COMMISSION OF THE EUROPEAN COMMUNITIES

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COMMISSION STAFF WORKING PAPER

REPORT OF

The Joint SGECA - SGRST sub-group meeting on

bio-economic modelling

Ispra
4-6 October 2005 and
7 – 9 March 2006

This report has been evaluated by the STECF at its November 2005 and its April 2006 Plenary Meeting

This report does not necessarily reflect the view of the European Commission and in no way anticipates the Commission's future policy in this area

STECF comments on the report of the Sub-group on bioeconomic models (SGECA-SGRST-05-01): propose a way forward for bio-economic modelling in the EU (STECF Plenary November 2005)

STECF was asked the following:

The recent subgroup meeting SGECA-SGRST-05-01, assessed bio-economic models, their data requirements and ongoing projects. Based on the outcome of this meeting STECF should propose how better bio-economic advice can be delivered in the future.

Background

STECF decided in 2003 to organize a series of subgroup meetings with the purpose of investigating the availability of bio-economic models, which could be used to support the advice of STECF on fisheries management. Firstly, a joint subgroup of SGECA and SGRST was asked to review the EIAA model, which is used to assess the economic repercussions of the ACFM advice i.e. fisheries that are subject to quota management. Secondly, a subgroup for Mediterranean fisheries should review models appropriate for economic assessment of fisheries not subject to quota management. Thirdly, the joint SGECA-SGRST subgroup was asked to review available models in a broader context. The meetings should be accomplished during 2004 and 2005.

The subgroup meeting about the EIAA review was held in June 2004, while the meeting in October 2005 addressed models in a broader context including models for fisheries in the Mediterranean Sea.

Further more, STECF emphasized that the review of the models should focus on the operationality of the models with respect to the needs of the Common Fisheries Policy in terms of TAC/quota management and fleet management. The operationality should include availability of data on a continuous basis.

The draft report from the October 2005 meting at Ispra concentrates on compilation of information about the pertinent models and is as such a valuable contribution to the discussion on the models usable for STECF.

Terms of reference for the subgroup

STECF has the following observations related to the terms of reference and the draft report.

Item 1. Objectives and methodologies of the bio-economic advice

1. Critically review the methodology of the bio-economic advice as it has been carried out in the CA and give adjusted methodologies.

The report notes that the EIAA model developed in the CA is a useful tool for short-term projections of the TAC/quota advice given by the ACFM and review by SGRST. The model is restricted by output in terms of TAC/quotas, and calculates the derived costs. Over the recent years input restrictions in terms of sea days have become still more binding, and it would be a useful development to include this restriction in the model. Further, it is considered useful to carry out projections that include in a more explicit way the impact of oil price increases (or other important price or cost changes). Finally, it is pointed out that the impact of resource rent should be considered, and how this issue could be developed.

2. Set out methodologies for the bio-economic advice in case of no stock assessments are available

The report points out that in most cases some stocks are subjected to assessment although the fisheries are not managed by quota restrictions but input restrictions. The bio-economic advice is sustained by input driven models that include a stock component which takes into account assessed stocks as well as stocks not subjected to assessment. These secondary stocks are included either as a function of the assessed stocks by use of time series analyses or by use of surplus production models.

It is the opinion of the STECF that models are available, but that reference points for management should be clarified.

3. Make a set of important bio-economic indicators that could be used as the basis of the advice

The report identifies two sets of indicators:

Biological indicators including spawning stock biomass and fishing mortality. These indicators are valued against reference points such as the precautionary principle and the lowest acceptable limit.

Economic indicators including operating profit margin and return on capital showing the economic performance of the fleet segments. These indicators are equally assessed against reference point such as interest rates on financial markets (e.g. interest rate on bonds).

The report touch upon indicators that should combine biology and economics by including resource rent. The report also presents indicators such as capacity utilisation as a useful indicator of the situation of the fishery.

STECF notes that the work finding common indicators for biology and economics needs to be elaborated.

Item 2. Review of types of models used

The report presents the scope of eight models where the causality of the models is that one is developed to be restricted by output mainly (quotas), five are constructed to be restricted mainly by input and two of them was optimisation models restricted by both input and output. These models serve different purposes.

STECF emphasises that it is important to clarify the operationality of the different models. This should require the models chosen to have

- proper documentation,
- software available and
- data available

Item 3. Relevant projects

This item has not yet been addressed by the Sub-group

Item 4. Data requirements

Data requirements are covered under the review of types of models used where it is stated that all the models are capable of running by use of the data prescribed by the data regulation 1639/2001 at least in the extended programme, but many of them requires further data input to be fully exploited.

STECF finds it necessary to detail the data requirements for all the reviewed models.

Item 5. Adjustment of data regulation

The group has highlighted that on one hand consistency over time in the fleet segment is required for making comparisons, but that this segmentation also hides the importance of different gear types, in particular if vessels use many different gear types throughout the year.

STECF emphasises that economic data can only be collected on an annual basis and on a business or vessel level, rather than on a gear perspective. From the economic point of view the prevailing fleet segmentation offers homogenous and applicable groups.

Item 6. Advice procedures and organizational framework

The group distinguishes between regular tasks, ad hoc tasks and strategic long-term tasks. The regular task i.e. the Annual Economic Evaluation of the ICES advice requires a solid structure that can be put quickly into operation, and this would require that the human and financial resources necessary to carry out the work may not (cannot) be secured safely only by relying on ad hoc group meetings.

The ad hoc tasks and strategic long-term tasks are not to the same extent dependent on a solid structure. These tasks require models that include interaction between the fleets and stocks and are able to include various harvest rules and uncertainty.

STECF finds it necessary to reconsider the procedures and organizational framework after finalization of the subgroup report.

General observations and recommendations

In general STECF observes that the draft report is incomplete in addressing the terms of reference of the subgroup. Therefore STECF recommends that the subgroup reconvenes with the purpose of finalizing the submitted report. In particular the emphasis to be put on the elaboration of operational models that produce information which make it possible to assess the situation of the fishery in a combined biological and economic way, i.e. produce common indicators.

STECF recommends that based on the current overview of available models a selection should be made of those models that are at present operational, publishable and do have a specific use for STECF. In addition it is recommended to establish a task force that will for each selected model create a manual on the use and data requirement of the specific model.

Furthermore it is reiterated that the economic data should be made available by the member states in due cause to allow for a proper assessment of the economic situation of the selected fisheries and to enable STECF to assess the economical impact of the proposed TAC/quota regime for the forthcoming year. In order to facilitate this process it is stressed that no later than the first of October the data for the past year should be made available to JRC. JRC will then stage the analysis of the data, resulting in both an assessment of the Economic Situation of selected fishing fleets and, by running the appropriate models, predict future developments.

STECF emphasizes that member states should be in a position to make available to JRC in time data on the economical position of the fishing fleet, preferably based on accounting information, but if not available in time, based on a proper estimate of the situation.

STECF comments on the report of the Sub-group on bioeconomic models (SGECA-SGRST-06-01) (STECF Plenary, Spring 2006)

The STECF Sub group on economic affairs (SGECA) met on 3-7 March, 2006 in Ispra to list operational bio-economic models that could be used by the STECF and to see what further steps would be needed to deliver a user manual and list of data requirements for each model. The terms of reference requested the Sub-group to address the following items:

1. Objectives and methodologies of the bio-economic advice
2. Review of types of models used
3. Relevant projects
4. Data requirements
5. Adjustments of data regulation
6. Advice procedures and organisational framework
7. Finalize the report with regard to ToR of the 1st meeting (items 1-6 above)
8. Setting up a task force

Based on the outcome of this meeting, STECF was asked to provide an opinion on the completeness of the list and to determine whether these models are sufficient to answer the needs of the STECF. The next steps in terms of model documentation, development and assessment should be recommended.

