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Report of the Workshop on Simple Mixed Fisheries Management Models (WKMIXMAN)

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ICES Headquarters

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Contents

1 Introduction

1.1 Terms of Reference

The Workshop on Simple Mixed Fisheries Management Models [WKMIXMAN] met over 9–13 January 2006 at ICES HQ, Copenhagen with the following terms of reference:

a) define a framework for simple models of mixed fisheries which can be used to obtain consistency between management (TAC and/or effort) advice for species caught together, given the current availability and accessibility of data;

b) provide operational guidelines for the use of such models;

A list of participants is given in Annex 1.

1.2 Justification

The justification for the workshop as given in ICES resolution 2005/2/ACFM27 is as follows:

The WKMIXMAN report is a first step in establishing guidelines for evaluation of fisheries with significant technical interactions.

ICES is requested to provide advice which is consistent across stocks for mixed fisheries. Behind this request is the hope that defining consistent TACs at the fishery level would reduce options for discarding and reduce the incentives for illegal landings.

The mixed fisheries problem can be formulated as providing tools for predicting the catch composition (species and age distribution) at the fleet/fishery level. This can be investigated on a per unit effort basis or on the basis of level of fishing mortality. Management has little use of fishing mortality in defining regulations; regulations must be defined in operational terms, e.g. effort units or catch or landing units.

The standard TAC scientific model defines a limit in terms of fishing mortality or stock size. Based on this limit the model infers an upper limit on the catch/landing that can be removed from the stock. The mixed fisheries models should do the same, but with the additional requirement that intermediate results on yields by individual fleets/fisheries are used in management

Attempts have been made to produce fisheries based forecasts based on effort policies and the MTAC model was developed for this purpose (SGDFF 2003; ICES CM 2003/ACFM:08 and 2004; ICES CM 2004/ACFM:11, STECF 2003a,b). However, it has been realised that fleet based predictions in the traditional quantitative sense are impractical as an advisory input to management (STECF 2004a,b and ACFM 2004 [= ICES 2004c]).

Reasons are various including

- catch composition is variable and it is not clear which aggregation level is required to achieve the needed predictability (haul, metier, fisheries, fleet);
- data required to run such models, notably discards data, do not exist at the resolution required;
- fishing strategy (e.g. choice of gear, fishing season and fishing ground) adapts to management and the flexibility in determining the catch composition available to the fishing fleets is not well understood;

The MTAC model run on input for a number of years might provide insight in the linkages and variability between the exploitation of various stocks and could be the first step in a more qualitative approach to mixed fisheries advice. Such studies are largely missing because time series on the fleet/fishery level are scarce.

New approaches are needed which can be used to give advice given the current low amount of fleet data and fleet behaviour when stocks, markets and regulations change.

The rationale for the WK is that in spite of the low level of data and knowledge, it should be possible for ICES to do better than at present, where no adjustment to the TAC advice from ICES is made at all.

The external experts are expected to contribute new modelling approaches to the work of the workshop.

1.3 Workshop Approach and Report Structure

Part of the background to this workshop is that recent attempts to incorporate mixed fishery effects in ICES advice have centred on the MTAC approach (Section 2.3), but for various reasons this approach has been found to be not suitable for this purpose (Section 2.3). Part of the role of this workshop was to develop alternative approaches for this purpose. To evaluate possible approaches, the problems with MTAC were first reviewed in order to identify a set of criteria that could be used to evaluate other approaches (Section 3.1). Based on these evaluations (Section 3) one of these approaches was identified for further development and possible operational use. This approach explicitly models the fleet structure of the relevant fisheries and thus provides the theoretical framework for the use and development of further approaches (Term of reference a, Section 4). Section 4 also highlights the development requirements of the selected approach. Section 5 considers the implications of the further use of mixed fisheries approaches in the ICES context and thus addresses term of reference b.

2 Background

2.1 Terminology

The following definitions were taken (with minor modification) from the 2003 SGDFF report, (ICES, 2003a):

Fleet: A physical group of vessels sharing similar characteristics in terms of technical features and/or major activity (e.g. the Dutch beam trawler fleet < 300 hp, regardless of which species or species groups they are targeting).

Fishery: Group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area (e.g. the Dutch flatfish-directed beam trawl fishery in the North Sea).

Métier: Homogeneous sub-division of a fishery by fleet (e.g. the Dutch flatfish-directed beam trawl fishery by vessels < 300 hp in the North Sea).

The text table below should help to elaborate the distinction between fishery and metier. In this report, however, the two terms are sometimes used interchangeably.

		TRIP ID (gear, area, mesh size (target species))	
		Fishery 1	Fishery 2
VESSEL ID (homeport, size, type)	Fleet A	Métier p	Métier q
	Fleet B	Métier r	Métier s

Relationships between fleets, fisheries and metiers. Variables in brackets are indicative of possible categorisation criteria.

2.2 The EU Management Context

The European Commission is a major client for ICES advice, and the establishment of the current Workshop reflects the following requirement stated in the Memorandum of Understanding between ICES and the European Commission.

"For each sea area ICES shall define groups of stocks within which ICES shall ensure close quantitative consistency between the advice given for each stock.

This should be considered a first step in the development of fisheries-based advice. ICES will be invited to explore during the course of the agreement how advice may be further developed to advise on changes in fishing practices for defined fishing fleets."

Within European Union waters, aggregate TACs are the current main management measure. This reflects at least in part the need to have an overall measure of annual fishing opportunities that can then be allocated across member states according to the principle of relative stability which is a key component of the Union's Common Fisheries Policy. This context defines that for the short term at least, the main requirement will be for management advice in the form of TAC advice. However, increasingly effort measures are being introduced alongside annual TACs, implying a situation where the need for effort advice becomes more routine. To address this context, the Workshop has anticipated that any method developed should be able to generate advice in terms of both TACs and effort. Effort-based advice typically also requires a fleet dimension, so this aspect is also considered.

2.3 The Development of MTAC

MTAC is the name given to the approach developed by Vinther *et al.* (2004) as a means of generating candidate TACs which takes mixed-fishery effects into account and thus represents a compromise between the individual single-species TACs. The approach takes as its starting point the single species catch forecasts from each of the species within the mixed fishery area of concern. In addition to these it also uses catch data by species and fleet/fishery for these same species to quantify the technical interactions. The other input required is a series of policy weightings which determine how much priority is given to each species; how any required effort reduction for a given species is allocated across fleets, and how each fleet is treated with regard to its target species. These weightings can be supplied externally, or the fleet-related weightings can be based on the fleet/fishery catch data. By adjusting the level of relative effort for each fleet/fishery, the approach then arrives at a set of TACs which fulfil the priorities set by the policy weightings, and which account for the technical interactions apparent in the data.

The approach was first developed for use at the first meeting of a subgroup of the European Commission's Scientific, Technical and Economic Committee on Fisheries (STECF) on the subject of mixed fisheries. The meeting (in October 2002) was timed to take place after the autumn ACFM meeting so that the single species advice could be used as input to MTAC. Other important developments in relation to the approach took place in the ICES Study Group on the Development of Fishery-based Forecasts, SGDFF (a core task for which was the compilation of data for use in MTAC), as well the North Sea demersal assessment WG, WGNSSK (reflecting the relatively good availability of data for the North Sea demersal fisheries), and ACFM. These developments are summarised briefly below. Many of these are described in greater detail in Section 14.1 of the 2004 WGNSSK report (ICES, 2005) and Kraak (2004).

2.3.1 MTAC, A Brief Chronology:

- October 2002: MTAC developed for the STECF Mixed Fishery meeting (STECF 2002); group noted that results should only be regarded as preliminary.
- February 2003: MTAC evaluated at the first ICES SGDFF meeting (ICES 2003a); numerical instabilities were detected and SGDFF concluded that it would be premature to use the present version of the MTAC model for fishery-based forecasting for advice.
- September 2003: corrected version of MTAC evaluated at WGNSSK (ICES 2004a); they identify lack of flexibility in fleet targeting as a problem and propose further evaluation by Methods WG
- October 2003: ACFM evaluates MTAC (ICES 2003b) and concludes that the mixed fisheries forecasts provided by MTAC are not yet adequate to provide an analytical basis for fishery-based advice, due to a number of limitations.
- .October 2003: STECF Mixed Fishery meeting (STECF 2003a); sensitivity analyses and response to ACFM comments; STECF plenary (STECF 2003b) concludes that outcomes should not be used for advice.
- January 2004: SGDFF evaluates MTAC (ICES 2004b), discusses problem of relative stability and considers MTAC only as a short-term fix.
- February 2004: The ICES Methods WG evaluates MTAC (WGMG, see Kraak 2004).
- October 2004: EC requests that MTAC be used at the STECF Mixed Fishery meeting (STECF 2004a); STECF plenary notes (STECF 2004b) that outcomes should not be used for advice.
- October 2005: similar to October 2004 (STECF 2005).

2.3.2 Concerns Raised with MTAC

Most of the concerns raised with the use of the MTAC approach are summarised in Kraak (2004) and ICES (2005). The broad areas of concern are as follows:

- The mismatch between the allocation of effort to individual fleets assumed within MTAC, and the overall fixed allocation of TACs across nations imposed by relative stability within European fisheries.
- The assumption that the historical catch compositions of fleets will remain constant in the prediction year, leading to the ACFM concern "that any approach to managing mixed fisheries that assumes constant species composition over time implicitly discourages adaptive behaviour".
- The high sensitivity of MTAC results to the inputs, both in terms of fleet/fishery catch data and policy weightings. This means that issues such as aggregation and

definition of fleets/fisheries, sampling coverage and availability of discard data have a large influence on the outcome. Further the close linkage between a fleet's recent catch composition and the effort allocated to it during the forecast period means that fleets can be seen to be penalised for their catch compositions, making the selection of fleet/fishery data a particularly sensitive issue.

- By nature, the TACs generated by MTAC are a compromise between the single species TACs. Unless total priority is given to the species most in need of effort reduction, the compromise will, at least for some species, lead to TACs that exceed the management objectives stated for the single species TACs (e.g. Precautionary Approach). Although this is a more general feature of mixed-fishery approaches, it has been raised as a concern about the use of MTAC.

3 Evaluation of Candidate Mixed-fishery Approaches

The group reviewed a number of alternative approaches to the problem of how to generate forecasts in the mixed fisheries context that are consistent across stocks. These alternative approaches had either been put forward by group members, or had been sent to the chairs by outsiders. No *a priori* choice of models had been made.

The approaches reviewed by the group were:

- MTAC (Vinther *et al.*, 2004). The history of MTAC is described in section 2.
- The Fleet and Fisheries Forecast (F^3) Model. This is a new approach that was developed at DIFRES and was presented to the group by participant Clara Ulrich-Rescan.
- A "Multi-species model for sustainable exploitation". The author of this model, Eckhard Bethke, had brought this model to the attention of the group by sending an ICES paper documenting the model (Bethke, 2004)
- The F-Coupling Approach. This approach had been initiated by ICES in February 2005 and was available to the group in the form of two documents: "MCAP, February 2005, Doc 10", and "Doc 10b AMAWGC February 2005". These documents are available from ICES.
- The EIAA (Economic Implications of ACFM Advice) model. This model is routinely used in STECF to calculate the economic consequences of the ACFM advice. It was brought to the attention of the group by participant Clara Ulrich-Rescan for possible use in mixed fisheries forecasting in the form of the EAFE-AC REPORT (2002).
- The SMP model. This model, developed by Hans-Joachim Rätz, has been presented on several occasions to the STECF Mixed Fisheries subgroup (Rätz, 2003, Rätz *et al.*, 2005). The latest document was sent to this group by the author.
- The Stock Rebuilding Framework Model. This model was developed by group participant Joachim Gröger and colleagues (Gröger *et al.*, 2004) and presented to the group by Joachim Gröger.

3.1 Evaluation Criteria

Part of the task of this Workshop can be summarised as finding a replacement for the MTAC approach. As a number of different candidate approaches had been submitted to, or identified by, the Workshop, it was necessary to find a way to evaluate these. For this reason, a set of criteria were developed against which all of the candidate approaches could be evaluated. As it would be clearly desirable that any replacement for MTAC would address as many of the problems with MTAC as possible, the criteria reflected the concerns identified in relation to the use of MTAC. The criteria also included a number of more general points. The evaluation criteria are summarised below. The points are followed by a brief rationale for selecting each criterion.

Criteria for evaluation

1) What are the data requirements?
2) What kind of process is modelled (assumptions, hypotheses)?
3) Can the flexibility of fishing practices be accommodated?
4) Can it be used to assess historical trends and/or to run predictions?
5) What kind of input from managers is required?
6) Does the model address the units of management?
7) Can it be used to give management advice on TAC and/or effort?
8) Can the scientific assumptions be tested (historical data?)?
9) Ease of communication of results
10) What kind of software environment is used?
11) Form of documentation
12) Areas for development if necessary

Points 1 and 2 are a basic explanation of the approach and its data requirements.

