were being made. These areas do not necessarily correspond to the most important parts of the juvenile distribution.

At the time most of the boxes were introduced, recruitment was at a low level in the stocks concerned. In some cases, the juvenile distribution might have changed or expanded as recruitment has improved and the stock recovered. In this case the present boxes may appear to be out of date in terms of the proportion of the juvenile area that they cover. In this case, it would be possible to evaluate the effects of closing larger or different areas. It is possible, however, that the boxes may cover a significant part of the area of distribution of poor year classes. It is necessary in this context to consider the relative importance of protecting large and small year classes. While large year classes make the largest contribution to future stock size, a succession of small year classes, whether environmentally or stock-induced, can cause a rapid decrease in stock size, particularly when the fishing mortality rate is high. Especially in the case of shoaling pelagic fish, there is often a depensatory relationship between fishing mortality and stock size such that a naturally-induced decrease in stock size is exacerbated by fishing, with the possibility of stock collapse. In this situation, it is of particular importance to protect small year classes. In this case, the closures may have an important effect at times when recruitment is at a low level. In theory, they could be reinstated as required. In practice, however, any warning of poor recruitment is likely to be short and it would be impracticable to reinstate the boxes in time for them to be effective.

Herring spawning area closures

Bans on fishing for herring immediately prior to and during the spawning season have been introduced in some herring spawning areas but not in others. In general the timing of the closures is intended to cover the period when the shoals are assembling to spawn and the spawning period itself. The boxes are not intended to protect the beds of spawn themselves because in general pelagic fishing methods have little impact on the sea bed. Neither is it the intention of the measures to protect the spawning fish during the act of spawning. There is no firm evidence that the success of spawning is affected by disturbance and, in terms of the mortality caused during the spawning season, there is no difference between catching fish at that time and any other time of year. Indeed, fish caught immediately prior to spawning are heavier than pre- or post-spawning fish and, therefore, less mortality is caused within a given weight of catch.

The main aim of spawning closures is to prevent the possibility of creating excess mortality, over and above that permitted within a TAC regulation, as a result of unavoidably making excessively large catches when fishing on dense spawning shoals. The areas which are closed during the spawning season are in general those in which dense aggregations of herring have been found and where fisheries have developed on these aggregations. Thus, closures have been introduced in the central North Sea, Division VIa and the Irish Sea, but not in the northern North Sea or the English Channel. In the northern North Sea, the individual spawning grounds appear from the distribution of larvae to be more numerous but of smaller extent. There has also been no evidence of fishing on spawning grounds in this area.

The rotational system of box closures in the Celtic Sea has been designed to prevent fishing on spawning concentrations in three different areas, by closing one each year. It has not so far been possible to evaluate the effectiveness of these closures.

7 MULTI-ANNUAL AND MULTI-SPECIES TACS

7.1 Consideration of the EC STCF Report

The STCF had discussed the use of multi-annual and multi-species TACs at its meeting in October 1992 (Anon., 1992a). Its report is of interest to this meeting and in particular to Term of Reference *f*. Consequently the relevant section of the STCF report was considered.

7.1.1 Multi-annual TACs

In principle a multi-annual TAC comprises a series of annual TACs aggregated over a specified period. Nominally, national quotas within each annual TAC would be taken within the specified year. However, it would be possible to depart from the nominal position in one of two ways: the uptake of a quota could be deferred from one year to a subsequent year, or a subsequent year's quota could be taken in advance of that year (in part at least). Various additional rules could also be applied. For example, any deferred uptake could attract interest in the form of an addition to the deferred quota when it was finally taken and, conversely, any advance uptake ("borrowing") would have to be repaid with interest in a subsequent year, i.e. the nominal quota in some subsequent year would be reduced by the amount borrowed and by the amount calculated as interest on the borrowing. The use of a multi-annual TAC would, therefore, be to impart a greater degree of flexibility to the quota system.