The sub group report includes the following main conclusions:

Identification of models

The sub group report presents the following models as relevant and has classified those according to the type of the model and harvest control rule (HCR) for which it applies. Output driven models are applicable for fisheries managed with quotas while input driven models are applicable to fisheries managed with effort restrictions. Optimisation models are applicable for both input and output restrictions and produce solutions for pre-defined objectives (e.g. maximum employment or maximum profit).

Table 0-1 bioeconomic models

Model	Type of model	Harvest Control Rule
EIAA	Output driven	TAC/quota

TEMAS	Input driven	Sea days, capacity
MOSES	Optimisation/input driven	All
BIRDMOD	Input driven	Sea days, capacity
MEFISTO	Input driven	Sea days, capacity
EMMFID	Optimisation	All
SRRMCF	Optimisation	All
COBAS	Input driven	Sea days, capacity
ECONMULT	Input driven	Sea days, capacity

The sub group report includes also a non-exhaustive list of relevant projects and models with regard to bio-economic modelling.

Indicators

The objective of managing the fishing capacity of the EU fleet is to achieve a balance between the capacity and available fishing opportunities. It is how the capacity that exists at a particular time is deployed and the availability of resources at the same time that will achieve the correct balance. This task requires development of suitable bio-economical indicators.

The report points out that the target reference points need to be elaborated. Instead of using exact target points as MSY or MEY, the report proposes the use of biological reference limits. Economic indicators such as resource rent and the value of the stock biomass should supplement these reference limits.

Type of advice and model selection

The report identifies different kinds of advice needed:

1. Regular tasks (e.g. annual TAC/quota decisions and effort restrictions)
2. Ad hoc tasks (e.g. impact of technical measures)
3. Long term strategic tasks (e.g. long term management objectives and reference targets)

For these different kinds of questions, different kinds of analysis and models are required. The sub group report introduces a selection of models that could be applicable for either calculation of consequences, simulation or optimisation.

Table 0-2 models suitable for different types of advice

HCR	Approach	Model candidate
1. TAC/quota or F	Output driven	EIAA
2. Days at sea and/or capacity	Input driven	MEFISTO and BIRDMOD
3. TAC/quota and sea days and capacity	Optimisation	EMMFID and SRRMCF

The sub group has identified three approaches to accomplish economic evaluations according to different kinds of HCR: a) TAC/quotas, b) effort restrictions, c) combinations of those above.

Task force and criteria for manual

STECF recommended (STECF 21st meeting, November 2005) establishing a task force to, for each selected model, compile a manual on the use and data requirement of the specific model. The report describes a detailed requirement for manual for each selected model. The aim of this work is to make models more broadly accessible and thereby increase the transparency, development and applicability to improve the ground for better advice.

STECF considerations and recommendations

STECF notes that the sub group has adequately addressed its terms of reference properly and endorses the findings of the report. STECF was informed by the Commission that the need for economic information is increasing as also stated in Council Regulation 2371/2002[1], Article 14, and Commission Regulation 1438/2003[2], Article 12. In this respect bio-economic models and the development thereof is of utmost importance. The models presented in the sub group report are considered useful instruments in answering questions related fisheries management in bioeconomic framework i.e. managing the fishing capacity of the EU fleet is to achieve a balance between the capacity and available fishing opportunities. STECF also notes that the sub group report refers to ongoing EU-funded projects such as EFIMAS and COMMIT that are developing and testing a new modelling platform. The results of the above mentioned task force work could be utilised on this platform.

STECF recommends that the Commission set up appropriate task forces to provide documentation for each model according to the guidelines given in the Report of the Subgroup on Bioeconomic models (SGECA 06-01). Such documentation should contain the following items:

1. Model language
2. Model objective and scope
3. Type of advice and time range (simulation, static comparative, optimisation)
4. Model overview - diagram
5. Full specification of the equations of the model
6. Full specification of the variables of the model
7. Full list of the parameters of the model (including parameter values)
8. Data requirements to initialise the model; i.e. a complete list of indicators
9. Required time to run the model, to produce and disseminate the advice
10. Format of output of the model
11. Procedure of how to run the model
12. Where has the model been used, outcome, validation and references
13. Institute and key personnel

[1] Council Regulation (EC) No 2371/2002 (OJ L 358 of 31 December 2002, p.59 -80)
[2] Commission Regulation (EC) No 1438/2003 (*OJ L 204 1 August 2003 p. 21- 29)*

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Introduction

STECF decided in 2003 to organise a series of subgroup meetings with the purpose of investigating the availability of bio-economic models that could be used to support the advice of the STECF about fisheries management.

The subgroup of economics, SGECA, and the subgroup of stock assessment, SGRST, was first asked to review the EIAA model that was used assess economic repercussions of the ACFM advice i.e. fisheries that were subject to quota management. Secondly, the group was asked to review models appropriate for economic assessment of fisheries not subject to quota management i.e. models appropriate for economic assessment of the fisheries in the Mediterranean Sea and adjacent waters. Thirdly, the group was asked to review available models in a broader context. The meetings should be accomplished during 2004 and 2005.

The first subgroup meeting about the EIAA review was held in June 2004, while the present meeting held in October 2005 addressed models in a broader context. Therefore, the present meeting addresses all three areas.

The STECF further emphasised that the review of the models should take into account the operationality of the models with respect to the needs of the Common Fisheries Policy in terms of TAC/quota management and fleet management. The operationality of the model included availability of data on a continuous basis.

The group has held two meetings to conclude to report, in October 2005 and in March 2006. At the first meeting it was not possible to comply fully with the Terms of Reference. A draft report was submitted to the STECF plenary meeting in November 2005. STECF recommended that based on the current overview of available models a selection should be made of those models that are at present operational, publishable and do have a specific use for STECF. And in addition STECF recommended to establish a task force that will for each selected model create a manual on the use and data requirement of the specific model.

Summary

i. The methodology of the bio-economic advice as carried out in the CA

The following models are considered important contributions and, therefore, dealt with in this report. The models are listed below to provide the reader with an overview of the models:

1. EIAA: Economic Interpretation of ACFM Advice
2. TEMAS: Bio-economic model to assess the effect of technical management measures
3. MOSES: Bio-economic models for Mediterranean fisheries
4. BIRDMOD: Methodological Support for a Bio-Economic Model of Population Analysis of Demersal Resources
5. MEFISTO: MEditerranean FISheries Tool
6. EMMFID: Economic Management Model of Fisheries In Denmark
7. SRRMCF: Swedish Resource Rent Model for Commercial Fishery
8. COBAS: A dynamic bio-economic model of the fisheries of the South-West to determine the costs and benefits of sustainable fisheries management
9. ECONMULT: Bio-economic multispecies models of the Barents Sea fisheries

Further, in chapter 3 a non-exhaustive list of relevant projects and models with regard to bioeconomic modelling is included.

The EIAA model (Economic Interpretation of ACFM Advice) has been built to assess the economic consequences of the TAC proposals formulated by ACFM by making. This will be done using data collected and disseminated in the annual economic reports (AER) produced by the Concerted Action EAEF.

The data collection of the EAEF was consistent with the requirements of the Data Regulation (1639/2001). The economic data collated and collected as part of this programme was designed to be done annually, covering the fleets defined. For a modelling approach that is updated annually, it is essential to establish and maintain consistency over time in both the fleet definitions, and the collection of related economic data. Also the most recent economic cost information for fleets must be available for implementation in the model.