Point 3 reflects the possibilities for vessels to change their fishing practices in response to future catching opportunities.

Point 4 helps to identify a basic feature of the approach in terms of whether it could be used only to reconstruct past trends, or only in a projection mode, or both.

Point 5 concerns the nature and extent of input required from managers, given that any approach based on fisheries rather than stocks requires some sort of prioritisation be applied to species and/or fleets.

Point 6 results from the problem of the mismatch between the assumptions of MTAC and the management context in which it would be used. Essentially, MTAC implicitly assumes that management will be fleet-based, hence the results are derived from allocating quota to individual fleets. In contrast, in the current European context, the results would only be used to determine TACs. Hence the allocation of quota is most unlikely to match that derived from the MTAC run. As a result a TAC derived in this way will not achieve the intended change in fishing mortality.

Point 7 is a basic requirement, again reflecting the immediate management context of the approach.

Point 8 Is linked to point 2 in that it reflects the scientific basis of the approach, and it is clearly desirable that any assumptions or hypotheses underlying the approach can be tested.

Attempts to discuss MTAC results with stakeholders have been hampered by difficulties in understanding and explaining the approach. From this it is apparent that simplicity and ease of communication are desirable features of any replacement approach. This is reflected in point 9.

Point 10 considers the software environment used as this may have implications for ease of future development.

Point 11 considers where and how well the approach is documented, whether it has been peer-reviewed etc.

If the approach was considered to need further development, Point 12 highlighted areas identified for such work.

Each of the alternative approaches is reviewed against the criteria in the following sections. The evaluations include an overall summary of the strengths and weaknesses of each approach.

3.2 MTAC

Data requirements:

Age based landings and discards disaggregated by fleet/fishery are required (effort data is not required).

The method is sensitive to misreported and missing data.

Model Basis and Assumptions:

MTAC operates under the assumption that the fleets only perform in one métier (i.e. that within the fleets the catchabilities for each of the species are constant (over the year and between areas)).

MTAC also assumes that within the fleets the catchabilities for each of the species are constant between the forecast year and one or more historical years.

Furthermore, all assumptions for single species forecasts are used (e.g. that fish weights stay the same as in some historical period).

Ability to Accommodate Flexibility of Fishing Practices:

Flexibility of fishing practices is not accommodated.

Can it be used to assess historical trends and/or to run predictions?

If the assumptions are valid, it can be used for prediction (forecast).

It cannot be used to assess historical trends.

Input Required from Managers:

Decision weights (i.e. priorities), and p- and q-options (i.e. rules on how to differentially allocate effort reductions/increases to the fleets), the targets by species (e.g. TACs or F-multipliers).

Does the Model Address the Units of Management?

Using MTAC implies fleet based management; hence, there is a mismatch with the current management context, which requires only aggregated forecasts (TACs).

Management based on MTAC would require that the fleet units used in MTAC are manageable units.

Ability to give management advice on TAC and/or effort:

Yes, MTAC can generate aggregate and fleet based catch and effort advice.

Can the scientific assumptions be tested (historical data?)?

Within the historical years the assumptions can be tested by checking whether the catch composition is homogeneous within the chosen fleet unit.

Across years it can be checked how stable fishing practices have proved historically.

Ease of Communication of Results:

It is quite complex to explain the procedure, as well as the implications of the options and decision weights.

Software Environment:

R for running MTAC.

Excel, SAS, or other data manipulators for preparing the data.

Documentation:

The method is described in a peer reviewed journal article (Vinther et al. 2004), and evaluated by the ICES Methods WG (WGMG, Kraak 2004). There is also a description by the authors of how to use the MTAC program circulated at working groups, with the title “Implementation of MTAC”.

Requirements for further development:

Developments to facilitate data compilation.

Summary and Conclusion:

Strengths

- It is fleet based.
- Flexible in its use of options for the allocation of effort reductions differentially to the fleets.
- Transparency with respect to the policy inputs.
- It gives actual TAC or effort advice for the forecast year as output.
- It is documented, it is worked out and ready for use, has been peer reviewed and tested.
- It uses R, which is freeware.

Weaknesses

- The flexibility of the approach in allocating catches between fleets is much greater than that of the management system. As a result it is difficult or impossible to apply the results in practice. A key problem in this respect is the lack of consistency with relative stability.
- The method relies on single species TACs and therefore requires accepted single species stock assessments and catch forecasts.
- The required data compilation is time consuming.
- Sensitivity to missing data, and misreported data at the fleet level.
- The close link between past fleet catches and future fleet effort allocations with some settings could encourage misreporting.
- The chance is high that the assumption is violated that the fleet units that the managers choose perform only one métier.
- It cannot accommodate the flexibility in fishing practices.
- Communication is difficult because it is complex.

Despite a number of weak points when using it for management advice, the model gives a lot of insight into the by-catches of vulnerable species in different fleets

In terms of developing a model for mixed fisheries advice the group feels effort would be better directed to development of one or more of the alternative approaches identified by this group.

3.3 Fleet and Fisheries Forecast (F^3) Model

In this section only the evaluation of the model against the criteria is given; a more complete description of the model is given in section 4.

Data requirements:

In order that this method can be used it is essential that for each nation, each trip of a fishing vessel is assigned to a fishery, and each vessel belonging to that nation is assigned to a fleet. The definition of national fisheries and fleets is, however, entirely at the discretion of each nation.

Landings and effort by fleet and fishery are required (discard data is not necessary). A minimum of three years data is recommended in order to calculate a mean catchability.

Data requirements can be more or less complex as required in that the model can be run using data averaged on an annual average basis or by quarter, or by month. If an external behaviour model is available for the case studies, then by using additional data (e.g. landings value), it could be included in the F3 framework for modelling future effort allocation schemes.

The model would be sensitive to incomplete landings by trip data. Without data by trip the ability to assign effort to fisheries could be compromised. The model, however, is no more sensitive than other models requiring landings data on a per trip basis.

Finally, F estimates and catch forecast from single species assessments, and stock quota shares by country and fleet are required (alternatively, relative landings by fleet can be used).

Model Basis and Assumptions:

The basis of the model is to forecast the level of effort by fleet corresponding to the set of single-species TACs, based on fleet effort distribution by fishery. This level of effort is in return used to forecast landings and discards by fleet and stock.

The model is a process model. Effort is assumed to have a linear relationship to fishing mortality.

If a behaviour model is not included then the distribution of effort between fisheries in the forecast year is assumed equal to the average calculated over a number of previous years (e.g. three years).

Ability to Accommodate Flexibility of Fishing Practices:

In its simple form, when the model is parameterised from historical averages of effort by fishery, it does not accommodate flexibility. However, in order to accommodate flexibility, recent results of behaviour analyses can be incorporated, e.g. by means of a behaviour model.

Can it be used to assess historical trends and/or to run predictions?

The method has been able to replicate changes in effort, catches and stock dynamics in the North Sea flatfish fisheries over the past five years fairly well (Marchal *et al.*, 2006).

The model is able to forecast effort and catches in the TAC year by fleet.

Input Required from Managers:

Managers need to tell whether and how stocks are to be prioritised.

Does the Model Address the Units of Management?

The method is structured to give results in terms of fleets and effort. Effort can be in terms of days at sea or kW days at sea if data on the power of vessels is available. Results can, however, be formed in terms of TACs.

Ability to give management advice on TAC and/or effort:

The method was developed to be used within the current system of TAC controls. The requirements of relative stability in TAC can be accommodated. However, the fact that this method is based on effort data would make it suitable for formulating advice under an effort based management system.

If the management system became effort based, existing catchability data could not be assumed representative of that which would be found under the new regime. This problem could prove long term, as an effort based system provides a strong incentive for fishers to improve their efficiency and this in turn could lead to a continued evolution in fishing patterns and technological improvements.

Ease of Communication of Results:

The units being used are familiar to fisheries managers and fishers, (F, effort), as well as the concepts and processes dealt with (fleets, fisheries, species). The underlying algorithm is relatively simple and assumptions can be clearly stated. Results can be presented as a table giving effort and/or TAC by fleet.

Software Environment:

This method is extracted from a larger simulation framework, (TEMAS). TEMAS is coded in Visual Basic with an Excel interface for input data. Currently a version written in R open software is being developed for TEMAS.

Currently, this framework is only being used for simulations. Should this method be used for management advice then a stand alone version needs to be developed.

An EXCEL demonstration sheet and an R coded equivalent have been developed during the Workshop.

Documentation:

There is no documentation dealing uniquely with this method in a stand alone form.

The method has been developed as part of the "TEMAS" model. The TEMAS model is documented in reports from the TECTAC EU project (Marchal *et al.*, 2006). There are also two journal papers in preparation. Finally, there is a conference paper on TEMAS (Vermard *et al.*, 2005). A journal article on an older version of the model (data by fleet and yearly average) is available (Ulrich *et al.*, 2002).

Requirements for further development:

The method should be tested on various data sets.

An R open source software version of this method in stand alone form should be developed.

Summary and Conclusion:

Strengths

- It makes better use of existing data than MTAC (i.e. it also uses effort), and is less dependent on discard data which can be missing.
- It is a process model.
- It is a simple mathematical model (section 4.1).
- It is compatible with the relative stability criteria.
- No assumptions on fixed catch composition.
- The method is transparent; the calculations break down into five basic steps (see section 4.1 excel demo sheet) and the points at which more sophisticated calculations of intermediate results can be substituted for the current calculations are readily identified.

Weaknesses

- The method relies on single species TACs and therefore requires accepted single species stock assessments and catch forecasts.
- The required data compilation is time consuming.
- The method can only be used if effort data are considered reliable, (trustworthy) and are available at the vessel level.
- The sensitivity of results to aggregation level and fleet-fisheries definition is unclear.
- The major parameter, catchability, varies a lot between vessels, time period etc.
- The method relies on the assumptions of (1) a relationship between fishing effort and fishing mortality, and (2), modelling of effort allocation. Both are strong assumptions concerning processes which are still little known and whose scientific validation is still weak.

The workshop concluded this was a method worth investigating further.

3.4 A "Multi-species model for sustainable exploitation" by Eckhard Bethke

Model Basis and Assumptions:

The aim of this method is to determine the maximum potential profit for a fleet or fleets from a stock (or combination of stocks) using fishing effort and gear mesh size as control parameters. The model combines the Beverton and Holt yield model with the economic model of Gordon and Schaefer.

The Beverton and Holt model is based in turn on the von Bertalanffy growth functions and the assumption of a constant fishing mortality for fish after entering the fishery. Selection model of a gear is a knife-edge function. Age of first capture corresponds to l_{50} length and all fish younger than age of first capture are assumed to escape.

Feeding yield results into the economic model allows calculation of revenue per recruit and cost per recruit. Using axes of effort relative to current effort and mesh opening, response surfaces of revenue per recruit and cost per recruit can be determined, (see Figure 7 of WD). The objective is then to obtain the maximum positive difference between revenue per recruit and cost per recruit.

Documentation:

The method is documented in an ICES paper (Bethke, 2004)

Summary and Conclusion:

This method appears not to address the ToRs of this working group. The method relies on the concept of a long term equilibrium achieved through an unchanging technical measure (mesh size) and levels of effort. This sub-group does not see how it could be used to give short term advice on multi-species harvest control measures.

3.5 The F-Coupling Approach

Data requirements:

This very simple approach only uses historic estimates of total Fs for each of the species considered.

As the approach uses the correlation or covariance between Fs, it is sensitive to their accuracy i.e. significant unaccounted mortality owing to e.g. a lack of discards data or misreporting will provide erroneous estimates and could result in inappropriate recommendations for TACs.

Basis and Assumptions:

The approach consists of two steps. The first step quantifies (in one way or the other, see below) the correlation between historic fishing mortality rates of different species. It is assumed that the degree of coupling reflects the strength of the historical technical interactions between the species and thus the extent to which the fleets have been able to catch the species independently in the past. In the second step that quantity is used, when a reduction of F is required for an endangered species, to calculate how large reductions of F are required for the other species that are fished in the same area, in order to protect the endangered species. Here it is assumed that if in the past it has been possible to decouple fishing on two species to a certain extent, this will be possible in the future again. Since the resulting TAC advice will be aggregated over the fleets, the approach further assumes that the fleets will – without any further incentives – behave in the way implied, namely such that they decouple fishing on the respective species as has been possible in the past.

In the MCAP and AMAWGC documents, which introduced the approach to the group, the quantification of the correlation (the first step) was as follows: It used the historic F values of cod, as an example, expressed as percentages of the corresponding historic F values of haddock, and then took the difference between the upper and lower percentages as being an indicator of the elasticity of the interaction between the two species. In the example the F of cod as percentage of the F of haddock ranged between 77% and 104%, and hence the quantity reflecting the strength of the technical interaction was (104 minus 77 =) 27%. The MCAP and AMAWGC documents proposed to use this quantity for forecasting (advice) as follows: If the advice is to reduce F on the cod stock to say 50%, then F on the haddock stock should be reduced to (100%-(50% - 0.5 * 27%) =) 63.5%, the argument being that this level of “elasticity” is realistic because it has been observed in the past.