The conditions under which a system of multi-annual TACs could be used were also outlined by the STCF. If catches are 'borrowed' from a subsequent year simply to avoid the early closure of a fishery because of overcapacity within the fleet, then this will only make the problem worse when the loan has to be repaid, unless the excess capacity had been shed. The term overcapacity has been used here to refer to the position where biologists may feel that too many boats are chasing too few fish. Additionally, it is not possible within most stocks assessed by ICES working groups to predict catches several years ahead with any precision. In this case it would be difficult to calculate an appropriate multi-annual TAC. However, if such predictions could be made with acceptable precision, and the STCF identified Western stock mackerel as a potential case, then multi-annual TACs could reasonably be envisaged. Further use could be made of multi-annual TACs where precautionary TACs, which are usually set to the average catch over a specified period, are used. If the annual catches are fairly stable then a multi-annual TAC could easily be calculated. However, if they are extremely variable then a multi-annual TAC may not reasonably reflect the catching opportunities in any year. The STCF concluded that multi-annual TACs are more easily calculated where catches are relatively stable but they are probably more needed where stocks are more variable. Unfortunately, in the latter case a multi-annual TAC cannot be predicted with any precision. It was noted that this did not preclude the use of a multi-annual strategy of fishing mortalities whereby the appropriate annual TAC could be calculated as the requisite data became available.

At the present meeting, the LTMWG agreed with the STCF that although it is desirable to include flexibility within the TAC structure, multi-annual TACs are not an answer to excessive fishing mortality. The question of defining overcapacity was briefly discussed and it was noted that, not only is it difficult to define or measure capacity, but, when economic circumstances change, the threshold at which overcapacity is defined can also change. Nevertheless, as many of the stocks assessed by ICES suffer from excessive fishing mortality, it is clear that in such cases the use of a multi-annual TAC is at present precluded.

The characteristics of a constant catch policy were also discussed by the LMTWG. Whilst recognising that this is not the same as a multi-annual TAC it does address a specific Term of Reference. A policy of constant annual catches implies stability only in the total annual catch. If stocks vary in abundance the catch may be taken more or less rapidly during the year depending on whether abundance is high or low; the catch may be constant from year to year but its temporal distribution is not. In fact, a constant catch implies both *increased* effort and fishing mortality when stocks are *decreasing* and *decreased* effort and fishing mortality when stocks are *increasing*. Moreover, if constant catches were set over an extended period it is likely that they would have to be set at a relatively low level, not only to avoid high fishing mortality under 'average' conditions, but also to avoid exacerbating difficulties induced by 'non-average' conditions, e.g. environmentally-induced recruitment failure. If catches were set at a constant level over a shorter period, say three years, then this may not be a great problem. However, although the interannual variation of the total catch would be stabilised within the period, the possibility remains that large adjustments in catches would have to be made between periods.

7.1.2 Multi-species TACs

The Working Group was asked to consider whether technical interactions between species allow TACs covering groups of species to be set. The Group recognised that the phrase 'multi-species' TAC was not used, presumably to avoid any misunderstanding in respect of its application to biological interactions. However, as biological interactions are not considered to be significant factors in the short-term predictions that are used to calculate TACs there is less scope for confusion and, to be consistent with the STCF, the Working Group will use the term multi-species TACs to refer to TACS covering groups of species which comprise genuine mixed-species fisheries.

Once again the STCF had considered the topic at its meeting of October 1992 (Anon., 1992a). The advantage with multi-species TACS is considered to be the introduction of further flexibility in the quota system. Instead of deferring or borrowing from a single species' quota from one year to another (as with multi-annual TACs), the principle is to convert from the quota for one species to the quota of a second species. (Note: this is not the same as quota 'swaps' between nations.) Conversion could be at differential rates on the basis of species-equivalent units and the principle of repaying converted quotas would be necessary to avoid permanent *de facto* changes in the allocation of quotas between nations.

In this context, the use of multi-species TACs is not seen as a solution to the problems of excessive fishing mortality and the Group considered that current fishing mortalities in many of the stocks assessed by ICES would preclude the immediate use of multi-species TACs as a management measure.

Flexibility within the quota system is only one motivation for implementing a multi-species TAC. A second could be to prevent the overshoot of an individual TAC within a mixed fishery. If the TAC for one species has been taken the fishery will continue in pursuit of those species for which quotas remain. It is likely that catches of the former species will continue but they will be either misreported, or not reported as landings, or discarded. In either case the fishing mortality on that species will exceed that used to formulate its TAC. One form of multi-species TAC, the so-called two-tier TAC of ICNAF (O'Boyle, 1985), addresses this problem. The second tier TAC was set at a level below the sum of the individual TACs based on either a multi-species general production model or consideration of by-catches. In either case the second tier TACs were 20% - 25% lower than the sum of the individual TACs.

7.2 Assessing the Utility of Multi-annual and Multi-species TACs

The Group was able only to undertake a brief and general discussion relating to multi-annual and multi-species TACs. In doing so it has provided only a fragmentary answer to a specific Term of Reference. However, the Group feels that the more general discussion elsewhere on the evaluation of management tools and procedures provides a basis for defining and testing the utility of multi-annual and multi-species TACs. The development of such an evaluation framework should be encouraged within this context.