ICES assess quotas and stocks on a yearly basis for a number of species. For the EIAA model, the status of quotas and stocks resulting from these assessments are available in October in time for use of the EIAA model. The most recent costs and earnings data are also available in October. Therefore, the key data applied in the EIAA model is the most recent information and must continue to be so if advice should be given to the STECF plenary meeting in November.

For other parameters used in the EIAA model, such as price and stock variability, the use of the most recent information may not be as important. One of the strengths of the EIAA model that it is an implementation that can be run quickly and that works robustly under scenarios of structural stability with respect to fleets and stocks.

The TACs are the only restrictions used in the current EIAA model to predict the economic performance of the fleet. However, for some of the European fleets, sea day restrictions have been used for some years. In cases where these input regulations become more restrictive for the fishing opportunities than the quota, the current EIAA model will overestimate the catches and the effort, and thereby overestimate the economic performance. In order to solve this problem, restrictions on inputs should also be part of the model. A fairly simple approach would be to estimate total activity (sea days) needed to catch the quota (the number of sea days per fleet segment was collated in the EAEF)) and scale down the catch, based on the restrictions on sea days. The problem with this approach is that the manner in which the fishing industry reacts to the restrictions is not taken into account.

The EIAA model uses the TAC advice and the most recent economic information for a projection of economic implications for each fleet segment. As useful follow up would be to predict economic implications given an estimate of the fuel price (or other cost items) in coming year(s). This, for example, would give an indication of how the different fleet segments are affected by the recent fuel price increases.

The EIAA model is comparatively static. A dynamic bio-economic model should include feedback between the stocks and fishing effort by each fleet in order to evaluate alternative future regulations by forward projections. This would allow for the prediction of the effect of reducing/increasing fishing mortality *F* in the short, medium and long term, for each species, in order to assess the effects on the stocks over time; and correspondingly the economic impact over time.

The problem of estimating effort in an output-constrained model, that has more than one stock, is that the estimated effort associated with each stock will not be the same value across/for all these stocks. Total effort is assumed to be species independent, and some estimate of effort is required. In order to allocate effort across all the stocks targeted, some advice in terms of choices is required. For example:

1) should the total effort be set at the minimum effort to catch one of the species in the catch composition vector;
2) should the total effort be set as the maximum effort required to catch all the species in the catch composition vector, or;
3) should the total effort be set as the arithmetic mean effort on all the species.

This mean value could be weighted by yield, stock or the value of the yield of each stock. Point 1), above, implies that the fishing is stopped as soon as the precautionary approach (a TAC) is exceeded for each stock. Point 2) would mean that fishing is stopped only when the precautionary approach (a TAC) is exceeded for all stocks (except for the stock to which the maximum relates).

Since the best “choice” between the above mentioned cannot be derived theoretically, the selection is best considered as a management issue. However, it is critical to make a decision as to the choice (of assumption) above, as it clearly has major implications for the outcome.

The EIAA model uses the weighted mean as the default case. However, each of the choices can be assessed by the model.

ii. Methodologies in case no stock assessment is available

In the particular case of fisheries regulated by effort and selectivity (most Mediterranean fisheries but also some coastal fisheries in the Atlantic) the biological part needs to include a biological model describing the dynamics of the population, and how this dynamic is affected by changes in fishing effort, other fish stocks and their ‘catchability’. Several types of biological models are available, from “simple” surplus production models to more data demanding age-structured models. The choice of the biological model is justified by the management measures to be tested, but also by data availability. If the end-user wants to test selectivity related measures, the model must necessarily be age (or size) structured. In this case, the biological data must include some sort of population assessment, usually done by Virtual Population Analysis (VPA).

Considering the difficulty in obtaining reliable assessments for some stocks, the input-driven models presented or known to the group (e.g., MEFISTO, MOSES, BIRDMOD and COBAS) propose different approaches to modelling the biological box.

The MEFISTO model works with one or more stocks that are subjected to assessment and these stocks are considered “main species” in the fishery (fleet) being analyzed. Other species making up the entire catch for a fleet are considered “secondary species” and their dynamics are expressed simply as *catch(second species) = f(catch(main species))*. The functional form is estimated from data series on catches by fleet.

The COBAS model assumes equally that one or more stocks are assessed, but surplus production models describe the dynamics of the non-assessed species with parameters empirically determined from catch-effort series.

The MOSES model does not use assessed stocks, but describes the dynamics of all species as a surplus production model or a partially age-structured model (Deriso-Schnute), with parameters estimated from catch-effort data. The version of MOSES called BIRDMOD is more similar to the MEFISTO model with respect to the biological box.

As an extension, even more complex biological models can be built into a bio-economic model if we were to include the ecological interaction among species (basically, predator-prey relationships), including non-fish species. This will be necessary for ecosystem-based bio-economic models.

In the Mediterranean Sea there is a low proportion of stocks assessed and routinely monitored. Furthermore, there is lack of connection between assessment and management, and a total lack of adaptive management.

This current situation is the result of the physical constraints of the Mediterranean (low productivity that results in a low economic importance of fisheries) and its status as a ‘sub-tropical sea’ with high diversity of commercial species (100+) in “low” quantities, and large quantities of small “artisanal” fishing fleets and many landing points.

However, some stocks such as hake, small pelagics, and valuable crustaceans, are well studied and assessed; and there exists fairly good data sets on landings dating back to 1970. Data on effort or capacity are more modest.

This absence of fish stock assessments is obviously important when working with the biological component of the bio-economic models, especially if we take into account that almost all fisheries in the Mediterranean and part of the Atlantic are considered multi-species. So, bio-economic modellers must face up to the fact that few stock assessments are available.

One solution to this problem is the one used by the MEFISTO model which divides the species between “main species” and “secondary species”. Another solution is adopted by the COBAS model, where mostly age-structured models are used. However, for all shellfish and cephalopods, surplus production models are implemented. In these cases, time series of catch and effort data are collated, from which a dynamic projection model is constructed.

The use of a surplus production model is based on the relation between catch and effort data defined for each species. In the Mediterranean, most of the species are exploited with different fishing gears and consequently it is very difficult to estimate the total amount of effort exercised on a single stock. A possible solution is to define an equivalent effort, independent of the different gears used to catch the species.

The BIRDMOD model by IREPA and SIBM (Italian Society of Marine Biology) uses an age-structured model for the target species, and the Schaefer model for the group of accessory species. The MOSES model can use alternative models, both logistic and biological.

iii. Important bio-economic indicators

While empirical indicators may be based on data collection and processing, indicators showing future development must necessarily be based on model calculations. Each year Member States are required to submit a report to the Commission on their efforts during the previous year to achieve a sustainable balance between fleet capacity and available fishing opportunities. In this respect, bio-economic models and their development is of utmost importance. Continued over-capacity and over capitalisation will tend to maintain over-exploitation, which is likely to result in unviable fisheries.

The objective of managing the fishing capacity of the EU fleet is to achieve a balance between capacity and available fishing opportunities. Depending on the objectives of the managers, the desired balance between exploitation rates and resource availability could be achieved by a large capacity fleet being deployed for a small amount of time or a smaller fleet for a longer amount of time. The objectives of resource conservation and stock recovery are sustained by a set of biological criteria (benchmarks) for biomass and fishing mortality:

- Biomass:
    - stock having full reproductive capacity is equivalent to being inside safe biological limits;
    - stock being at risk of reduced reproductive capacity, or suffering reduced reproductive capacity, is equivalent to being outside safe biological limits.