Concerning the first step, the group noted that this quantity (the range of one F expressed as a percentage of the other F) depends not only on the strength of the correlation between the two Fs, but also on the level of one F relative to the other. For example, if the cod F would on average be double the haddock F, a very different value would be obtained than if the cod F would on average be half the haddock F, even if in both cases the correlation, and therefore the strength of the linkage, would be exactly the same. The group therefore suggested that the Pearson’s correlation coefficient between the two Fs might be a better way of calculating that quantity reflecting elasticity.

It remained unclear to the group what the actual process is that this method tries to model. Elasticity describes the relationship between independent and dependant variables and in the context presented here, it is difficult to see how the Fs of one species are dependent on the other.

Using the original formulation, no consideration is given as to whether the correlation is negative or positive as it simply relies on the numerical difference between the upper and lower values.

The group found that the Review Group of the Hake, Monk and Megrim Working Group (RGHMM, 2005; available from ICES) had looked at the approach when exploring linkages between hake and anglerfish. For step one, they used a more formal mathematical formulation in terms of the “elasticity” concept from economic theory, which is defined as the rate of incremental percentage change of one variable against another dependant variable. This approach uses the slope of the regression between the natural logarithms of the F values.

The approach makes a number of assumptions. In the current form, expert judgement or *a priori* knowledge of the fishery is needed to check or filter the outputs (as in the AMAWGC document) to ensure that correlations are true and not an artefact of the data. This is particularly true if Fs for species that are not taken in the same species assemblage, exhibit similar trends over time e.g. North Sea cod and southern hake. This could be overcome by disaggregating to a métier level.

By using aggregated data, the model assumes that the elasticity is the same for all fleet segments, disaggregating the data may give quite different outputs. However, dealing with high resolution, e.g. at a métier level, could possibly result in an inability to determine correlations due to data noise; therefore, some level of aggregation may be desirable.

The explorations of the RGHMM had demonstrated that output values are also susceptible to the reference periods used. Using two different reference periods (1986–2004 and 1996–2004), the RG concluded that there appears to be no stability in the estimation of elasticity. This may indicate adaptive behaviour of the fleets.

Ability to Accommodate Flexibility of Fishing Practices:

Yes. The model implicitly assumes that fishing practices (effort allocation) will change such that fishing on the endangered species is restricted exactly according to the TAC while at the same time fishing on the other species remains high (up to the advised TAC), which is assumed to have been possible in the past.

Can it be used to assess historical trends and/or to run predictions?

The approach consists of two steps. Step 1 intends to quantify historical linkage between species, and step 2 would involve using this to predict candidate TACs.

Input Required from Managers:

Managers need to provide priorities across species and provide the requirements to modify F for the critical species; the model output will then predict the associated TACs for other species.

Does the Model Address the Units of Management?

Yes, the model outputs stock TACs.

Ability to give management advice on TAC and/or effort:

Yes, the model outputs TACs.

Can the scientific assumptions be tested (historical data?)

Data could be disaggregated to a métier level to determine if aggregated assumptions are consistent between aggregated and disaggregated outputs.

Ease of Communication of Results:

The computation of the between species correlations and the required reductions of F are easy to understand and disseminate as the procedure is essentially very simple. However, the underlying concepts and assumptions are not at all clear and therefore difficult to disseminate.

Software Environment:

Excel, or any other calculator.

Documentation:

The approach has only been explored so far. These explorations are documented in the MCAP paper, the AMAWGC paper and the RGHMM paper.

Requirements for further development:

Assumptions should be made explicit and a mathematical formulation should be created accordingly. For example, it should be investigated whether and how the correlations could be modified to remove effects such as that several stocks change their distribution in the same way due to a variable (e.g. climate) external to the model.

The potential could be explored to use disaggregated data to provide allocation keys for TACs/effort between fleets.

More detailed and accessible documentation is required.

Summary and Conclusion:

Strengths

- Approach is simple, even at disaggregated fleet level (see section on future developments).
- Computational requirements are low.
- No additional data requirements for TAC advice.

Weaknesses

- The quantity is sensitive to unaccounted mortality.
- It is unclear what underlying process is being modelled.
- Lack of documentation.
- Procedure is relatively undeveloped.
- The approach as presented by MCAP and AMAWGC can provide quantities that do not only reflect the correlation between Fs but also the absolute levels of the Fs. Beyond that it is not clear what the quantity reflecting the elasticity of the fleets should be (Pearson's correlation coefficient or the elasticity concept from economic theory).
- The quantity is sensitive to choice of reference period.

Because the procedure is simple in comparison to other models and does not require any additional data, the group decided to explore the F-Coupling approach further. These explorations are documented in Section 3.9. The group concluded from these explorations that the approach is not useful for assessing historical linkages nor for producing forecasts. This is, among other reasons, because no sound theoretical basis for the approach could be identified and because the many factors that confound the correlation between the Fs cannot be separated from the technical linkage between the species. The group recommends that the approach is not considered further for TAC advice.

3.6 EIAA (Economic Implications of ACFM Advice) model

Data requirements:

TAC advice by species.

Quota shares by fleet.

SSB forecasts.

Price information.

Model Basis and Assumptions:

EIAA is a method to estimate the economic consequences of the ACFM advice. Therefore, the main characteristics of the method deal with economic formulae. However, for our purposes the main interest is in the model of effort allocation by fleet (segment) given a mixture of quota. The evaluation will only deal with the effort allocation part of EIAA.

Effort allocation is modelled as:

$$E fcast_j = \sum_i \left(\frac{LVTAC\ fcast_{i,j}}{\sum_i LVTAC\ base_{i,j}} \cdot \left(\frac{LTAC\ fcast_{i,j}}{LTAC\ base_{i,j}} \right)^{(\chi)} \cdot \left(\frac{SSB\ fcast_i}{SSB\ base_i} \right)^{(-\beta)} \right)$$

Where LVTAC is the landed value of the TAC(=landings), LTAC is the weight of the landings and SSB is the spawning stock biomass, *base* refers to the current (?) years and *fcast* to the forecast year, *i* to the species and *j* to the fleet. So the forecast effort is the weighted average of the landed values of the TACs, modified by a TAC flexibility factor and an availability factor (SSB).

The parameters χ and β that specify the flexibility terms have not been estimated from data.

Ability to Accommodate Flexibility of Fishing Practices:

Flexibility of fishing fleets is not explicitly addressed. It is assumed that this fishing pattern will not change from the reference year to the year for which the evaluation is made.

Ability to Recreate Historical Trends, make Predictions and Test Model Assumptions:

Effort changes in history could be tested with this model. Historical data for different fleet segments could be used to estimate the flexibility parameters and these could then be used to predict forward and to test the predictions to the observations.

Input Required from Managers:

None required.

Does the Model Address the Units of Management?

Yes, it refers to national fleet segments.

Ability to give management advice on TAC and/or effort:

This model can give effort implications of TAC advice. The full EIAA model can also generate economic consequences of TAC advice.

Ease of Communication of Results:

This model can give effort implications of TAC advice. The full EIAA model can also generate economic consequences of TAC advice.

Software Environment:

Excel

Documentation:

Documented in EAFE report (EAFE-AC REPORT 2002)

Requirements for further development:

Could be used in full simulation models as the module that deals with the effort allocation under different TAC regimes.

Alternatively: could generate consistent TACs based on the effort allocation model.

Summary and Conclusion:

Strengths

- Simple model of effort allocation.
- Can be tested on historical data.
- Relatively easy to explain.
- Routinely used in STECF.

Weaknesses

- Not an advice generating model; needs to be incorporated into another model in order to generate advice. In that setting the effort allocation could be modelling the fleet response to TAC measures.
- Theoretical basis not well established
- Requires catch forecasts of all species.

In conclusion this looks to be a useful approach to model effort allocation. It could be incorporated into management simulation models or into methods that calculate the predicted quota uptake given the fleet effort.

3.7 SMP model

It should be noted that the author of the SMP model was not present at the meeting and therefore not able to clarify some difficulties the working group encountered. However, it was decided to evaluate the model according to the criteria set for the other models.

This model is structurally similar to the MTAC model although it differs in the optimisation method, how the fleet/species weights are used, and that it can explicitly incorporate the Precautionary Approach as a constraint. Therefore only main differences from the MTAC model are listed below, as well as strong and weak points.

Input Required from Managers:

Decision weighting.

Constraints on SSB and Fishing mortality.

Software Environment:

The program is written in Visual Basic for Applications with input and output data presented as the EXCEL spreadsheets.

Documentation:

The method is documented in Rätz (2003) and Rätz *et al.* (2005).

Requirements for further development:

A more detailed description of algorithms would be desirable, especially the way "species weighting" is applied and optimisation is carried out.

Summary and Conclusion:

Strengths

- It explicitly allows constraints on SSB and fishing mortality, taking into account precautionary principles
- It is a simple traditional deterministic stock projection model for multi-fleet multi-stock fishery.
- It is fleet based.
- Flexible in its use of options for the allocation of effort reductions differentially to the fleets.
- It gives actual TAC advice for the forecast year as output.
- It is documented, it is worked out and ready for use.

Weaknesses

- The possibility to allow constraints on SSB and fishing mortality can not be switched off.
- Due to the approach being fleet based, it is difficult or impossible to apply within the current management system; problems with relative stability, difficult to impose differential restrictions to fleet.
- Accepted ACFM assessments and/or advice for each species is required as input; if this is not available, nor anything specified by the managers, this model cannot be used.
- The required data compilation is time consuming.
- Sensitivity to missing data and misreported data at the fleet level.
- It cannot accommodate the flexibility in fishing practices.
- Communication is difficult because it is complex.

The working group considers that although this model differs from MTAC, both methods are sufficiently similar that to develop both models would an unnecessary duplication of effort. If further development of either method is to be conducted, it seems sensible to attempt to combine the better features of both into a unified model.

3.8 Stock Rebuilding Framework Model

Data requirements:

Minimum: Starting population numbers (age based or production model).

Weight (age based or not).

Target value for biomass at end of rebuilding period.

Upper value for F, on each species.

Prediction function (estimated parameter values for recruitment functions or production models). In case economical representation of the objective functions is used for optimisation, economical data (prize, costs) are needed.

Technical interaction matrix.

Model Basis and Assumptions:

This is more a projection modular based framework than a fixed model or algorithm.

It can be used in a deterministic or stochastic process.

Age disaggregated or production model.

The model can be set-up for an optimisation not only on biological parameters but also for economical value of catches.

Based on constraints by decision weights of the species, rebuilding targets for biomass and F. Optionally the user can give constraints on stabilizing catch.

Ability to Accommodate Flexibility of Fishing Practices:

Technically possible but it would need a function to predict fishermen’s behaviour.

The by-catch matrix would then have to be modified with that function.

Can it be used to assess historical trends and/or to run predictions?

The model is a tool for looking forward and not designed to reproduce historical trends.

Input Required from Managers:

Decision weights for the species, limits to rebuilding targets + upper limits for F.

Does the Model Address the Units of Management?

Yes, the model can be modified in a way that it addresses the units needed in the EU waters.

Ability to give management advice on TAC and/or effort:

Yes but these are a by product and the main purpose of the approach is to find optimum strategies for medium to long term advice.

Can the scientific assumptions be tested (historical data?)?

The optimisation process is not testable but the assumptions of the technical interaction matrix can be tested by comparing predictions with realized catches over the years.

Ease of Communication of Results:

The end result is easily communicated in graphs but the model itself is quit sophisticated. The technical interaction matrix is, as in most mixed fisheries models rather difficult to communicate.

Software Environment:

SAS, MATLAB.

Documentation:

The model is documented in an ICES paper (Gröger *et al.*, 2004).

Requirements for further development:

Economic evaluations on optimisation (profit is the issue).

Management units should be redefined into fisheries if changes in fishing behaviour need to be taken into account and incorporated in this model.

Summary and Conclusion:

Strengths

- It is a method which optimises fishing mortality for meeting the predefined management goals
- Each stock can be assessed by different model

Weaknesses

- At present fleet behaviour is not incorporated in the model. However, if a function model should be available, it could be incorporated and the result of these simulations need to be evaluated. It should be noted that this is not a specific issue of this model but applicable for most of the other mixed fisheries models evaluated in this group.

In conclusion, although this framework takes into account the mixed species interactions, it is more intended for medium to long term projections ,optimising control variables (eg effort, TAC) than a short term prediction tool using mixed fisheries information.

3.9 Further Consideration of the F-Coupling Approach

Because the procedure is simple in comparison to other models and does not require any additional data, the group decided to explore the F-Coupling approach further. The approach consists of two steps. The first step concerns a descriptive evaluation of some period in the past through exploration of historical data. The second step is concerned with using this knowledge of the past for forecasting.