8 RECOMMENDATIONS AND SUGGESTED WORK FOR THE NEXT MEETING

8.1 Recommendations

The Working Group makes the following recommendations which will have an impact outside the membership of the Working Group itself.

a. That consideration be given to varying the venue of future meetings and soliciting appropriate participation. The Working Group considered that January-February 1994 would be an appropriate time for its next meeting (see Section 2.1.2).

b. That the Chairman of the Working Group liaise with the Chairman of the Methods Working Group and members of the steering committee of the proposed EC study group* to formulate possible ways of developing methods to determine the performance of management procedures for fisheries systems such that work is facilitated but not repeated (see Section 2.1.10).

c. That discard estimates of commercial demersal species be obtained (see Section 3.4.2).

d. That an annual update of the North Sea STCF base be made for at least one more year. The Working Group recognises that production of such a database requires a lot of extra work for national institutes and that such work needs external funding (see Section 3.4.2).

e. That a Steering Group be set up to oversee the transfer of the STCF database and computer programs to the ICES Secretariat and to advise the Secretariat on what services should be provided to users (see Section 3.4.3). The Steering Group should determine:

- hardware and software facilities needed
- maintenance requirements
- checking procedures
- error corrections
- updating procedures
- extraction procedures
- confidentiality rules
- access rights
- etc.

f. That the STCF database should be made available to the ICES working groups relevant to the management of the North Sea fish stocks (see Section 3.4.3).

g. The Working Group strongly supports the proposal for an EC Workshop (see proposed terms of reference in Section 5.3) and recommends the involvement of sociologists and economists in this kind of work.

8.2 Suggested Work Items for the Working Group

In addition to the above recommendations, the Working Group also made the following proposals for further work to be initiated prior to the next meeting:

a. That existing data on the short-term reaction of fishermen to new technical measures be analysed to determine how they reallocate fishing effort (see Section 5.3).

b. That an overview of existing sources of data on migrations, in particular tagging data and area distributions of stocks and catches, be made (see Section 4.8).

c. Analyse the spatially-disaggregated data-sets of North Sea fleets for 1989 and 1991, with particular regard to the spatial distribution of populations, catch and effort. Consider uses that might be made of bottom trawl survey data.

d. Review progress on the development of computer programs to implement multi-fleet, multi-species, spatially disaggregated models. Validate any programs and recommend ways in which they should be modified.

e. Review reports from recent workshops, study groups etc. on management under uncertainty (e.g. the IWC, EC study group, CAFSAC workshop, Alaska conference). Consider the use of specific biological reference points that stem from models such as yield per recruit, SSB per recruit, general production etc. in terms of their estimation and application.

f. Review the EC workshop report on defining fleets and consider effort reallocation models and, in this context, solicit input from economists.

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*It was recommended by an EC Study Group (Horwood and Griffith, 1992) that a further EC study group should be established for a three year period to develop and evaluate strategies for medium- and long-term management of EC fisheries.

g. Evaluate recent work on gear selectivity and its use in assessment and management models.

h. Consider methods available for the calculation of migration rates, from catch data and tagging data, for use in spatially disaggregated prediction models. Consider how biological information might provide a basis for calculating such rates in the absence of other data.

i. Review the difficulties associated with the absence of discard data and suggest methods of inferring discard rates from other data.

j. Consider methods for studying the relationship between stock abundance and environmental conditions on fish distributions.

9 ANY OTHER BUSINESS

9.1 Genetic Effects of Long-term Exploitation

The notion that exploitation may affect the genetic make-up of populations has recently received increasing recognition in circles of fisheries biology (Nelson and Soulä, 1987; Stokes *et al.*, in press). The attention has mainly focussed on theoretical studies of the selective effects of exploitation on growth rate, onset of sexual maturity and reproductive investment (Law and Grey, 1989; Stokes *et al.*, 1993), although an empirical study showed that it may also affect genetic diversity (Smith *et al.*, 1991).

The empirical evidence for life history evolution comes mainly from experiments with non-commercial fish species characterized by a small size and short life span, such as guppies and platy-fish (Stearns, 1983; Reznick *et al.*, 1990). Studies of larger sized commercial species have shown changes in life history parameters that are consistent with expected changes due to genetical selection (Ricker, 1981; Rijnsdorp, 1992; Rowell, 1993).