- Fishing mortality:
  - stock harvested sustainably is equivalent to being harvested inside safe biological limits;
  - stock harvested outside precautionary limits is equivalent to being harvested outside safe biological limits.

Managers should initiate a debate about what information we want from models and how we link this to our decision of where we want to go? Short run options are: economic impact, social impact, while long run options include: optimal fleet structure, resource rent, Maximum Economic Yield (MEY), and Maximum Sustainable Yield (MSY), the latter being the commitment for all fish stocks (World Summit of Sustainable Development 2015).

To include fishing effort in terms of capacity and sea days and the impact of the economic behaviour of the fishermen, considerations should be given to indicators such as:

- capacity utilisation by the fleet (number of sea days per year deployed per fleet segment in proportion to the maximum number of sea days) ;
- economic performance
  - operating profit margin (net profit relative to gross revenue), does not require estimates of invested capital;
  - return on capital (profit before interest and depreciation relative to invested capital), requires an estimate of invested capital that is often difficult to accomplish;
  - break-even revenue in proportion to current revenue (estimate of overcapacity), offers the advantage of allowing an investigation into the impact of prices and costs as well as landings;
  - remuneration from the SSB, considers the fish resource a national asset that warrants a return in the same way as private assets.

These indicators could be supplemented by classification criteria that inform about the status (level) of the economic performance.

From a socioeconomic point of view the return on invested capital and labour is a key indicator:

- Development in Gross Value Added

This indicator could include the remuneration from the Spawning Stock. There is a need for development of methods to assess the value of the Spawning Stocks in parallel to the way the value of vessel capital is estimated. The EIAA model already contains elements that calculate remuneration from the stocks. Stock assessments in value terms, however, are also required exogenously from the model; or at least procedures have to be developed to estimate the stock value endogenously.

iv. The scope of the output driven models

The TACs are the only restriction used in the current EIAA model to predict the economic performance of the fleet. The model is constructed to fit directly to Harvest Control Rules (HCRs) in terms of TAC/quota. If a biological component is not built into the model, HCRs have to be made every year. This is not necessary with built-in biological models with feed-back mechanism between the fishing fleets and the fish stocks.

Optimisation models (e.g. EMMFID, SRRMCF and MOSES) could be categorised as an output driven models in the sense that HCR, in terms of TAC/quota, are used as restrictions. This type of model can work with any HCR (restriction) be it on output or input (sea days). Optimisation models are constructed by using inequalities instead of equalities. The restrictions define a space, which makes it necessary to formulate objectives in order to find solutions. The optimisation models are often comparatively static, but could be dynamic in the sense that the model traces an optimal path to a predetermined equilibrium.

v. Suitable effort driven operational models

The effort driven models reviewed are:

1. TEMAS: A bio-economic model to assess the effect of technical management measures;
2. BIRDMOD: Methodological Support for a Bio-Economic Model of Population Analysis of Demersal Resources;
3. MEFISTO: Mediterranean Bio-Economic Simulation Model;
4. COBAS: A dynamic bio-economic model of the fisheries of south-west England that can determine the costs and benefits of sustainable fisheries management
5. ECONMULT: Bio-economic multispecies models of the Barents Sea fisheries;

For further advice on the suitability of these models the reader is referred to the other sections of the summary.

vi. Overall data requirements of the models including availability

The EIAA is fully flexible in its ability to handle different fleet segments. It requires data on EU TACs per management area and stock assessment, landings composition by species per fleet segment, and the associated costs and earnings data. TEMAS, EMMFID, and SRRMCF are particularly data demanding models. TEMAS includes detailed multi-stock and multi-fleet aspects. Therefore, it caters for full ‘VPA-type’ stock information (as used by ICES stock assessments) and full fleet definitions, including structure and economic data. EMMFID and SRRMCF require a detailed dis-aggregation of the fleet, TACs per management area and detailed information regarding landings and effort with respect to area, month and species. COBAS also requires detailed inputs. Data are obtained from a number of different sources: through surveys for economic, regional and environmental data; through logbooks for structure and activity of the commercial fishing fleets; and through ICES and CEFAS for stock-relationships. The breakdown of costs required is remarkably detailed. The extent to which the models run with the data specified in Commission Regulation 1639/2001 is shown below. Technically all the models can run with these data. But the question is whether it makes any sense. All models make use of biological information that is specified in the Data Regulation (Commission Regulation 1639/2001) but the input driven models are constructed with the aim of long run simulations which are not dependent on data input to the same extent as the models used for regular projections.

Table vi.1 Data requirements

Model	1639 (MP)	1639 (EP)	Needs
EIAA	Yes	Yes	TAC/quota and stock assessments for extensive use
TEMAS	No	No	Comprehensive biological model component
MOSES	Yes	Yes	If time series data are available.
BIRDMOD	Yes	Yes	If the fleet segments use more than one fishing gear, the model needs information on the activity distribution among the fishing gears.
MEFISTO	Yes	Yes	Economic data disaggregated by vessel is desirable to take full advantage of the model capabilities
EMMFID	No	Yes	Extensive use needs catch per day/species/segment/area
SRRMCF	No	Yes	Extensive use needs catch per day/species/segment/area
COBAS	Yes	Yes	If analysis identifies activity not captured by extended 1639/2001 (e.g. fleet disaggregation), additional technical and economic data may be required
ECONMULT	Not relevant	Not relevant	Comprehensive biological model component

The models concerning the Mediterranean must be much less data intensive, since the availability of information is limited. The main elements lacking are the target stocks and the geographical dimension. These absent elements inhibit the practical use of bio-economic modelling for empirical purposes. The models MOSES, MEFISTO, BIRDMOD, and also ECONMULT are models mainly designed for analytical purposes. They may serve as appropriate tools for less *ad hoc* tasks and long term strategic tasks, which also imply that the data availability is not a restriction in the same way as for the urgent tasks.

vii. Organisation and adaptation of the data to fit the models

When discussing this item the group found it useful to distinguish between:

- Regular tasks
- Ad hoc tasks
- Long term strategic tasks

vii.1 Regular tasks

One (important) form of short run biological advice is the annual preparation by STECF and the EC for the Council meeting in December, where next year's quotas have to be agreed. For the last four years this has been supplemented by assessments of the economic repercussions.

This work has been supported financially through a Concerted Action that was discontinued at the end of 2004. In 2005, an EC grant was provided to make it possible to continue the work for a further year. The Joint Research Centre will be responsible for this work from 2006 onwards.

The biological and economic advice is channelled into the STECF committee by use of two subgroups. The economic advice depends on the biological advice with respect to TACs and the cost and earnings information provided hitherto by the Concerted Action EAEF. Preparation of the economic advice is subject to strict time restrictions in terms of data collection and provision, and in terms of using the EIAA model, which is developed to account for these restrictions.

Ideally, the model should be used *before* next year's quotas are agreed, i.e. before the Council of Ministers meets in December and *after* the quota proposals have been forwarded. This stricture leaves very little time in late October and early November to carry out calculations and present results. Therefore the model set-up ensures that it is very easy and quick to use.

In the future (from 2006) the economic data collection will be based on Commission Regulation 1639/2001, and the Joint Research Centre (JRC) will carry out the secretariat function of the STECF.

The regular tasks, i.e. the annual economic evaluation of the ICES advice, require a firm structure that can be quickly made operational. This means that the human and financial resources necessary to carry out the work cannot realistically be secured using only *ad hoc* working group meetings.