The underlying process is that fishing activity (as the independent variable, the cause) affects the Fs of several species (dependent variables, the effects), via the catchabilities (F=q*E). The assumption is that within any métier catching e.g. two species, the Fs of these two species would vary similarly with E in that métier. (This assumption can only be valid if the species abundances and distributions do not change relative to those of the other species, because this would affect the catchabilities.)

The theory behind the first and the second step is explored separately.

3.9.1 Step 1, Historical linkage

Step 1 of the approach should identify a quantity that can be computed at the aggregated level that reflects what happens at the métier level. One such approach would be to investigate the correlation between fishing mortality for two stocks. Factors that may affect the correlations include:

- Random noise and errors in the estimation of the Fs.
- Changes in spatial distribution, affecting the catchabilities.
- Species specific technological creep.
- External variables that affects both Fs.

Apart from these factors (and possibly others) the strength of the correlation is affected by the degree to which the stocks have been fished independently in the past. Weak correlations reflect that fishing, at least partly, has taken place in métiers with weak technical interactions. For example, increases (or decreases) in F in one species that are not accompanied by increases (or decreases) in F in the other species indicate that fishing has increased (or decreased) in a métier that catches the one but not the other species. This implies that the strength of the correlation is partially a measure of the extent to which it has been possible, historically, to change F on one species independent of F on the other species.

In order to assess the stability of the estimated correlations between fishing mortality, we explored the effects of using different historical periods for determining the slopes of the regressions of log fishing mortalities. In these explorations we considered the 2004 assessments of cod in the North Sea (cod-347d), haddock (had-34), North Sea herring (her-47d3), Northern hake (hke-nrthn), North Sea plaice (ple-nsea), North Sea sandeel (san-nsea) and North Sea sole (sol-nsea). In the exploration we explicitly looked at stocks which were either in different areas (e.g. Northern hake) or for which the fisheries are very distinct (e.g. North Sea herring and sandeel).

Results are shown in Figure 3.1 (1960–2004 and 1980–2004) and Figure 3.2 (using short time series 1980–1989 and 1995–2004). In general we observed a high dependency of the slope of the regression on length of the time period. For example, the relationship between cod and plaice gave a positive slope when using the longest time series (1960–2004) but a flat slope when using a shorter time series. We also noted a negative slope for plaice and sandeel whereas there are no obvious relationships between the fisheries on these two species. A third observation was that the confidence intervals around the regressions (not shown) increased substantially when using shorter time series (Figure 3.2).

We conclude that the method of estimating flexibilities in exploitation using a regression analysis between the logs of fishing mortality is sensitive to the number of years that are included into the analysis. It could provide a rough indicator of the covariation in fishing mortality but the signal cannot be taken at face value and needs to be backed up by additional analysis, e.g. using fishery based information. Furthermore, with regard to the specific regression approach used here, there seems to be no theoretical basis for choosing one F as the independent and the other F as the dependent variable.

3.9.2 Step 2, Use in forecasting

The second step of the approach would then use the correlation between the Fs for forecasting.

The reasoning behind the second step is as follows (see Figure 3.3). Imagine that stock 1 is endangered and needs protection through a reduction in F by a certain quantity, A. This necessitates a reduction in F on stock 2 by quantity B. Under the (big) assumption that the uncertainty in the relation between the two Fs (compare the two panels in Figure 3.3: the upper panel with a low uncertainty and the lower panel with a high uncertainty) is fully caused by the degree to which the two stocks can be fished independently, it could be argued that F on stock 2 does not need to be reduced as far as by quantity B to achieve the reduction of F on stock 1 by quantity A. Under this assumption some “extra” fishing on stock 2 can be allowed, and fishing on stock 2 needs to be reduced only by quantity C. The “extra” fishing allowed should then in some way depend on the strength of the correlation between the two Fs. However, we cannot propose a mathematical formulation for the computation of this “extra” from the parameters of the correlation. According to this reasoning the F reduced by quantity C, is the maximum F on stock 2 that would still achieve the necessary reduction of F on stock 1, given that this has been possible in the past. The advised F on stock 2 should then be this F, or the F of the single species advice, whichever of the two is lower.

It is important to note that if management is in the form of TAC advice (e.g. based on the above approach) without any fleet- or fishery-specific management regulations, it cannot be ensured that the fleets will re-allocate their effort such as is implied by the approach, i.e. to direct more effort to métiers where stock 2 can be fished without catching stock 1. The approach only states that it is possible to uncouple fishing on the two stocks to a certain extent, but not that the fishers will actually do so without any further incentives. As has been noted before, this problem is inherent to aggregated TAC advice based on mixed fisheries considerations (thus also to the use of MTAC for TAC advice). Such TACs can only have the desired effect if the fishers redirect their efforts into different metiers or if the fleets' effort is reduced differentially.

3.9.3 Conclusion

The group concludes that the F-Coupling Approach cannot easily be developed into a usable method with proper underlying mathematics that correspond to reasonable assumptions. The main reason is that the correlation between the Fs of two stocks is influenced by too many confounding factors whose effect cannot be removed without a detailed analyses on métier level and on e.g. changes in distribution of the stocks. The fact that the choice of reference period has a large influence on the slope and strength of the correlation makes results in the output of the method being very arbitrary. On top of that, the group has noted the discrepancy between using a method for aggregated TAC advice while the assumed underlying process is at a very disaggregated level. To accommodate the latter, a fleet- or fisheries-based management would be more suitable.

3.10 Summary and conclusions from evaluations

Of the methods considered during the evaluation stage, only the F^3 model came out as worth to be developed further, in the context of the first term of reference, for possible operational use. The F^3 approach has a strong theoretical basis, with explicit representation of some key processes, although the mathematical representation of these is simple. The major drawback would be its data requirements. The approach requires further exploration and development before it could be considered for operational use, and this follows in section 4.

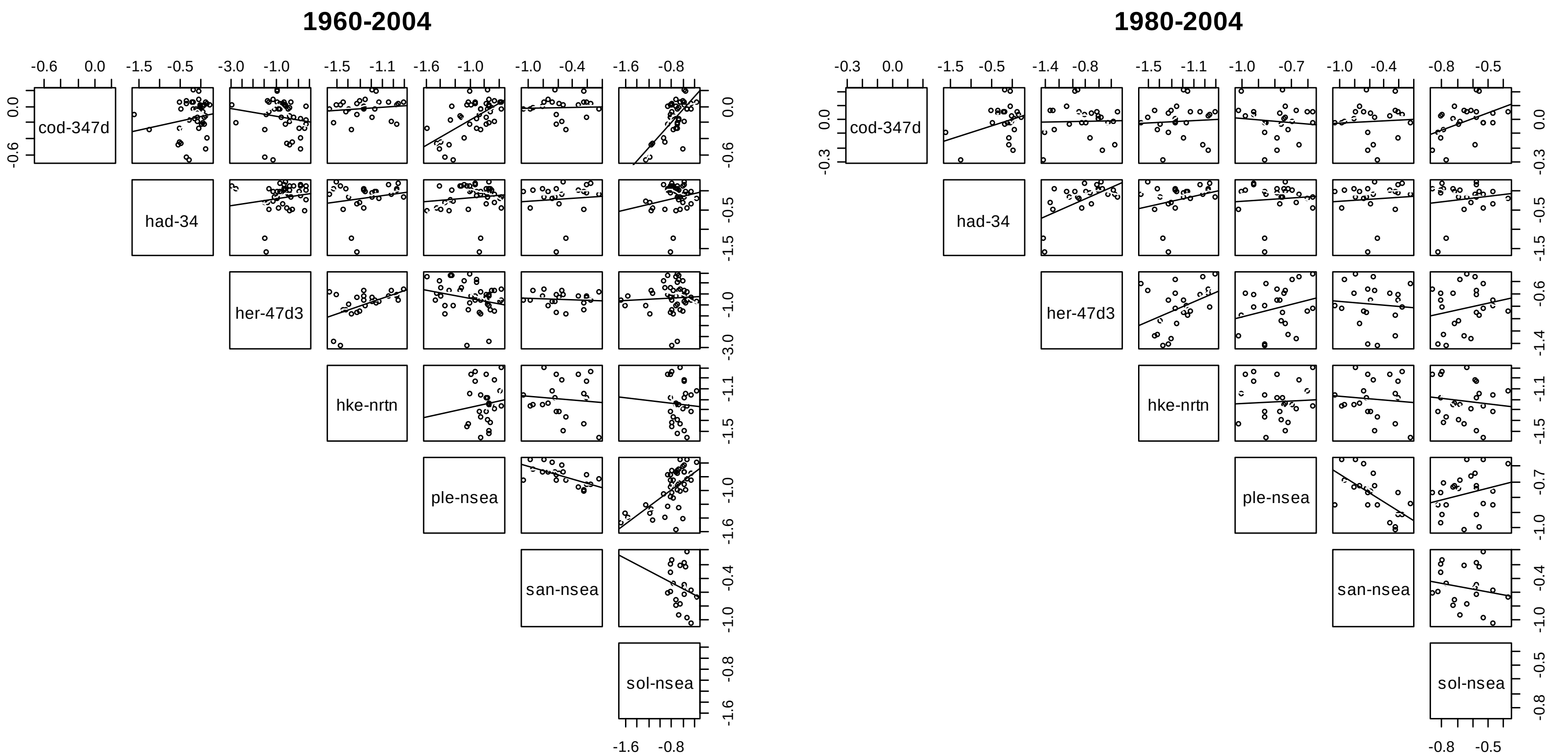


Figure 3.1 pairwise log-log relationship of fishing mortalities of cod in the North Sea (cod-347d), North Sea haddock (had-34), North Sea herring (her-47d3), Northern hake (hke-nrthn), North Sea plaice (ple-nsea), North Sea sandeel (san-nsea) and North Sea sole (sol-nsea) with superimposed the regression line.

Left: using assessment data from 1960-2004, right using data from 1980-2004.

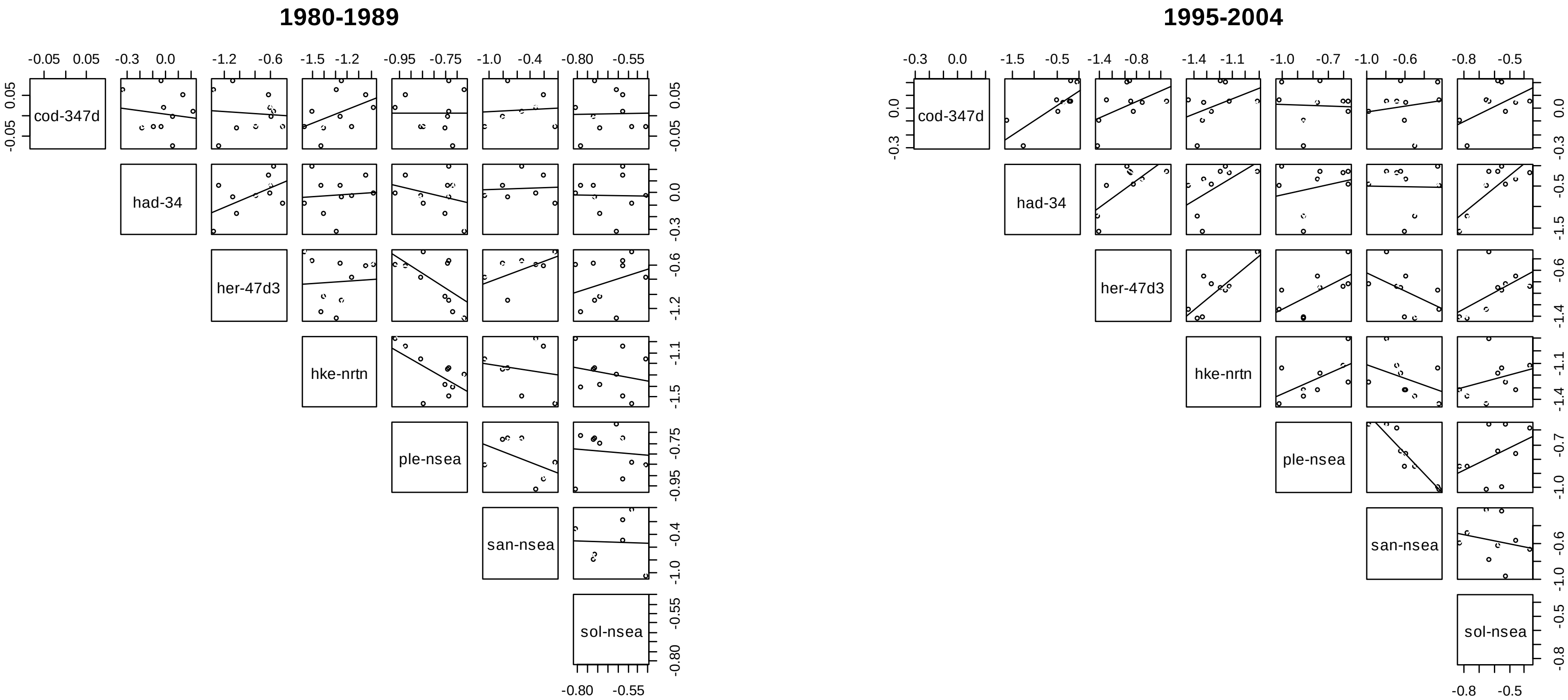


Figure 3.2 pairwise log-log relationship of fishing mortalities of cod in the North Sea (cod-347d), North Sea haddock (had-34), North Sea herring (her-47d3), Northern hake (hke-nrthn), North Sea plaice (ple-nsea), North Sea sandeel (san-nsea) and North Sea sole (sol-nsea) with superimposed the regression line.