In considering long-term management measures there is a need for information about the sensitivity of various exploited species to genetical effects. A powerful tool for exploring this sensitivity, though still in its infancy, is provided by modelling studies that integrate quantitative genetics with fisheries management. Results of the first explorations (Law and Grey, 1989; Stokes, in press) provide warning that harvesting levels may be dangerously high for some stocks (Anon., 1992e). Using this approach the implications of genetical selection for long-term management measures may be evaluated by categorising the various types of life history patterns of exploited species - defined as the set a characteristics like the length and age at maturation, reproductive investment, longevity - and exploring the potential selective effects of different harvesting strategies in relation to life history type. Such an approach may further guide the study of changes in life history parameters of those species that are likely to be most sensitive to genetical selection. From the point of view of the LTMWG the topic of genetical selection is not considered to have the highest priority. Its importance is nevertheless recognised and future contributions are sollicited which can be taken along in the discussions during future meetings of the Working Group.

10 REFERENCES AND WORKING DOCUMENTS

10.1 References

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10.2 Working Documents

The list of working documents available at the meeting is given below. Some are also included in the Reference list under their authorship.

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WD 3. Skagen, W.D. Stock prediction using stochastic recruitment numbers with empirical stock-dependent distribution.

WD 4. Lewy, M., M. Vinther and L. Thomsen. Description of the STCF North Sea database system and the prediction model ABC: assessments of bio-economic consequences of technical measures.

WD 5. Extract from STCF Report: Advantages and problems with multispecies and multiannual TACs.

WD 6. Extract from STCF Report: Comments from STCF on the existing boxes.

WD 7. Extract from the STCF Working Group 1991: Scenario 4: Plaice box.

WD 8. Webb, J. Migration and stock assessment.

WD 9. Pedersen, L. A short outline of the data structure in IFAP.

WD 10. Pedersen, L. IFAP: ICES Fisheries Assessment Package.

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WD 25. Objectives of fisheries management.

WD 26. Eide, A. and O. Flaaten. Bio-economic multispecies modelling of he Barents Sea fisheries.

WD 27. V.P. Serebryakov. Reproductive capacity estimation in some North Atlantic food fishes based on population fecundity concept.

WD 28. Risk analysis.

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APPENDIX 1

THE IWC APPROACH TO MANAGEMENT UNDER UNCERTAINTY

Definitions:

Operating Model: A "data generator" based on knowledge, assumptions (and even guess work) which includes biology, population dynamics, stock structure, fleet structure, etc...

Assessment Procedure: The assessment methodolgy as actually applied to determine stock status and to estimate relevant parameters and quantities.

Management Strategy: The set of rules applied to calculate catches, including not just a quota calculation but all management tools utilised.

Management Procedure: The Assessment Procedure + The Management Strategy.

Performance Indices: The quantities used to test performance from one individual simulation.

Performance Statistics: The statistics calculated from a set of performance indices.

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; new data are then generated using the **Operating Model**.The loop is repeated a set number of times (say 100) and **Performance Indices** are calculated.

The Method:

A number of **Simulation Trials** are run (say 100) and **Performance Statistics** are calculated from the set of **Performance Indices**.

The above set of **Performance Statistics** might now represent a baseline against which comparisons can be made. There are now essentially two options - 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.

APPENDIX 2

INPUT/OUTPUT TO MSVPA

As a summary of the MS models, the input and output of MSVPA and MSFOR are listed below.

A special notation for "past", "present" and "future" years is used in the tables:

y1, y1+1, ... , y2 is a sequence of past years ("data-years")
y3 is the present year
y3+1, ... , y4 is a sequence of future years with y3 = y2+1

The following indices are used for number caught:

[s,y,q,a,fl] = [species, year, quarter, age group, fleet]

INPUT

MANDATORY INPUT TO MSVPA:

For each species (prey and predators):