There is, therefore, a need to build a stable framework for the collection, processing and evaluation of economic data on an annual basis. Furthermore, it is the opinion of the Sub-group that only appropriate experts from each member state should undertake the annual economic evaluation of the ICES advice. Such experts need to be able to make an annual commitment to undertaking the evaluation, which should be timetabled well in advance. Expert participants will only be able to make such a commitment if they are supported financially.

vii.2 Ad hoc and long term strategic tasks

While the EIAA model is suitable for certain *ad hoc* tasks, the model is not designed primarily to handle the economic repercussions of input regulation such as sea days. Furthermore if it is considered that input regulations in many fisheries are used together with output regulations, then the model clearly needs to be developed further to deal with the situation. Input regulation in terms of sea days requires information about catch per day. The EMMFID model may serve as an appropriate starting point, as it is well developed. The Swedish SRRMCF model is of similar type. The MOSES and COBAS models are also similar to EMMFID, although COBAS is still under development. These models, however, require very detailed data, the procurement of which may not be possible to the necessary deadline

The models TEMAS, MEFISTO, BIRDMOD, and ECONMULT were designed for analytical purposes. They may also serve as appropriate tools for less *ad hoc* tasks, and especially long term strategic tasks, which also implies that data availability is not as restrictive as it is for the more urgent tasks.

Currently the main (only) model that is used by the European Commission as an aid to assist in evaluating management proposals in the ICES area is the EIAA. The EIAA has been accepted as a useful aid to fishery managers for a number of years. Nevertheless developments in the way that managers have asked for advice, and the ensuing changes in the way that ICES has produced its advice, means that additional bio-economic approaches are desirable.

The EIAA model essentially takes an estimate of the TACs available for the forthcoming year and assumes that these will be the landings actually realised by the Community fleets. In summary, the EIAA provides an answer to the question, “what will the economic performance of EU fishing fleets be next year relative to their average economic performance over the most recent three years, assuming the fleets fish in the same way next year as they have done for the past three years, and that their landings next year are the same as the proposed TACs? The EIAA also provides an estimate of the potential economic performance of the existing fleet segments, assuming that all stocks exploited are being fished at a rate corresponding to the precautionary fishing mortality rate (F_{pa} or a proxy) under long-term equilibrium conditions.

There are a great variety of potential objectives for managers. In the situation where stocks are depleted or harvested unsustainably, the primary concern is to increase stock sizes to levels where recruitment is not impaired and to reduce fishing rates to sustainable levels: the focus is, therefore, on stock development and yield. However, commercial fishing is an economic activity, i.e. commercial fishers do what they do to make money and, inevitably, the true objectives for managers have an economic basis. It follows therefore, that to make informed decisions that will help to achieve economic objectives, the performance or likely performance of those decisions, with respect to those objectives also needs to be evaluated. There is, therefore, a need for the development of tools that can provide economic evaluations of Harvest Control Rules, Management Plans, Long Term Management Strategies, and Recovery Plans.

The development of tools within ICES to evaluate economic issues are largely restricted to modelling the development of the stock, and the yield from the stock, on an annual basis assuming specific exploitation patterns, overall levels of fishing mortality and predicted recruitment (derived from a stock-recruit relationship). The modelling can be either deterministic or stochastic. Such an approach permits a year-on-year prediction of the developments of the stock and overall yield under different management scenarios. The economic evaluation tool that is currently used only addresses the potential impact in the immediate future (assuming a catch for next year) and in the long-term equilibrium situation where the stocks are each fished at F_{pa} (or a proxy for F_{pa} where this is not defined). However, to better inform managers of the potential economic development of the fleets under different management scenarios, an alternative approach is desirable. For example, when you deal with a multi-stock (mixed fisheries) problem you avoid the complication of aggregating the stocks.

Long run socio-economic objectives include: optimal fleet structure, resource rent and Maximum Economic Yield (MEY), cf. Maximum Sustainable Yield (MSY) commitment for all fish stocks (World Summit of Sustainable Development 2015). The multi-layered objectives of the CFP (Council Regulation 2371/2002) comprise: 1) biological/environmental; 2) economic; 3) social; and 4) sustainable development/exploitation goals which are contradictory and, therefore, extremely demanding to pursue.

Last but not least, the fishermen's objectives are to make money from fishing. Making money in the short and medium-long run involves the risk of depleting the stocks, while closures of fisheries 'deplete' the fishing fleet. There is a trade off, and our demanding task is to find a common indicator. One possible route is to put more emphasis on fleet development reference points, in parallel to what has been done for the stocks. An example of this long-term strategic task is found in the results presented for the ECONMULT model, which could provide inspiration for developments in this field.

Two types of development of economic models could be considered for the immediate future.

- Assigning the degree of risk to the economic effects of proposed TACs. History has shown that the proposed TACs may not actually be adopted, and that the TACs adopted are often not achieved or are exceeded. The degree of error for each stock could be calculated from historic series of TACs and catches. This would be of limited use for taking management decisions but it would inform managers of the potential range of consequences of those decisions.
- Application of a model to the projected annual yields arising from the evaluation of envisaged HCRs, MPs etc. and provision for changing the behaviour of the fleet segment to take account of effort restrictions, for example, and feed back to biology.

At present, for many stocks, the priority is to get back to a healthy state with sustainable harvest rates. Hence biological objectives are the primary concern which can be achieved through exploitation rates, which have a direct influence on yield from the fisheries (2015 objective). If this state is achieved, what kind of economic indicators will be required and how should they be calculated so that managers can take appropriate decisions based on criteria that will achieve their economic objectives without returning stocks to a perilous state?

The Green Book of the European Commission states that the Mediterranean fisheries have to be regulated by effort control, not TACs. Current management regimes for Mediterranean fisheries are based on effort and technical measures, such as selectivity control. So, there is a need for scientific advice, not in quotas terms, but in effort units. With respect to fisheries not subject to TAC it is recommended that the input driven models such as MEFISTO be considered as a practical tool for evaluating the outcome of management measures proposed by the sub-committee of Stock Assessment of the General Fisheries Council for the Mediterranean and in the long-term management of Mediterranean fisheries resources. Fisheries are important in the Mediterranean Sea in employment and social terms; even though catches are lower than in Atlantic waters.

viii. Task force groups

To prepare the road for long term, ad hoc and strategic advice, and to secure short term regular advise is continued, it is recommended that task forced are established.

The objective of a task force is produce detailed information in terms of user manuals about the operational models identified in this report. The aim is to provide information that increases the assessability and applicability of the models to a broader group of people and institutes. It should be noted that for example that the EIAA and the MEFISTO models were developed in projects financed by EU programmes, while the other models have been developed by national grants.

The manual produced by the task force should address as minimum the following items:

1. Model language
2. Model objective and scope
3. Type of advice and time range (simulation over years, static comparative, optimisation)
4. Model overview - diagramme
5. Full specification of the equations of the model
6. Full specification of the variables of the model
7. Full list of the parameters of the model (including parameter values)
8. Data requirements to initialise the model; i.e. a complete list of indicators (often the same as the variables)
9. Description of the required time to run the model and to produce and disseminate the advice.
10. Format of output of the model
11. Procedure of how to run the model
12. Where has the model been used, outcome, validation and references
13. Institute and key personnel

The models that are recommended for further elaboration in terms of user manuals are listed in the following table viii.1.