Left: using assessment data from 1980–1989, right using data from 1995–2004.

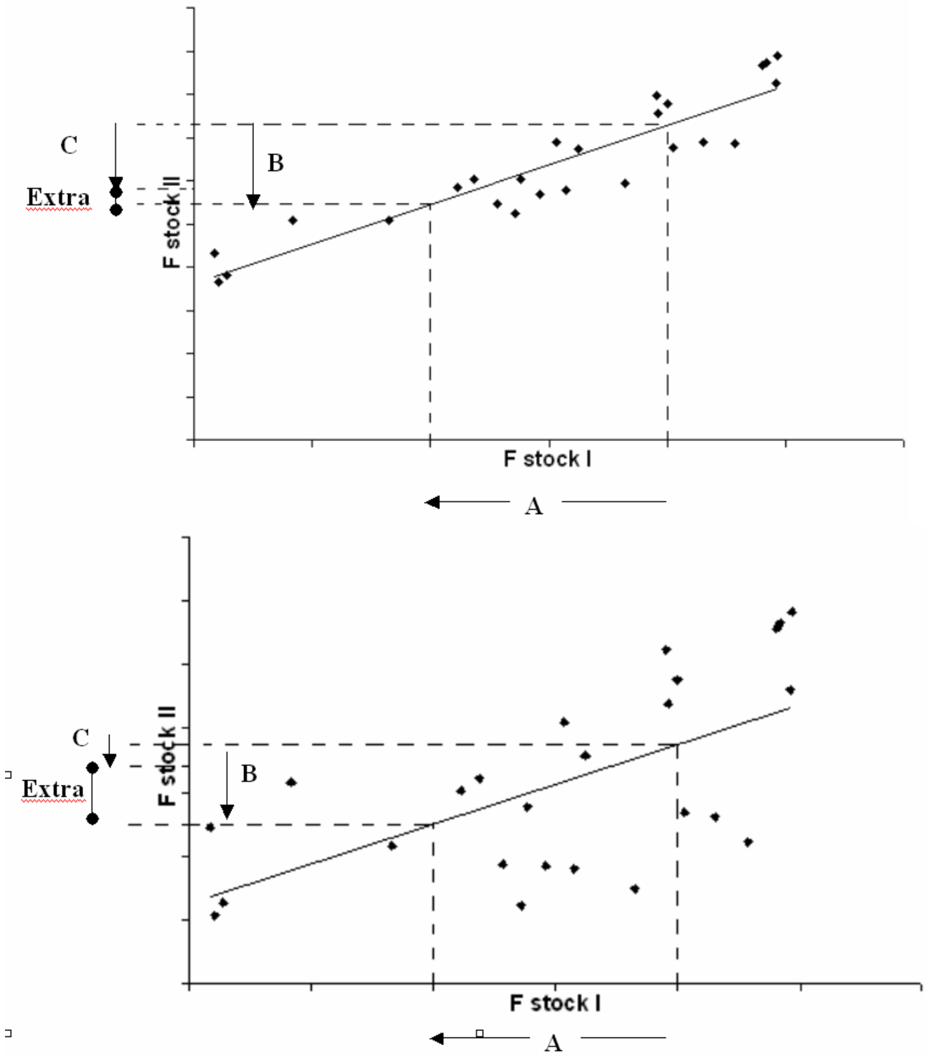


Figure 3.3 **Hypothetical example of using the relationship between the Fs on two stocks fished together in a forecast. The upper panel gives an example with relatively low uncertainty and the lower panel gives an example with high uncertainty. See section 3.9.2.**

4 A Framework for Models of Mixed Fisheries

Amongst the various candidate approaches evaluated by the Workshop, only the F^3 model was identified for development towards possible operational use. This approach has a strong theoretical basis and as a result it also provides a framework for further development of models of mixed fisheries. The approach is described in detail here with the intention of documenting the model, providing a framework for further development, and identifying the work needed to make the model operational.

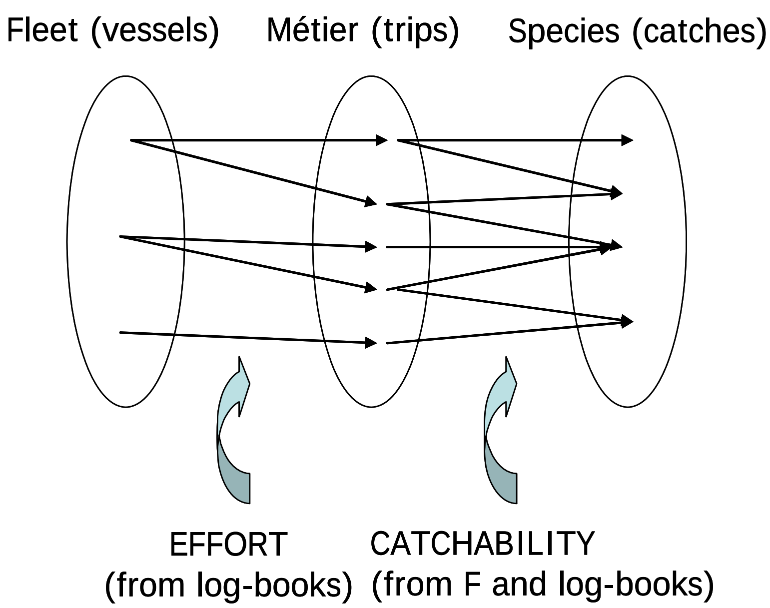
4.1 Fleet and Fisheries Forecast (F^3) Model

4.1.1 Introduction and background

The F^3 method was developed within the larger development of the multifleet multi-species bioeconomic simulation framework TEMAS (DIFRES, unpublished; Marchal *et al.*, 2006), where forecast simulations of stocks and fleets dynamics are performed in order to evaluate the consequences of various management scenarios. This simulation framework is built on the explicit description of fleets' flexibility, allowing vessels within one fleet to share their activity on several métiers. In this regards, various modelling hypotheses were tested, in order to best capture future effort allocation schemes under changing TACs conditions. The F^3 method was developed from these hypotheses.

4.1.2 Principles

The cornerstone of F^3 is to consider the vessel as the basis of manageable unit, and to account for all its trips within each year. Trips are aggregated into homogeneous categories (referred to as métiers), based on consideration of landings profile and/or gear descriptors. Vessels are aggregated into homogeneous fleets, and their average activity patterns are described in terms of percentage of effort spent in the various métiers (see chapter 2.1 on definitions). The metiers are then linked to the stocks (target species and bycatch) through catchability matrices. Activity (proportional effort) matrices by fleet and métiers and catchability matrices by métiers and stocks can be estimated from usual catch and effort databases and F estimates (see figure below)



The basic principle of the F^3 method is to predict the future levels of effort by fleet, knowing catchability and effort distribution by métier and TAC forecast by stock. These effort levels by fleet are thus used to model forecast catches by fleet and stock. Catches can in return be broken into landings and over-quota discards. The required input data are (i) single species assessments and catch forecasts, (ii) observed effort and landings by fleet, métier and stock and (iii) fixed quota shares by fleet and stock. Further information about data requirements is given in Annex 2.

4.1.3 Algorithm

The first two steps aim at estimating partial fishing mortality *F* and catchability *q* by fleet *Fl*, métier *m* and stock *St* from observed landings *LND*, effort *E* and fishing mortality *Ftot* estimates for the past years *Y* :

$$F(Fl,m,St,Y) = Ftot(St,Y) * \frac{LND(Fl,m,St,Y)}{LNDtot(St,Y)} \qquad (1)$$

$$q(Fl,m,St,Y) = F(Fl,m,St,Y) / E(Fl,m,Y) \qquad (2)$$

These data are averaged over a user-defined window of most recent years and used to forecast parameters $\overline{F}(Fl,m,St,Y+1)$ and **Error! Objects cannot be created from editing field codes.** at year *Y+1*.

As a third step, the observed distribution of effort by fleet across métiers is estimated :

$$P(E(Fl,m,Y) = E(Fl,m,Y) / E(Fl,Y) \qquad (3)$$

The forecast effort distribution **Error! Objects cannot be created from editing field codes.**is predicted, either as a average of past observed effort allocation (assuming a conservative fishing behaviour) or by using results of behaviour analyses if available (not detailed here).

The fourth step uses the previous variables for the forecast estimates of catchability by stock for each fleet. This catchability cannot be directly estimated from observed data, as it is linked to the flexibility of the fleet: the "true" catchability being dependent of the métier practised, the resulting catchability by fleet varies with the time spent in each métier. The catchability of a fleet is thus equal to the average catchability by métier weighted by the proportion of effort spent in each métier for the fleet:

$$q(Fl,St,Y+1) = \sum_m \overline{q}(Fl,m,St,Y+1) * \overline{P}(E(Fl,m,Y+1)) \qquad (4)$$

Then the management target by stock (e.g. Fpa) is converted into forecast effort by fleet. This step is rather hypothetical, in that it introduces the concept of "Stock dependent fleet effort". The "stock-dependent fleet effort" is the effort corresponding to a certain partial fishing mortality on a given stock, disregarding all other activities of the fleet. The total target fishing mortality *Ftarget(St)* is first divided across fleet segments (partial fishing mortalities) through coefficients of relative fishing mortality by fleet. These coefficients are fixed quota shares estimated from observed landings, reflecting the rigid sharing rules applied within the principle of relative stability and national processes of quota allocation across fleets (alternatively, mean proportions of landings between fleets could be used). These partial fishing mortalities are subsequently used for estimating the stock-dependent fleet effort:

$$F(Fl,St,Y+1) = Ftarget(St,Y+1)*QuotaShare(Fl,St)$$
$$E(Fl,St,Y+1) = F(Fl,St,Y+1)/q(Fl,St,Y+1) \qquad (5)$$

Then the final effort by fleet and fishery across species is decided upon. It is unlikely that the effort corresponding to each single-species TAC is the same across species, and the resulting effort is therefore a management choice. Under the current management regime, we assume that the resulting effort is set at the maximum across stock-dependent effort by fleet (a bounding upper limit can be decided). The underlying hypothesis is that fishermen continue fishing until the last quota is exhausted. Over quota catches of species which quota were exhausted before this last one, are discarded.

$$E(Fl,Y+1) = MAX_{St}[E(Fl,St1,Y+1),E(Fl,St2,Y+1),...] \qquad (6)$$

Changes in management regimes could for instance state that all stocks should be exploited at or under the management target, and that the fleets should set their effort at the minimum across stocks. In this case the fleet would stop fishing when the first quota is exhausted.

Finally, in the fifth and last step forecast effort by fleet is distributed across métiers, and fishing mortality, landings and over-quota discards by fleet and métier are estimated :

$$E(Fl,m,Y+1) = E(Fl,Y+1)*\overline{P}(E(Fl,m,Y+1)$$
$$F(Fl,m,St,Y+1) = \overline{q}(Fl,m,St,Y+1)*E(Fl,m,Y+1)$$
$$Catch(Fl,m,St,Y+1) = TAC(St,Y+1)*F(Fl,m,St,Y+1)/F\text{target}(St,Y+1)$$
$$Catch(Fl,St,Y+1) = \sum_m Catch(Fl,m,St,Y+1)$$
$$\begin{cases} if\ \_Catch(Fl,St,Y+1) >= TAC(St,Y+1)*QuotaShare\ (Fl,St)\_then \\ LND(Fl,St,Y+1) = TAC(St,Y+1)*QuotaShare\ (Fl,St)\_else \\ LND(Fl,St,Y+1) = Catch(Fl,St,Y+1) \end{cases}$$
$$\begin{cases} if\ \_Catch(Fl,St,Y+1) >= TAC(St,Y+1)*QuotaShare\ (Fl,St)\_then \\ DISC(Fl,St,Y+1) = Catch(Fl,St,Y+1) - LND(Fl,St,Y+1)\_else \\ DISC(Fl,St,Y+1) = 0 \end{cases}$$

(7)

Further explanation is given in an Excel demo sheet in Figure 4.1. This is also available from ICES.

4.1.4 Development and Testing Required for Model to Become Operational

It was decided to categorize further development into three priorities to do:

1. High priority with a deadline of 30 January 2006 (ICES AMAWGC meeting)

- The R-script to be finalised

- To set up a trial database for the North Sea Flatfish based on the latest TECTAC results, which consist of pre-defined fisheries/metiers by different countries, taken from single vessel-trips for the period 2000-2004. (Belgium, Denmark, UK, The Netherlands). These data should include landings per species for the main species sole and plaice by fishery/metier as well as the effort associated in KWdays.