INPUT:	NUMBERS CAUGHT OF SPECIES s				
a q\y	y1	y1+1	y1+2	....	y2
0 3	C[s,y1,3,0]	C[s,y1+1,3,0]	C[s,y1+2,3,0]	....	C[s,y2,3,0]
4	C[s,y1,4,0]	C[s,y1+1,4,0]	C[s,y1+2,4,0]	....	C[s,y2,4,0]
1 1	C[s,y1,1,1]	C[s,y1+1,1,1]	C[s,y1+2,1,1]	....	C[s,y2,1,1]
2	C[s,y1,2,1]	C[s,y1+1,2,1]	C[s,y1+2,2,1]	....	C[s,y2,2,1]
3	C[s,y1,3,1]	C[s,y1+1,3,1]	C[s,y1+2,3,1]	....	C[s,y2,3,1]
4	C[s,y1,4,1]	C[s,y1+1,4,1]	C[s,y1+2,4,1]	....	C[s,y2,4,1]
•••••	••••••••••	••••••••••			
A 1	C[s,y1,1,A]	C[s,y1+1,1,A]	C[s,y1+2,1,A]	....	C[s,y2,1,A]
2	C[s,y1,2,A]	C[s,y1+1,2,A]	C[s,y1+2,2,A]	....	C[s,y2,2,A]
3	C[s,y1,3,A]	C[s,y1+1,3,A]	C[s,y1+2,3,A]	....	C[s,y2,3,A]
4	C[s,y1,4,A]	C[s,y1+1,4,A]	C[s,y1+2,4,A]	....	C[s,y2,4,A]

For each species (prey and predators):

INPUT:	BODY WEIGHT IN THE SEA, SPECIES s				
a q\y	y1	y1+1	y1+2	....	y2
0 3	wp[s,y1,3,0]	wp[s,y1+1,3,0]	wp[s,y1+2,3,0]	....	wp[s,y2,3,0]
4	wp[s,y1,4,0]	wp[s,y1+1,4,0]	wp[s,y1+2,4,0]	....	wp[s,y2,4,0]
1 1	wp[s,y1,1,1]	The most common approach is to assume that all wp´s have the same value for all years.		....	wp[s,y2,1,1]
2	wp[s,y1,2,1]			....	wp[s,y2,2,1]
3	wp[s,y1,3,1]			....	wp[s,y2,3,1]
4	wp[s,y1,4,1]			....	wp[s,y2,4,1]
•••••	•••••••••••				
A 1	wp[s,y1,1,A]	wp[s,y1+1,1,A]	wp[s,y1+2,1,A]	....	wp[s,y2,1,A]
2	wp[s,y1,2,A]	wp[s,y1+1,2,A]	wp[s,y1+2,2,A]	....	wp[s,y2,2,A]
3	wp[s,y1,3,A]	wp[s,y1+1,3,A]	wp[s,y1+2,3,A]	....	wp[s,y2,3,A]
4	wp[s,y1,4,A]	wp[s,y1+1,4,A]	wp[s,y1+2,4,A]	....	wp[s,y2,4,A]

For each species (prey and predators):

INPUT: **RESIDUAL NATURAL MORTALITY, SPECIES s**					
a q\y	y1	y1+1	y1+2	....	y2
0 3	M1[s,y1,3,0]	M1[s,y1+1,3,0]	M1[s,y1+2,3,0]	....	M1[s,y2,3,0]
4	M1[s,y1,4,0]	M1[s,y1+1,4,0]	M1[s,y1+2,4,0]	....	M1[s,y2,4,0]
1 1	M1[s,y1,1,1]	The most common approach is to assume that all M1s have the same value for all years and age groups If not, then it is common to assume that M remains constant from year to year		....	M1[s,y2,1,1]
2	M1[s,y1,2,1]			....	M1[s,y2,2,1]
3	M1[s,y1,3,1]			....	M1[s,y2,3,1]
4	M1[s,y1,4,1]			....	M1[s,y2,4,1]
•••••	••••••••••••				
A 1	M1[s,y1,1,A]			....	M1[s,y2,1,A]
2	M1[s,y1,2,A]	M1[s,y1+1,2,A]	M1[s,y1+2,2,A]	....	M1[s,y2,2,A]
3	M1[s,y1,3,A]	M1[s,y1+1,3,A]	M1[s,y1+2,3,A]	....	M1[s,y2,3,A]
4	M1[s,y1,4,A]	M1[s,y1+1,4,A]	M1[s,y1+2,4,A]	....	M1[s,y2,4,A]

For each species (prey and predators):

INPUT: **TERMINAL FISHING MORTALITY, SPECIES s**					
a q\y	y1	y1+1	y1+2	....	y2
0 3					
4					F[s,y2,4,0]
1 1					
2	In case tuning is made these terminal fishing mortalities will become output				
3					
4					F[s,y2,4,1]
•••••	•••••••••••••••••••••••••				
A 1					
2					
3					
4	F[s,y1,4,A]	F[s,y1+1,4,A]	F[s,y1+2,4,A]	....	F[s,y2,4,A]

For each predator species, p, and predators age group, j:

INPUT: **FOOD RATION OF PREDATOR p, age j,**						
R[p,0,3]	R[p,0,4]	R[p,1,1]	R[p,1,2]	R[p,1,3]	R[p,1,4]	.....