Table viii.1 Key information about the selected models

Acronym	Type	Institute	Contact person	Home page	E-mail
EIAA	Output driven	FOI/LEI	Hans Frost	www.kvl.foi.dk	hf@foi.dk
MEFISTO	Input driven	GEM/ICM-CSIC	Jordi Guillen & Francesc Maynou	http://www.gemub.com	jordi@gemub.com
BIRDMOD	Input driven	IREPA	Paulo Accadia	www.irepa.org	accadia@irepa.org
MOSES	Optimization	IREPA	Paulo Accadia	www.irepa.org	accadia@irepa.org
EMMFID	Optimization	FOI	Jens Kjærsgaard	www.kvl.foi.dk	jk@foi.dk
SRRMCF	Optimization	F-Verket	Anton Paulrud	www.fiskeriverket.se	Anton.Paulrud@fiskeriverket.se

The criteria for selection are that the model has been operated and verified with respect to robustness and data assessability. It should be noted however that the model have been constructed subject to the problems addressed and the available data and data formats.

The EIAA model has been used for the last four years (2002-2005) to assess the economic impact of the biological advice in terms of TACs. In 2006 a transition takes place, due to the adoption of the data regulation that becomes effective with respect to costs and earnings statistics from 2006. To secure smooth transition and continued regular advice it is recommended that an EIAA task force is established as soon as possible having in mind that the advice is due before the STECF plenary meeting in November.

With respect to the input driven model the nature of input control rules implies that the time restrictions are not as strong as for the output regulated fisheries. However it is recommended that task forces are set up soon to ensure continuity and further development. Even though these models do not face the same time restrictions with respect to STECF advice, they are very useful not least with respect to ad hoc questions and long term advice given by STECF. It should be noted that although the input driven models often are used for long run simulations the results can be up-dated as soon as data are up-dated both on a year by year basis as well as on a long run basis.

Further, it is noted from the review of models in this report that a third type of models, optimization models, has been developed and is operational. So far, they have been applied on a national scale, but can potentially be used more widely, in particular in areas where output- and input controls are both in use at the same time. These are characterised by being useful for analysing long term strategic advice. Therefore a task force producing user manuals for this type of models considered very useful and is recommended to be established soon.

The models chosen above are well described mainly with respect to the equations of the models. The availability of this information facilitates the work with the user manuals. Although it differs what amount of resources is required to produce the manuals it is the opinion of the group that such manuals could be prepared within a rather short period of time that could take the format of working group meetings including tutorials in their use.

Terms of reference for the meeting 4-6 October 2005

1. Objectives and methodologies of the bio-economic advice

Over the last years the bio-economic advice has been based on the fish stock assessments and subsequent TAC proposals. These assessments are not available for all European regions.

Until 2003 the obligations of the STECF (Council Regulation 3760/92) was to ‘report on the economic repercussions of the situation of the fish stocks’. The general objective of the Concerted Action (CA) Economic Assessment of European Fisheries (Q5CA-2001-01502 was: To integrate and analyse the economic information available on European fisheries and to develop decision support tools applicable for fisheries management.

In the revision of the CFP (Council Regulation 2371/2002) the need for economic assessment has been specified in the articles about recovery and management plans (art. 5 and 6) having regard to: ‘the economic impact of the measures on the fisheries concerned’, as well as in the obligations of the STECF (art. 33).

With reference to the objectives and obligations last specified in Council Regulation 2371/2002 the group is asked to:

1. Critically review the methodology of the bio-economic advice as it has been carried out in the CA and give adjusted methodologies.
2. Set out methodologies for the bio-economic advice in case no stock assessments are available.
3. Make a set of important bio-economic indicators that could be used as the basis of the advice.

Ref.: CA (Q5CA-2001-01502): Economic Performance of Selected European Fishing Fleets. http://www3.lei.dlo.nl/ca/

2. Review of types of models used

At least three categories of models seem relevant: 1) output-driven models (exogenous output and endogenous inputs) 2) effort-driven models (exogenous inputs and endogenous output) and 3) integrated models where causality shifts. For all three model categories, the appropriate methodology may be either simulation modelling or optimisation modelling.

It is mandatory that the models in question are operational with respect to the objectives and available data.

The group is asked to:

1. Determine the scope of the output driven models within a multi-species, multi-fleet bio-economic context, including a review of the EIAA model and pertinent developments, ref.: SEC (2004) 1710, SEC (2005) 259.

2. Advise on suitable effort driven operational models that can be used, E.g. MOSES, MEFISTO, and TEMEC.
3. Consider overall data requirements of the models, including availability in time.

In selecting models, the group should take into account the practicalities of data availability and collection of the required data.

You can find (and download) the SEC reports from:

http://europa.eu.int/comm/fisheries/doc_et_publ/factsheets/legal_texts/rapp_en.htm

3. Relevant projects

In order to avoid overlapping work, the group is asked to:

1. List relevant concluded and on-going research projects comprising operational bio-economic modelling (clear model and data procedures) inside and outside the EU.
2. Examine the scope and the time schedule of these projects, with respect to model structure, data needs and availability, and operational model and data interaction.
3. Take a position on research needs to develop new models.

4. Data requirements

In order to run the models data are needed. With reference to Council Regulation 1543/2000 and, in particular the Commission Regulation 1639/2001 about the EU data collection the group is asked to assess:

1. The type of data needed for the operational models:
    a. variables needed
    b. aggregation levels of the data (segmentation)
2. The procedures for organisation and adaptation of the data to fit the models.
3. Sources of data.

5. Adjustments of data regulation

The group is asked:

1. To reflect on the consistency between the data needs for the bio-economic models and the data provided by the data regulation and to list discrepancies and advice on changes, cf. SEC (2004) 1024, chapter 9 and Report of the workshop 'Economic Indicators' Paris 10-14 May 2004, IFREMER.

The meeting should produce input for the SGRN meeting on bio-economic data in October, cf. SEC (2005) 159 and SEC (2005) 255.

6. Advice procedures and organisational framework

Good advice needs to be trustworthy and presented in a way that is useful and understandable. Thus, the procedure and the human resources that transform information into good advice are important to address.

The CA (Q5CA-2001-01502) is organised with a database http://www3.lei.dlo.nl/ca/ that contains data in a format used to run the EIAA model.

Currently JRC is the secretariat for the STECF and, in the future, will also be responsible for data provision based on the national data collection programmes, cf. Commission Regulation 1639/2001.

The group is asked:

1. To provide criteria that forms the basis for this procedure in terms of the required human resources and institutional framework.

Terms of reference for the meeting 7-9 March 2006

1. Finalize the report

STECF recommends that the report is finalized with regard to ToR of the 1st meeting October 4-6. 2005, and the recommendations of the STECF plenary meeting November 2005

STECF recommends that based on the current overview of available models a selection should be made of those models that are at present operational, publishable and do have a specific use for STECF.

2. Setting up a task force

In addition STECF recommended establishing a task force that will for each selected model create a manual on the use and data requirement of the specific model.

1. Objectives and methodologies of the bio-economic advice

1.1 The methodology of bio-economic advice of the CA and adjusted methodologies

1.1.1 Derivation of TAC proposals by the STECF

The TACs input to the EIAA are derived from the advice given by the International Council For the Exploration of the Seas' (ICES) Advisory Committee for Fisheries Management (ACFM).

The results of single stock assessments undertaken by ICES Assessment Working Groups are reviewed by the ACFM, which then issues advise for each stock. Such advice is presented in terms of single stock exploitation boundaries in relation to three criteria.

1. Exploitation boundaries in relation to existing management plans.
2. Exploitation boundaries in relation to high long-term yield, low risk of depletion of production potential and considering ecosystem effects.
3. Exploitation boundaries in relation to precautionary limits

Advice on the mixed fisheries implications for each stock is also given by the ACFM.