Detailed adaptations to the R-script and output:

- In a first attempt of computation it was decided to give only two management decision options (e.g. max effort and min effort for the combined fisheries/metiers).
- Standard outputs should be delivered in csv-files
- Output plots and tables should consist of:
  - a) check plot by fleet: window panel by selected fleet and selected stocks with time trends (input plus forecast for effort, F and landings by species)
  - b) Check plot by stock : window panel by stock with time trends of catches and/or landings and/or discards
  - c) Output table by fleet with effort and catches (or landings?) by stock
  - d) Over-quota discard estimates by fleet and stock
  - e) Comparison of various management options (effort by fleet)
- To test the R-script before the 30th of January 2006 with the data mentioned above so that a preliminary demonstration-version is available for the AMAWGC meeting.

2. Medium priority depending on the outcome of the AMAWGC meeting to:

- Check how things work with different kinds of data, including test runs with real data sets
- How to handle different cases of missing data
- Improve robustness and usability
- Documenting the model and providing example datasets and outputs

3. Low priority

- Future development – tuning of effort allocation (probably integration with another programme core), age-based disaggregation of catch forecasts
- Translate it into FLR objects and functions.

4.1.5 Further development

A further advantage of the approach is that while its basic form is numerically straightforward, the framework allows for scope for development of more sophisticated models of each process. In its simplest form, no modelling of fishermen behaviour and effort allocation is used, and the model is simply based on the assumption of fixed activity patterns. While some progress has been made in the understanding of the behaviour process (e.g. Marchal *et al.*, 2006) much work is still necessary to increase the scientific basis underlying this aspect of mixed-fisheries forecasts.

FCUBE (Fleet and Fisheries Forecast)

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CREDITS:	DIFRES Management section
LAST MODIFI	12/01/2006 WKMIXMAN

INPUT DATA - STOCK

	TOT_LND	TOT_LND	TOT_LNI	TAC Y+1
SP_A	100,000	80,000	50,000	40,000
SP_B	30,000	50,000	40,000	60,000

RELATIVE STABILITY - COUNTRY AND FLEET SHARE

	C1 - FL1.1	C1 - FL1.2	C2 - FL2.1	C2 . FL2.2
SP_A	0.25	0.25	0.25	0.25
SP_B	0.4	0.2	0.3	0.1

	TOT_F Y-	TOT_F Y-1	TOT_F Y	F Y+1
SP_A	0.6	0.5	0.7	0.6
SP_B	0.8	0.9	0.7	0.8

INPUT DATA FLEETS

Countr	Fleet	Metier	EFFORT	EFFORT	EFFORT Y	LND SP_A	LND SP_A	LND SP_A Y	LND SP_B Y	LND SP_B Y	LND SP_B Y
C1	FL1.1	MET1.1.1	50	60	40	10000	7000	2500	6000	12000	9000
		MET1.1.2	250	240	260	15000	13000	10000	6000	8000	7000
	FL1.2	MET1.2.1	130	100	70	12500	10000	7000	2000	5000	3000
		MET1.2.2	180	200	210	12500	10000	5500	4000	5000	5000
C2	FL2.1	MET2.1.1	140	140	140	20000	15000	10000	9000	15000	12000
		MET2.1.2	140	140	140	5000	5000	2500	0	0	0
	FL2.2	MET2.2.1	280	300	250	25000	20000	12500	1000	2000	1000
		MET2.2.2	20	20	60	0	0	0	2000	3000	3000

CALCULATIONS

STEP 1 : PARTIAL F BY METI

$$F(SP_k, Y-i) = TOT\_F(SP_k, Y-i) \cdot \frac{LND(FL, MET, SP_k, Y-i)}{TOT\_LND(SP_k, Y-i)} \qquad i = 0,1,2\ ; k = A, B$$

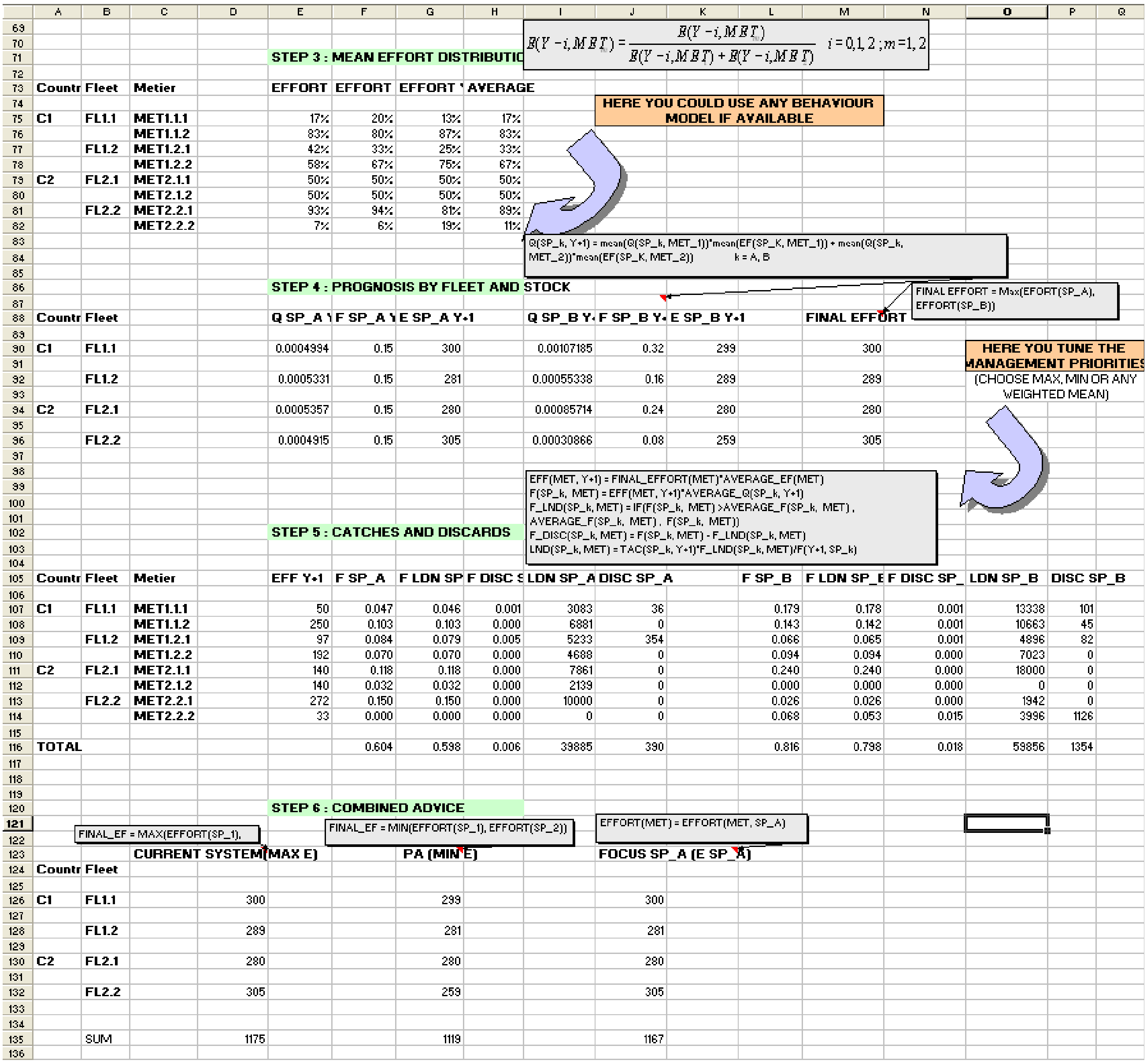
Countr	Fleet	Metier	F SP_A Y	F SP_A Y	F SP_A Y	AVERAGE	F SP_B Y-	F SP_B Y-	F SP_B Y	AVERAGE
C1	FL1.1	MET1.1.1	0.060	0.044	0.035	0.046	0.160	0.216	0.158	0.178
		MET1.1.2	0.090	0.081	0.140	0.104	0.160	0.144	0.123	0.142
	FL1.2	MET1.2.1	0.075	0.063	0.098	0.079	0.053	0.090	0.053	0.065
		MET1.2.2	0.075	0.063	0.077	0.072	0.107	0.090	0.088	0.095
C2	FL2.1	MET2.1.1	0.120	0.094	0.140	0.118	0.240	0.270	0.210	0.240
		MET2.1.2	0.030	0.031	0.035	0.032	0.000	0.000	0.000	0.000
	FL2.2	MET2.2.1	0.150	0.125	0.175	0.150	0.027	0.036	0.018	0.027
		MET2.2.2	0.000	0.000	0.000	0.000	0.053	0.054	0.053	0.053

STEP 2 : CATCHABILITY BY I

$$Q(SP_k, Y-i) = \frac{F(FL, MET, SP_k, Y-i)}{E(FL, MET, Y-i)} \qquad i = 0,1,2$$

Countr	Fleet	Metier	Q SP_A Y	Q SP_A Y	Q SP_A Y	AVERAGE	Q SP_B Y-	Q SP_B Y-	Q SP_B Y	AVERAGE
C1	FL1.1	MET1.1.1	0.00120	0.00073	0.00088	0.00093	0.00320	0.00360	0.00394	0.00358
		MET1.1.2	0.00036	0.00034	0.00054	0.00041	0.00064	0.00060	0.00047	0.00057
	FL1.2	MET1.2.1	0.00058	0.00063	0.00140	0.00087	0.00041	0.00090	0.00075	0.00069
		MET1.2.2	0.00042	0.00031	0.00037	0.00037	0.00059	0.00045	0.00042	0.00049
C2	FL2.1	MET2.1.1	0.00086	0.00067	0.00100	0.00084	0.00171	0.00193	0.00150	0.00171
		MET2.1.2	0.00021	0.00022	0.00025	0.00023	0.00000	0.00000	0.00000	0.00000
	FL2.2	MET2.2.1	0.00054	0.00042	0.00070	0.00055	0.00010	0.00012	0.00007	0.00010
		MET2.2.2	0.00000	0.00000	0.00000	0.00000	0.00267	0.00270	0.00088	0.00208

Figure 4.1 Excel worksheet for F-cube model



$$E(Y-i,MET_m)=\frac{E(Y-i,MET_m)}{E(Y-i,MET_1)+E(Y-i,MET_2)}\quad i=0,1,2\,;m=1,2$$

STEP 3 : MEAN EFFORT DISTRIBUTIC

HERE YOU COULD USE ANY BEHAVIOUR MODEL IF AVAILABLE

Countr	Fleet	Metier	EFFORT	EFFORT	EFFORT '	AVERAGE
C1	FL1.1	MET1.1.1	17%	20%	13%	17%
		MET1.1.2	83%	80%	87%	83%
	FL1.2	MET1.2.1	42%	33%	25%	33%
		MET1.2.2	58%	67%	75%	67%
C2	FL2.1	MET2.1.1	50%	50%	50%	50%
		MET2.1.2	50%	50%	50%	50%
	FL2.2	MET2.2.1	93%	94%	81%	89%
		MET2.2.2	7%	6%	19%	11%

Q(SP_k, Y+1) = mean(Q(SP_k, MET_1))*mean(EF(SP_K, MET_1)) + mean(Q(SP_k, MET_2))*mean(EF(SP_K, MET_2)) k = A, B

STEP 4 : PROGNOSIS BY FLEET AND STOCK

FINAL EFFORT = Max(EFORT(SP_A), EFFORT(SP_B))

Countr	Fleet	Q SP_A Y	F SP_A Y	E SP_A Y+1	Q SP_B Y+	F SP_B Y+	E SP_B Y+1	FINAL EFFORT
C1	FL1.1	0.0004994	0.15	300	0.00107185	0.32	299	300
	FL1.2	0.0005331	0.15	281	0.00055338	0.16	289	289
C2	FL2.1	0.0005357	0.15	280	0.00085714	0.24	280	280
	FL2.2	0.0004915	0.15	305	0.00030866	0.08	259	305

HERE YOU TUNE THE MANAGEMENT PRIORITIES (CHOOSE MAX, MIN OR ANY WEIGHTED MEAN)

EFF(MET, Y+1) = FINAL_EFFORT(MET)*AVERAGE_EF(MET)
F(SP_k, MET) = EFF(MET, Y+1)*AVERAGE_Q(SP_k, Y+1)
F_LND(SP_k, MET) = IF(F(SP_k, MET) >AVERAGE_F(SP_k, MET) , AVERAGE_F(SP_k, MET) , F(SP_k, MET))
F_DISC(SP_k, MET) = F(SP_k, MET) - F_LND(SP_k, MET)
LND(SP_k, MET) = TAC(SP_k, Y+1)*F_LND(SP_k, MET)/F(Y+1, SP_k)

STEP 5 : CATCHES AND DISCARDS

Countr	Fleet	Metier	EFF Y+1	F SP_A	F LDN SP	F DISC S	LDN SP_A	DISC SP_A	F SP_B	F LDN SP_E	F DISC SP_	LDN SP_B	DISC SP_B
C1	FL1.1	MET1.1.1	50	0.047	0.046	0.001	3083	36	0.179	0.178	0.001	13338	101
		MET1.1.2	250	0.103	0.103	0.000	6881	0	0.143	0.142	0.001	10663	45
	FL1.2	MET1.2.1	97	0.084	0.079	0.005	5233	354	0.066	0.065	0.001	4896	82
		MET1.2.2	192	0.070	0.070	0.000	4688	0	0.094	0.094	0.000	7023	0
C2	FL2.1	MET2.1.1	140	0.118	0.118	0.000	7861	0	0.240	0.240	0.000	18000	0
		MET2.1.2	140	0.032	0.032	0.000	2139	0	0.000	0.000	0.000	0	0
	FL2.2	MET2.2.1	272	0.150	0.150	0.000	10000	0	0.026	0.026	0.000	1942	0
		MET2.2.2	33	0.000	0.000	0.000	0	0	0.068	0.053	0.015	3996	1126
TOTAL				0.604	0.598	0.006	39885	390	0.816	0.798	0.018	59856	1354

STEP 6 : COMBINED ADVICE

FINAL_EF = MAX(EFFORT(SP_1),

FINAL_EF = MIN(EFFORT(SP_1), EFFORT(SP_2))

EFFORT(MET) = EFFORT(MET, SP_A)

Countr	Fleet	CURRENT SYSTEM (MAX E)	PA (MIN E)	FOCUS SP_A (E SP_A)
C1	FL1.1	300	299	300
	FL1.2	289	281	281
C2	FL2.1	280	280	280
	FL2.2	305	259	305
	SUM	1175	1119	1167

Figure 4.1 (cont.)