For years where stomach data have been collected:
For each predator species, p, and predators age group, j:

INPUT: **RELATIVE STOMACH CONTENT OF PREDATOR p, age j, IN YEAR y**				
a q\y	prey 1	prey 2	....	prey X
0 3	U[1,y,3,0,p,j]	U[2,y,3,0,p,j]	....	U[X,y,3,0,p,j]
4	U[1,y,4,0,p,j]	U[2,y,4,0,p,j]	....	U[X,y,4,0,p,j]
1 1	U[1,y,1,1,p,j]	U[2,y,1,1,p,j]	....	U[X,y,1,1,p,j]
2	U[1,y,2,1,p,j]	U[2,y,2,1,p,j]	....	U[X,y,2,1,p,j]
3	U[1,y,3,1,p,j]	U[2,y,3,1,p,j]	....	U[X,y,3,1,p,j]
4	U[1,y,4,1,p,j]	U[2,y,4,1,p,j]	....	U[X,y,4,1,p,j]
•••••	••••••••••••	••••••••••••		
A 1	U[1,y,1,A,p,j]	U[2,y,1,A,p,j]	....	U[X,y,1,A,p,j]
2	U[1,y,2,A,p,j]	U[2,y,2,A,p,j]	....	U[X,y,2,A,p,j]
3	U[1,y,3,A,p,j]	U[2,y,3,A,p,j]	....	U[X,y,3,A,p,j]
4	U[1,y,4,A,p,j]	U[2,y,4,A,p,j]	....	U[X,y,4,A,p,j]

Where the set {prey1, prey2,..., preyX} is the set of predators to predator [p,j] and A can take any value from 0 to the oldest age, and can vary from prey to prey. Not all cells will always contain data.

For years where stomach data have been collected:
For each predator species, p, and predators age group, j:

INPUT: **BODY WEIGHT IN STOMACH OF PREDATOR p, age j, IN YEAR y**					
a	q\y	prey 1	prey 2	....	prey X
0	3	wp[1,y,3,0,p,j]	wp[2,y,3,0,p,j]	....	wp[X,y,3,0,p,j]
	4	wp[1,y,4,0,p,j]	wp[2,y,4,0,p,j]	....	wp[X,y,4,0,p,j]
1	1	wp[1,y,1,1,p,j]	wp[2,y,1,1,p,j]	....	wp[X,y,1,1,p,j]
	2	wp[1,y,2,1,p,j]	wp[2,y,2,1,p,j]	....	wp[X,y,2,1,p,j]
	3	wp[1,y,3,1,p,j]	wp[2,y,3,1,p,j]	....	wp[X,y,3,1,p,j]
	4	wp[1,y,4,1,p,j]	wp[2,y,4,1,p,j]	....	wp[X,y,4,1,p,j]
••••••		••••••••••••	••••••••••••		
A	1	wp[1,y,1,A,p,j]	wp[2,y,1,A,p,j]	....	wp[X,y,1,A,p,j]
	2	wp[1,y,2,A,p,j]	wp[2,y,2,A,p,j]	....	wp[X,y,2,A,p,j]
	3	wp[1,y,3,A,p,j]	wp[2,y,3,A,p,j]	....	wp[X,y,3,A,p,j]
	4	wp[1,y,4,A,p,j]	wp[2,y,4,A,p,j]	....	wp[X,y,4,A,p,j]

Where the set {prey1, prey2,..., preyX} is the set of predators to predator [p,j] and A can take any value from 0 to the oldest age, and can vary from prey to prey. Not all cells will always contain data.

Biomass of OTHER FOOD (one single figure, guesstimate) or (depending on assumption on other food): TOTAL BIOMASS IN ECOSYSTEM

Maturity ogive for each species, s

INPUT: **MATURITY OGIVE FOR SPECIES s,**					
As[s,0,3]	As[s,0,4]	As[s,1,1]	As[s,1,2]	As[s,1,3]	....