The advice from the ACFM is expressed in terms of a fishing mortality rate. Since the main tool for management under the Common Fisheries Policy is the setting of a TAC (with or without concomitant technical measures and/or fishing effort restrictions), the advised fishing mortality rate is used to estimate an equivalent catch in weight for the forthcoming year using a deterministic catch projection. The STECF then assumes that the calculated catch will form the proposal for the TAC for the forthcoming year.

Since the advice arising from the ACFM is expressed in relation to different criteria, the STECF undertakes alternative economic evaluations using different sets of TAC proposals. For example, in its 2004 Report (SEC (2004) 1710) on the potential economic impact of the ACFM advice for 2005, three sets of TAC proposals were evaluated. The criteria and rationale for the different sets of TAC proposals are outlined in the following extract from section 2 of the 2004 report.

1. Single species TACs. As far as possible, TACs for 2005 were taken directly from the ICES advice for single species exploitation boundaries. These were used to demonstrate the economic performance of the fishing fleets in 2005 relative to the 2001-2003 baseline run if TACs were set according to the single species advice and ignoring any interactions between stocks and fisheries. For some stocks, the single species advice was for zero catch in 2005 and in such cases the TAC input to the EIAA was therefore zero. For other stocks, ICES was unable to provide quantitative assessments and advice on catch options for 2005 and in such cases the TAC for 2005 was set equal to the 2004 TAC.

2. TACs set in line with ICES' mixed fishery advice. This scenario was undertaken to evaluate the economic performance of the fleets where the interactions between stocks and fisheries are taken into consideration. This represents a worst-case scenario, since it implies zero catch for a large number of demersal stocks that are caught in mixed fisheries. For example, for the North Sea mixed fisheries, the ICES advice states:

Fisheries in Division IIIa (Skagerrak-Kattegat), in subarea IV (North Sea) and in Division VIId (Eastern Channel) should in 2005 be managed according to the following rules, which should be applied simultaneously:

- With minimal bycatch or discards of cod;
- Implement TACs or other restrictions that will curtail fishing mortality for those stocks for which reduction in fishing pressure is advised;
- Within the precautionary exploitation limits for all other stocks (see text table above).
- Where stocks extend beyond this area, e.g. into Division VI (saithe and anglerfish) or are widely migratory (Northern hake), taking into account the exploitation of the stocks in these areas so that the overall exploitation remains within precautionary limits.

The group has interpreted the wording "with minimal by-catch or discards of cod" as meaning a zero TAC for cod and for those species caught together with cod. Hence, for example, in this case the catch of haddock, whiting, plaice and sole was also set to zero.

3. TACs set in line with existing management agreements and proposed management plans. For several stocks management agreements exist. For such stocks, the group selected the TAC consistent with such agreements. For other stocks not subject to management agreements the 2005 TAC was set in line with single stock exploitation boundaries, unless they were stocks associated with the stocks subject to the management agreement. For example, the management plan for Northern hake calls for a 25% reduction in fishing mortality for hake. Hence the group chose to estimate a TAC consistent with a 25% reduction in fishing mortality for anglerfish and megrim stocks that are associated with the fisheries exploiting hake. Pelagic stock TACs were set according to single stock exploitation boundaries, since there is no significant interaction with demersal stocks in the fisheries exploiting pelagic species.

For many stocks the assessment area encompasses more than one management area. In such cases the TAC for the stock was partitioned according to the allocation of the 2004 TACs to the different management areas.

In the absence of SSB estimates in the ICES advice, SSB for 2005 was assumed to be the same as that of 2004.

The long-term TACs were calculated by taking the long-term equilibrium yield per recruit (Y/R) at the precautionary fishing mortality (F_{pa}) and multiplying this by the average (arithmetic) recruitment for the assessment time series as it appears in the ICES summary table. This figure was then adjusted to reflect the likely EU share by applying the 2003 total TAC to EU share ratio [$\text{EU share}_{\text{long term}}=\text{TAC}_{\text{long term}}*(\text{EU Share}_{2003}/\text{TAC}_{2003})$]. In some cases (e.g. blue whiting) these were then further subdivided into TACs for each sub-division by applying the 2003 TAC to the sub-division ratio. The long-term SSBs were calculated by taking the SSB per recruit (SSB/R) at the precautionary fishing mortality (F_{pa}) and multiplying this by the average (arithmetic) recruitment for the assessment time series as it appears in the ACFM summary table. In most cases, values of Y/R and SSB/R were derived directly from the plots in the ACFM report; this is clearly not very precise, but essential in the absence of the comprehensive data. In cases where information was missing from the ACFM report (e.g. yield per recruit plots) data were taken from either working group reports, or from previous ACFM reports. In cases were F_{pa} was not available, an appropriate fishing mortality (e.g. F_{sq}) was chosen.

Since the long-term equilibrium estimates of TAC and SSB should be largely unaffected from one year to the next, the long-term calculations presented in this report are based on the ICES advice for 2004.

1.1.2 The methodology of the Concerted Action

The Concerted Action (EAEF) 2002 – 2004: ‘Economic Assessment of European Fisheries’ (QLRT - 2000 – 01502) and its predecessor (CA: Economic Interpretation of ACFM Advice, 1998-2000) has formed basis for collection of cost and earning statistics on an EU wide scale. Costs and earnings data have been collected and presented in a report (AER): Economic Performance of Selected European Fishing Fleets and in a database (CAClient) hosted by LEI, http://www3.lei.dlo.nl/ca/ for 73 segments within the EU (25). These segments cover 62 % of the landings value of the EU.

The information is presented in AER in a standardised format (to fit one page) for each member state’s total fleet and for each fleet segment, see example in Figure 1 on the next page for the Danish national fleet. Further, the report contains a ‘European overview’ and a summary by regions. More detailed information is presented in annexes and stored in the CAClient database as time series.

Figure 1. An example of the format of the information in AER

2.1 National fleet

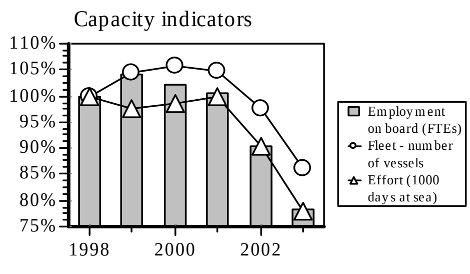
In 2003 the commercially active fleet is defined as fishing vessels……..*text*……….*text*……..the whole fleet also include different types of multipurpose vessels, beam trawlers, shrimp trawlers, mussel dredgers and vessels using fixed gear.

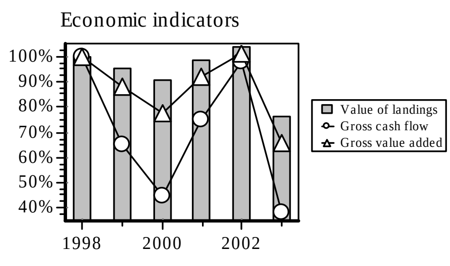
	2003	Change 2003/2002, %
Economic indicators (total fleet, mEUR)		
Value of landings	371	-26.0
Gross value added	206	-34.8
Gross cash flow	43	-60.7
Net profit	-41	-379.8
Other economic indicators (total fleet)		
Employment on board (FTE)	3,506	-13.5
Invested capital (mEUR)	578	-5.5
Fleet – number of vessels	1,244	-11.7
Fleet - total GT (1000)	89	-3.0
Fleet - total kW (1000)	295	-10.0

In 2002 net profit was positive: mEUR 14.7.

Economic performance
The overall result for the Danish fishery in 2003 became significantly lower…….*text*………*text*…….. gross output per vessel was reduced by 16% even though the number of economically active vessels was reduced by 12%.