5 Operational Guidelines

The further development of mixed fishery approaches can be interpreted as a first step towards an approach to giving advice on a fishery- and/or fleet-basis rather than a stock basis. Such a shift would have a number of implications for the data needs and operation of assessment Working Groups, and also for management. These are considered below with particular reference to data requirements and presentation and the need for input from managers. Presentation and visualisation of data is an important precursor to any modelling approach and this should form part of any fishery-based approach. This is also considered below, together with a number of example graphs. Problems encountered in incorporating mixed-fishery approaches into the existing Working Group structure are also described with reference to how these might be resolved in future.

5.1 Data Requirements

- Fleet/fishery approaches require disaggregation of catch and effort data into more homogeneous fleets and fisheries.
- Much of this additional trip-level data is already available, reflecting the stratification of existing sampling schemes. However, additional analyses may be required to resolve the problems of accounting for all effort for each fleet (i.e. including trips in other areas – see Annex 2).
- There is a need to ensure consistency between the aggregated data used in the stock assessments and the disaggregated data used in any mixed fishery analyses.
- Consistency between nations in terms of definition of fleets/fisheries is also desirable.
- The presentation of these data should form part of ‘fishery assessments’ where trends and developments in the fleets/fisheries are described in a manner analogous to the stock trends obtained from a stock assessment.
- A further desirable feature would be to obtain and present data on a spatial/temporal basis to highlight when and where mixed fishery problems are most and least pronounced.
- The InterCatch database is a system that is under development for assembling fish stock assessment data at the ICES working group level (Jansen *et al*, 2005). The system is currently mainly directed at assembling catch-at-age/catch-at-length data from the fleet/fishery level to the total international level. At present the InterCatch database does not store fleet/fishery based information with a high spatial resolution (although in theory this could be added in the database, this could generate substantial consistency problems). The WKMIXMAN therefore **recommends** to develop a downscaled version of the InterCatch system that is specifically devoted to storing high resolution space/time information for different catch components (landings, discards, industrial bycatch, misreporting). This information will not be subdivided into ages or lengths and will be used to generate space/time maps of changes in fleet/fishery distributions and their associated catch components.

5.2 Input from managers

- Any shift to providing advice more tailored to fleets/fisheries than stocks will require clear inputs from managers on the unit (e.g. stock, fleet or fishery) for which they require advice.
- Any approach to providing advice consistent across multiple species in the same fishery will require input from managers on the relative priorities to be assigned to each species.

5.3 Visualizing mixed fisheries data

Visualizing data is an important step before any modelling takes place. In the case of mixed fisheries data, this step is probably even more important because the data have many dimensions and the intricacies are difficult to grasp from a database or a table. Therefore, we propose to develop a number of basic descriptive graphs that will allow an interpretation of the data from two different angles:

- Viewed from a species
- Viewed from a fleet/fishery

It is important that métiers are nested within fleets so that they can be collapsed if necessary. Two types of variable need to be analysed:

- Catch components (e.g. landings, discards, industrial bycatch, misreporting)
- Effort

If spatial and/or seasonal data are available it may also be useful to represent these aspects.

When presenting an overview of mixed fisheries data, it is important to determine how representative the data sources are:

- Are all major fleets and fisheries covered? How to deal with missing strata (interpolating?)
- Are all the catch components, including misreporting, covered?
- How is incomplete coverage likely to affect the data that are presented ?

Examples of data visualization are given on the following pages:

- Figure 5.1 graphs of catch compositions by gear in a certain year.
- Figure 5.2 spatial distribution of landings, effort and CPUE of a fleet in a certain year.
- Figure 5.3 time trend of fishing effort of a fleet separated into different engine size classes.
- Figure 5.4 time and space trends in fishing effort of a fleet. These can be used to document any changes in fishing patterns that are thought to exist.

Note that these examples are not intended to be prescriptive. The main purpose of the visualizations is to get to know different aspects of the mixed fisheries data. The graphs can also be used to demonstrate changes in fishing behaviour over time, space or species compositions. This information can be used in the further analysis of trends in the stocks.

5.4 The Mixed-fisheries Approach in the Work Process of ICES Assessment Working Groups

After the theoretical aspects of the mixed-fisheries approach were discussed and established in SGDFF, its practical aspects were assumed by the respective assessment working groups. Some points can be drawn from experience gained over the last three years:

- Integration of mixed-fisheries approach into the assessment WG’s agenda:
    - Lack of specific coordinators: Not all assessment groups have members who are familiar with the mixed-fisheries approach.
    - Lack of clear mixed-fisheries guidelines: given the lack of mixed-fisheries coordinators, some WG chairpersons decide not to carry out any mixed-fisheries forecast, and give priority to other tasks, especially when the group is overloaded with new working lines.

- Out of step work: the mixed-fisheries inputs needed to set scenarios for forecasting are obtained as outputs from the single-stock assessments which are typically not available before the middle of the meeting. This fact delays the mixed-fisheries analyses to the last part of the meeting with the risk of not having enough time.
- Distribution of species by WG: some stocks caught together by the same fleet are assessed in different WGs. E.g. in some cases fleets catch both demersal and pelagic species together.
- Out of step single- and mixed- models: when the stocks of a mixed-fisheries forecast are assessed by different single-stock assessment models it is possible the mixed-fisheries model could get different kind of inputs, some of which do not observe the mixed-fisheries models constraints (stocks assessed by production models, stocks without age-structured data…).
- Data compilation: frequently the fleet units used in the single-stock assessment WGs are different to those required by a mixed-fisheries forecast, forcing a "re-compilation" of the data under different criteria during the meeting.

○ Mixed-species definition: Stock distribution: the geographical distribution of stocks is not always coincident (eg. Northern hake covers a wider area than Northern stocks of megrim and monk and FUs of *Nephrops* in the area).

○ Interaction between STECF-ICES WGs: ICES and STECF have tried to achieve the same objective separately. That has sometimes resulted in duplication of work when different specialists were asked to do the same work under different criteria or with different inputs.

5.4.1 The implications of mixed-fishery approaches for the work of ICES

Regional Assessment Working Groups have been set up in the past so that they could deal with mixed fisheries aspects. So far this has been with limited success, as indicated above. In order to advance the evaluations of developments in fisheries, the first step is that Assessment Working Groups prepare and evaluate mixed fisheries data and devote sufficient time and expertise to this issue. The compilation and evaluation of mixed fisheries data could be dealt with before and without final assessments being available.

The issue of mixed fisheries forecasting is a separate issue from mixed fisheries data. Because assessments are currently only available towards the end of the Working Group meetings, it could be considered to establish a mixed fisheries Working group to carry out such forecasts. The timing of a mixed fisheries group is problematic with regards to the timing of the ACFM meeting and the Working Groups delivering analysis to ACFM.

The alternative approach to establishing a dedicated mixed fisheries group, would be to task the regular assessment working groups with carrying out mixed fisheries forecasts. This can only be achieved if the burden of working groups with regards to regular assessment work is reduced (e.g. assessments carried out before the working group meeting).

However, it should be taken into account that as long as there is no agreed methodology to carry out mixed fisheries forecasts, there is a much greater need to develop the methodology than to set up the organization around mixed fisheries forecasts.

5.5 Conclusions

There are a number of linkages between the issues of data requirements, the need for input from managers, data visualisation and the incorporation of the mixed fishery approach into the work of ICES assessment Working Groups.

There is a strong requirement for consistency in the data used by WGs. This includes consistency between the data used in single-species assessments and mixed-species approaches; consistency between the fleets and fisheries defined by different nations fishing in the same area; consistency between the fleet definitions and national sampling programmes, and consistency between the fleet/fishery definitions and the level at which advice is required by managers. The units for management advice and the extent to which these are reflected in sampling programmes is perhaps the key issue, and illustrates the need for dialogue with managers and the bodies funding national sampling.

The incorporation of mixed-fishery approaches into the ICES work is likely to have implications for the work of both ICES and the assessment WGs. Within the WGs this might involve changing the emphasis away from individual stock assessments more towards 'fishery assessments', but this issue needs to be discussed more fully by other groups such as AMAWGC and ACFM. One of the core problems in addressing mixed fishery problems is the need for software which is able to compile and aggregate data to the required level. The ICES InterCatch database (Jansen *et al.*, 2005) should be able to fulfil this requirement, but it would be desirable that it, or a version of it, would also be able to handle the spatial aspects of mixed-fishery data

There is an important distinction between mixed fishery data and mixed-fishery forecasts. In circumstances when it may not be possible to run forecasts for various good reasons, it should still be possible to present the available mixed-fishery data in order to illustrate the extent and nature of the technical interactions in the fisheries of interest.

5.6 Proposal

We recommend that the WKMIXMAN have another meeting in 2007 to:

- further develop the visualization and analysis of mixed fisheries data
- further develop the methodology to carry out mixed fisheries forecasts
- apply visualizations and forecasts to a number of case studies.

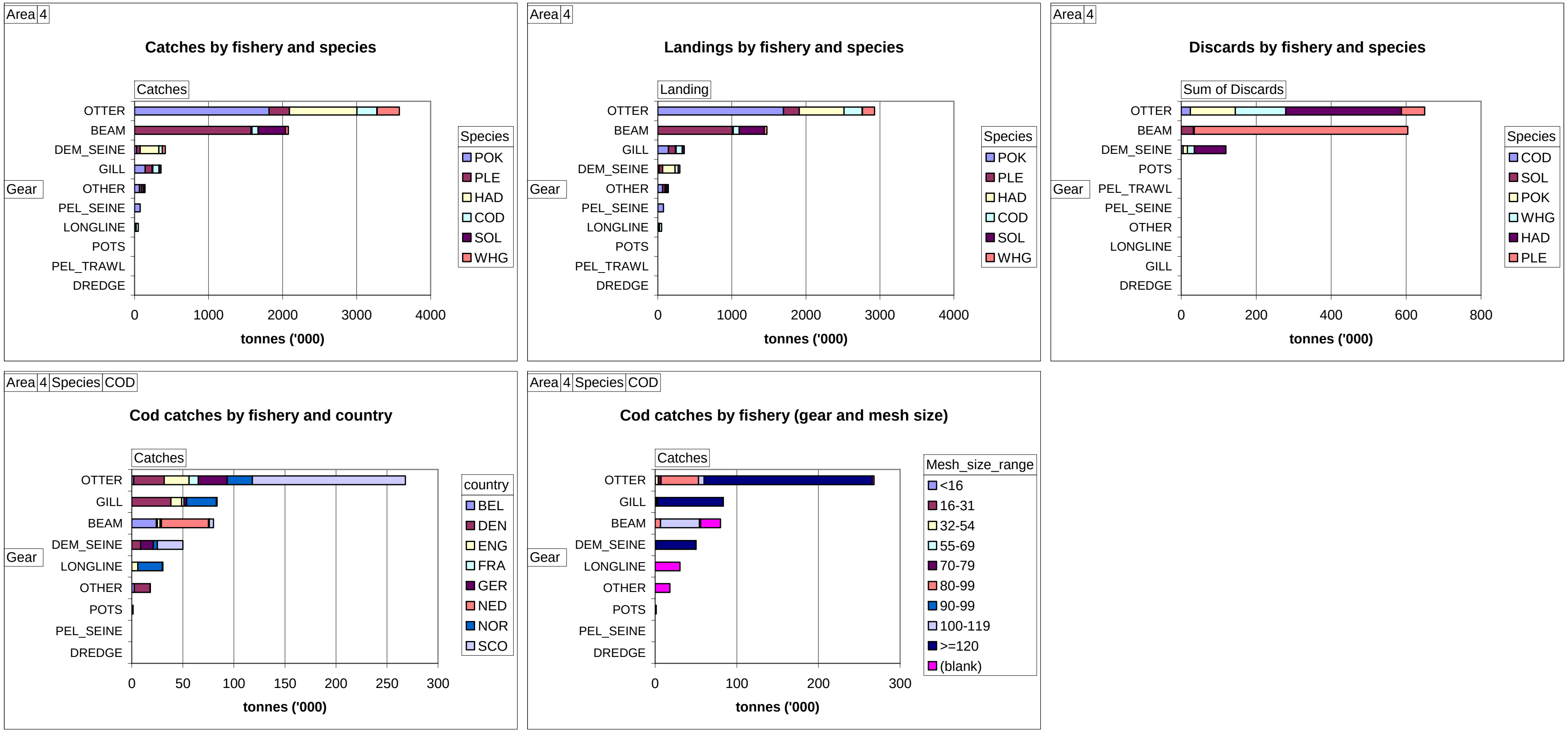


Figure 5.1. Catch compositions of North Sea fisheries by gear and species (top) and catches of cod in the North Sea by fishery and country (bottom left) and by fishery (gear and mesh size).