OPTIONAL TO MSVPA INPUT

TUNING DATA: TIME SERIES OF CPUE FOR SELECTED FLEETS OR RESEARCH VESSELS TIME SERIES OF BIOMASS ESTIMATES FROM, FOR EXAMPLE, ACOUSTIC SURVEYS

OTHER PREDATORS: Stock numbers and feeding ration for each "other predator" N[0], N[1],...., N[A] and R[0], R[1],...., R[A]

OUTPUT FROM MSVPA (only the principal output is listed here)

For each species (prey and predators):

OUTPUT:		**STOCK NUMBERS, SPECIES s**				
a	q\y	y1	y1+1	y1+2	....	y2
0	3	N[s,y1,3,0]	N[s,y1+1,3,0]	N[s,y1+2,3,0]	....	N[s,y2,3,0]
	4	N[s,y1,4,0]	N[s,y1+1,4,0]	N[s,y1+2,4,0]	....	N[s,y2,4,0]
1	1	N[s,y1,1,1]	N[s,y1+1,1,1]	N[s,y1+2,1,1]	....	N[s,y2,1,1]
	2	N[s,y1,2,1]	N[s,y1+1,2,1]	N[s,y1+2,2,1]	....	N[s,y2,2,1]
	3	N[s,y1,3,1]	N[s,y1+1,3,1]	N[s,y1+2,3,1]	....	N[s,y2,3,1]
	4	N[s,y1,4,1]	N[s,y1+1,4,1]	N[s,y1+2,4,1]	....	N[s,y2,4,1]
••••••		••••••••••••	••••••••••••			
A	1	N[s,y1,1,A]	N[s,y1+1,1,A]	N[s,y1+2,1,A]	....	N[s,y2,1,A]
	2	N[s,y1,2,A]	N[s,y1+1,2,A]	N[s,y1+2,2,A]	....	N[s,y2,2,A]
	3	N[s,y1,3,A]	N[s,y1+1,3,A]	N[s,y1+2,3,A]	....	N[s,y2,3,A]
	4	N[s,y1,4,A]	N[s,y1+1,4,A]	N[s,y1+2,4,A]	....	N[s,y2,4,A]

Tables similar to N for stock biomass, mean stock biomass and spawning stock biomass.

For each species (prey and predators):

OUTPUT: **FISHING MORTALITIES, SPECIES s**					
a q\y	y1	y1+1	...	y2-1	y2
0 3	F[s,y1,3,0]	F[s,y1+1,3,0]	...	F[s,y2-1,3,0]	F[s,y2,3,0]
4	F[s,y1,4,0]	F[s,y1+1,4,0]	...	F[s,y2-1,4,0]	*)
1 1	F[s,y1,1,1]	F[s,y1+1,1,1]	...	F[s,y2-1,1,1]	F[s,y2,1,1]
2	F[s,y1,2,1]	F[s,y1+1,2,1]	...	F[s,y2-1,2,1]	F[s,y2,2,1]
3	F[s,y1,3,1]	F[s,y1+1,3,1]	...	F[s,y2-1,3,1]	F[s,y2,3,1]
4	F[s,y1,4,1]	F[s,y1+1,4,1]	...	F[s,y2-1,4,1]	*)
••••••••••••••••••••••••••••••••					
A 1	F[s,y1,1,A]	F[s,y1+1,1,A]	...	F[s,y2-1,1,A]	F[s,y2,1,A]
2	F[s,y1,2,A]	F[s,y1+1,2,A]	...	F[s,y2-1,2,A]	F[s,y2,2,A]
3	F[s,y1,3,A]	F[s,y1+1,3,A]	...	F[s,y2-1,3,A]	F[s,y2,3,A]
4	*)	*)		*)	*)

*) In case of tuning these terminal Fs are output.

For each species (prey and predators):

OUTPUT: **PREDATION MORTALITY OF SPECIES s**				
a q\y	y1	y1+1	...	y2
0 3	M2[s,y1,3,0]	M2[s,y1+1,3,0]	...	M2[s,y2,3,0]
4	M2[s,y1,4,0]	M2[s,y1+1,4,0]	...	M2[s,y2,4,0]
1 1	M2[s,y1,1,1]	M2[s,y1+1,1,1]	..	M2[s,y2,1,1]
2	M2[s,y1,2,1]	M2[s,y1+1,2,1]	...	M2[s,y2,2,1]
3	M2[s,y1,3,1]	M2[s,y1+1,3,1]	...	M2[s,y2,3,1]
4	M2[s,y1,4,1]	M2[s,y1+1,4,1]	...	M2[s,y2,4,1]
••••••••••••••••••••••••••••••••				
A 1	M2[s,y1,1,A]	M2[s,y1+1,1,A]	...	M2[s,y2,1,A]
2	M2[s,y1,2,A]	M2[s,y1+1,2,A]	...	M2[s,y2,2,A]
3	M2[s,y1,3,A]	M2[s,y1+1,3,A]	...	M2[s,y2,3,A]
4	M2[s,y1,4,A]	M2[s,y1+1,4,A]	...	M2[s,y2,4,A]