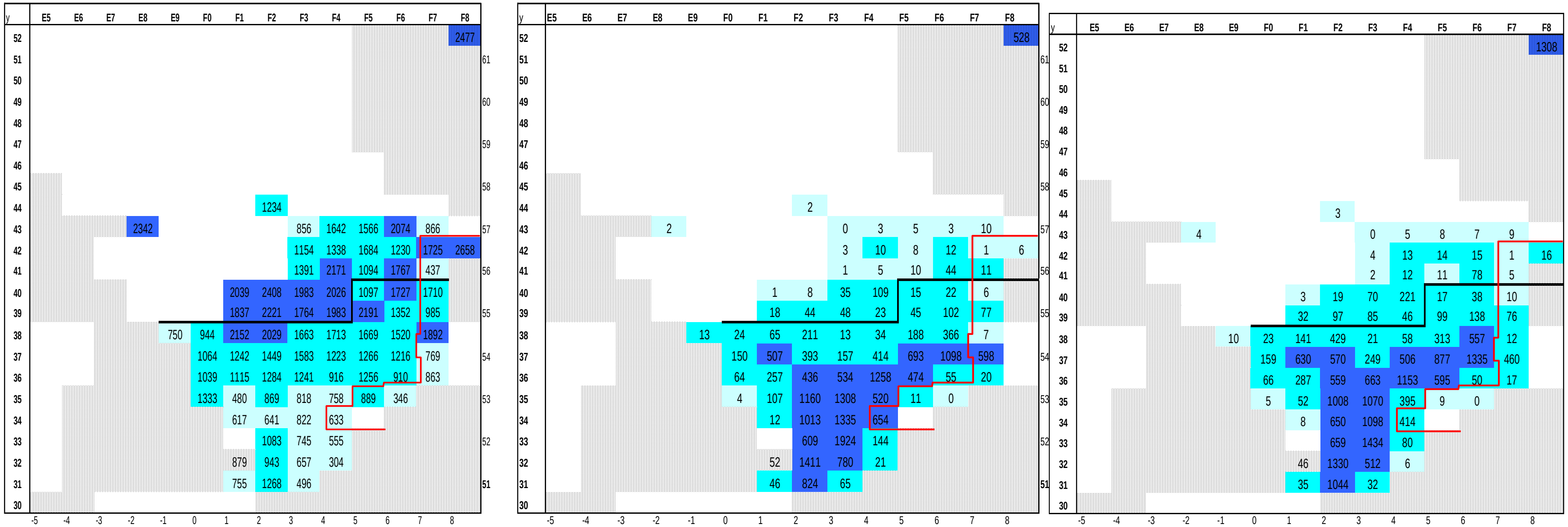


Figure 5.2 North Sea plaice and the Dutch beamtrawl fleet (vessels > 300 Hp) in 2004. Spatial distributions of landings (left), effort (middle) and CPUE (right) by ICES rectangle based on official logbook data. Discards are not included.

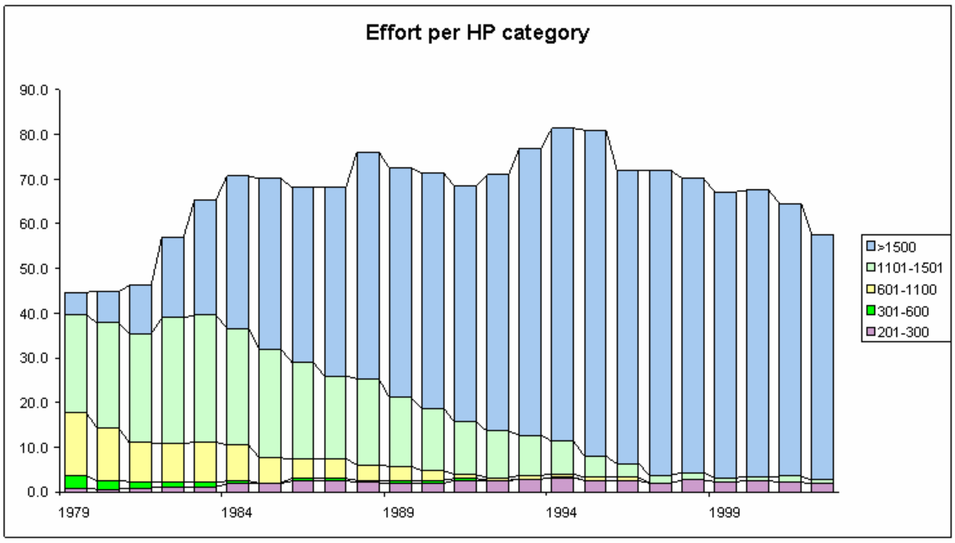


Figure 5.3 **Time trend in fishing effort (million HP days) of the Dutch beamtrawl fleet separated by engine size class**

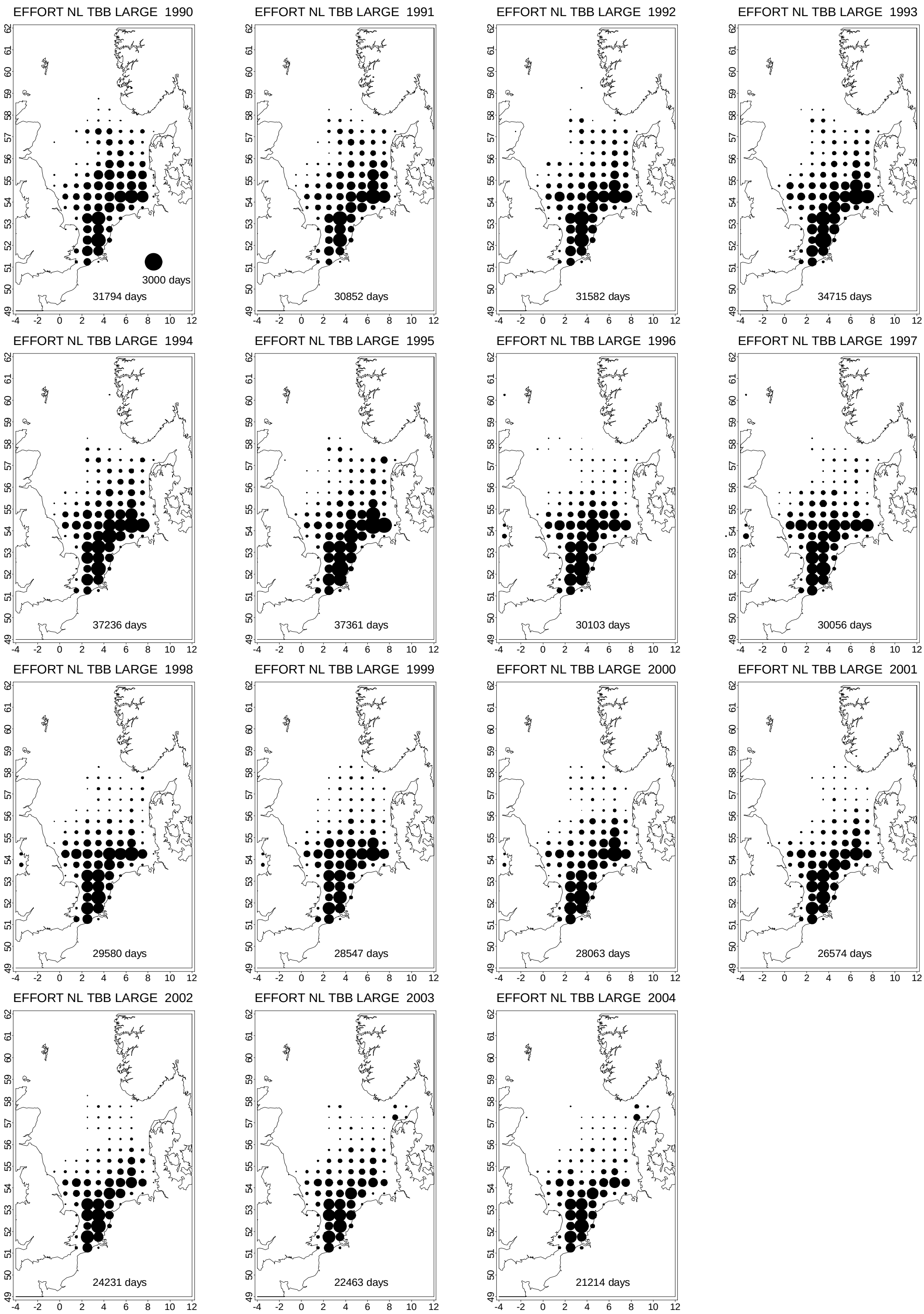


Figure 5.4 Dutch beamtrawl fleet (vessels with engine power > 300 Hp). Time and space trends in fishing effort

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Annex 2: Defining fleets and fisheries, and the "OTH" category

The following text is copied from guidance provided by Denmark to other North Sea partners institutes during the TECTAC project, in order to fulfil data requirements for simulation modelling:

The inclusion of all sources of fishing mortality for the stocks of interest in the one hand, and of all effort and sources of revenues for the fleets of interest in the other hand, is a tricky issue. In the case of the NS flatfish case study for example, it is particularly acute for the Danish fleets, given the flexibility of vessels coming from remote areas (Kattegat, Baltic) and fishing only few trips a year in the North Sea, or conversely most North Sea fleets sharing their activity between flatfish, roundfish, *Nephrops*, industrial species and also other areas. It is important to keep as much as possible of the observed diversity of vessels and fisheries, but without having too many categories for keeping the model manageable. The final proposal for Danish fleets and fisheries was a long and not straightforward trial-error process. Here are some of the guidance we agreed upon and which might be useful for other countries :

- All vessels from the North Sea and spending a consequent part of their time on flatfish fisheries should be explicitly included into the modelled fleets. For example, subsequent analyses were performed by Denmark to decide whether or not to include vessels having homeport located at the edge of the North Sea in the North Sea fleets.
- For these vessels, all fisheries of importance should be defined as such, even the ones with low catchability on flatfish. This is important for modelling the effort allocation, even if the species of interest are not in the model.
- Only the minor fisheries should be gathered into an OTH fishery. As a general rule all "OTH" categories should be desirably smaller than the explicit categories (this is not always the case, especially if cod is not explicitly included in the model).
- The vessels spending only a limited amount of time on North Sea flatfish fisheries ("external vessels") should not be explicit in the model, because we do not bother about their dynamics and costs. However their effort is important for the dynamics of the stocks, as they have non nul fishing mortality. In these cases, we should only consider the total amount of effort spent by these vessels in the NS flatfish fisheries, and not the true number of vessels it represents. The OTH fleet will then be constructed as a theoretical fleet. For example, if the total effort from these external vessels sums up to 300 days in Plaice Gillnetting, 600 days of demersal trawling and 100 days of beam trawling, the OTH fleet could be entered in the model as a fleet spending 30% of its time gillnetting, 60% trawling and 10% beam trawling, and corresponding to 5 vessels fishing on average 200 days per year. In this way, the OTH fleet will be treated as any other, except that it will be given fixed rules of effort allocation and that we will not bother about setting reliable costs parameters.
- Here again, it is important that the OTH fleet is kept small compared to the North Sea fleets. And if the total effort of external boats on the various fisheries is dependent of the vessel size, we might consider dividing the OTH fleet in several size categories.