For each predator species, p, and predators age group, j:

OUTPUT: **MEAN SUITABILITY FOR PREDATOR p, age j**				
a q\y	prey 1	prey 2	....	prey X
0 3	$\overline{\mathrm{SUIT}}$[1,3,0,p,j]	$\overline{\mathrm{SUIT}}$[2,3,0,p,j]	....	$\overline{\mathrm{SUIT}}$[X,3,0,p,j]
4	SUIT[1,4,0,p,j]	SUIT[2,4,0,p,j]	....	SUIT[X,4,0,p,j]
1 1	$\overline{\mathrm{SUIT}}$[1,1,1,p,j]	$\overline{\mathrm{SUIT}}$[2,1,1,p,j]	....	$\overline{\mathrm{SUIT}}$[X,1,1,p,j]
2	$\overline{\mathrm{SUIT}}$[1,2,1,p,j]	$\overline{\mathrm{SUIT}}$[2,2,1,p,j]	....	$\overline{\mathrm{SUIT}}$[X,2,1,p,j]
3	$\overline{\mathrm{SUIT}}$[1,3,1,p,j]	$\overline{\mathrm{SUIT}}$[2,3,1,p,j]	....	$\overline{\mathrm{SUIT}}$[X,3,1,p,j]
4	SUIT[1,4,1,p,j]	SUIT[2,4,1,p,j]	....	SUIT[X,4,1,p,j]
••••••••••••••••••••••••••••••••				
A 1	$\overline{\mathrm{SUIT}}$[1,1,A,p,j]	$\overline{\mathrm{SUIT}}$[2,1,A,p,j]	....	$\overline{\mathrm{SUIT}}$[X,1,A,p,j]
2	$\overline{\mathrm{SUIT}}$[1,2,A,p,j]	$\overline{\mathrm{SUIT}}$[2,2,A,p,j]	....	$\overline{\mathrm{SUIT}}$[X,2,A,p,j]
3	$\overline{\mathrm{SUIT}}$[1,3,A,p,j]	$\overline{\mathrm{SUIT}}$[2,3,A,p,j]	....	$\overline{\mathrm{SUIT}}$[X,3,A,p,j]
4	SUIT[1,4,A,p,j]	SUIT[2,4,A,p,j]	....	SUIT[X,4,A,p,j]

Where the set {prey1, prey2,..., preyX} is the set of predators to predator [p,j] and A can take any value from 0 to the oldest age, and can vary from prey to prey.

Various "Who eats Whom Tables".

Estimates of "food switching" parameters

Parameters in the multi-dimensional log-normal distribution of recruitment. This include a variance/co-variance matrix.

MANDATORY INPUT TO MSFOR

Input also used in single-species/multi-fleet model: Fishing mortality: F[s,y,q,a,fl] Discard fishing mortality: FD[s,y,q,a,fl] Landing fishing mortality: FL[s,y,q,a,fl] Body weight in the catch: wy[s,y,q,a,fl] Body weight in the discards: wyd[s,y,q,a,fl] Body weight in the landings: wyl[s,y,q,a,fl] Sales price (per kg): Pr[s,y,q,a,fl] Stock numbers from VPA: N[s,y,q,a] Body weight in the sea: ws[s,y,q,a] Maturity ogive: As[s,q,a] Recruitment: N[s,y,3,0], y = y3, y3+1, ..., y4
Input only used in multi-species model: Suitability coefficients Food consumption rates OTHER FOOD OTHER PREDATORS Residual natural mortality: M1[s,y,q,a]

Base-line simulation, from MSVPA

OPTIONAL INPUT TO MSFOR

Parameters for stochastic simulation of recruitment. (These parameters can also be estimated within the VSPA program)

OUTPUT FROM MSVPA

The complete list of output from MSFOR is very long. The principal ouput is yield discarded and landed by each fleet. Also stock stock numbers and stock biomasses (total, mean and spawning stock biomass) are principal output quantities.

MSFOR can produce short term scenario predictions and long term (equilibrium) scenario predictions. The latter include stochaslic simulation of recruitment and recruitment sensitivity analysis.