Assessment for 2004 compared to 2003
Figures for the first 8 months of 2004 show a 13% fall in the price on industrial fish…..*text*………*text*……. industrial fishery combined with the quota situation for codfish may result in a total loss in landing value by 5-10% compared with 2003. The cost of fuel is still high and is not expected to drop.





A specific task of the concerted actions was to construct and develop a model that could link the costs and earnings information to the biological advice in terms of TACs. In the EIAA model a sample of 25 of the above mentioned segments has been subjected to projections of economic performance taking the pertinent quota changes into account.

The EIAA model is constructed to pursue the objective: to assess the economic consequences of the TAC proposals formulated by ACFM by making use of the data collected and disseminated in the annual economic reports (AER) produced by the Concerted Action EAEF.

The EIAA model includes an allocation procedure that brings TACs to the fleet segment level. The catch composition of each member state and each fleet segment relative to the TAC on EU level for a base period serves as the link to the agreed TAC for the coming year. By use of the relative stability matrix, agreed by the EU, the member state share is calculated first. The member state’s actual catch composition is put in proportion to the agreed quotas for the member state to calculate the up-take ratio, which is afterwards assumed constant for the projected years. The up-take ratio plays a rather important role in the comparison between the projected and the historical results because recorded landings seldom equal the quotas.

The EIAA model works to a large extent with matrices and arrays (vectors). Table 1 shows an example of the type of information (matrices) that are used in the allocation procedure. The left hand side shows the agreed TACs on EU level while the right hand side shows the recorded landings of a particular country/fleet segment. The segment share of the total quota is used to scale cost and earnings for future periods.

The EIAA model takes into account that landings are not recorded for all species, either because there are no landings or because information is not available. These landings are included in the ‘other’ group.

Table 1. The EIAA model's catch compositions to allocate shares of the TACs

Total TACs per species (sum of management areas)

	Volume (1000 t)				
Major species	**2001**	**2002**	**2003**	**2004**	**2005**
Herring	640	567	586	661	892
Anchovy	43	41	41	41	10
Cod	150	128	100	102	84
Megrim	29	26	25	27	20
Anglerfish	54	44	34	39	39
Haddock	76	107	59	85	55
Whiting	57	77	54	35	17
Hake	32	35	37	45	40
Blue whiting	326	267	180	309	358
Norway lobster	56	55	54	56	46
Northern prawn	12	11	11	11	11
Plaice	104	97	100	81	57
Pollack	22	21	20	20	20
Saithe	57	89	105	119	43
Mackerel	403	412	368	351	417
Common sole	36	31	30	30	32
Sprat	419	428	408	446	446
Horse mackerel	359	258	230	237	186
Turbot	7	7	6	5	3
Lemon Sole	11	10	8	7	7
Dab	27	27	23	18	18
Skates and rays	5	5	4	3	3
Norway pout	199	223	173	173	173
Sandeel	970	863	863	902	174
Atlantic salmon	396	339	347	347	347

Total national fleet. Composition of landings

	Volume (1000 t)		
Major species	**2001**	**2002**	**2003**
Herring	136	112	116
Anchovy			
Cod	44	37	31
Megrim			
Anglerfish	2	2	2
Haddock	5	8	4
Whiting			
Hake	1	1	1
Blue whiting			0
Norway lobster	5	5	5
Northern prawn	3	4	5
Plaice	27	24	21
Pollack	0	0	0
Saithe	4	5	6
Mackerel	30	33	27
Common sole	1	1	1
Sprat			
Horse mackerel			
Turbot	1	1	1
Lemon Sole	2	1	1
Dab	2	3	3
Skates and rays			
Norway pout			
Sandeel	1084	1053	693
Atlantic salmon			
Other	144	139	115
Total	1491	1429	1033

Information of landings compositions for each considered fleet segment, similar in format to the table for the national landings, are included in the model. For each fleet segment the change in activity is calculated by use of the change in prices, landings, and spawning stock biomasses (SSB) in future periods relative to the base line period, see appendix 1. Table 2 explains the weighting procedure on activity (effort) on each species in the EIAA model, and the activity change after changes in quotas. In the numerical example in table 2 the product of price changes, quota changes, and changes in SSB in future periods entails an activity at 0.971 relative to the base line at 1, which is a decrease in activity at 2.9 %.

Table 2. Numerical example of activity change for a fleet segment as a function of changes in quotas and spawning stock abundance (SSB)

Landings and quotas										**Stock abundance SSB**			
	Base year				Year t					Base	Year t		
Species	Landings/ quotas	Price	Revenue	Share	Quota	Price	Revenue	Price effect	Volume effect	SSB	SSB	SSB effect	Total effect year t
1	50	12.0	600	0.308	50	12	600	0.308	1	200	200	1.000	0.308
2	40	10.0	400	0.205	30	10.5	420	0.215	0.75	150	100	1.500	0.242
3	30	5.0	150	0.077	45	4.5	135	0.069	1.5	100	200	0.500	0.052
4	10	70.0	700	0.359	15	63	630	0.323	1.5	50	75	0.667	0.323
5	5	20.0	100	0.051	7.5	18	90	0.046	1.5	50	75	0.667	0.046
Total	135		**1950**	1.000	147.5		1875	0.962					0.971

The formula that form basis for the example in table 2 is found in Aappendix 1 equation (2). It is noted that the "price effect" is calculated by use of the landings/quotas in the base period multiplied with the calculated prices of year t (an index from economic theory known as Laspeyres' index). This index is adjusted with a volume and a stock abundance effect. The underlying formula for the calculation includes flexibility rates that are omitted in table 2. These flexibility rates determine the impact on activity by changes in landings, and by changes in stock abundance (returns to scale).

The cost per fleet segment in the base period is extracted from the Annual Economic Report. By multiplying these costs with the activity coefficient *A* the cost in the future period is obtained. Future revenue is determined by the fixed quotas for the future period multiplied with a set of fixed prices. For non-quota species the baseline gross revenue is transferred to the future period and added to the revenue from the quotas.

Finally the EIAA model includes procedures that are required to match different set of data from different sources. That is the costs and earnings data on one hand and the catch and quota data on the other.

1.1.3 Projection or prediction of costs (e.g. fuel price)

Given the TAC advice the EIAA model uses these and the most recent economic information for a projection of the economic implications for the fleet segments. As a follow up to this, a second step could be to predict economic implications given an estimate of the fuel price (or other cost items) in the coming year(s). This would give an indication of how the different fleet segments are affected by the recent fuel price increases.

1.1.4 Utility of the most recent information

The data collection of the CA as referred to in this section is assumed to be consistent with the requirements of the Data Regulation (1639/2001). The economic data collated and collected as part of this programme is designed to be a yearly procedure covering the fleets defined. For the consistency of any modelling approach that is updated and applied regularly, consistency over time in the definition of fleets and in the collection of related economic data must be established and maintained. Due to this, the most recent economic cost information of fleets is available for implementation in the model.

As far as the biological information is concerned, quota stocks are assessed by ICES on a yearly basis. For the EIAA model, quotas and stock status resulting from these assessments are available at the time of model use. Therefore, the key raw data (economic costs and quotas) implemented in the EIAA model are the most recent information and must be ensured to be so.

For other parameters used in the EIAA model, such as price flexibilities and stock flexibilities, the most recent information may not be as important. It can be expected (unless markets and stocks change radically) that such parameters can be modelled as a constant. It is one of the strengths of the EIAA model (see the Review of the EIAA model (SEC (2005), 259)) that it is a short-run implementation (i.e. yearly), that works robustly under scenarios of structural stability with respect to fleets and stocks.

1.1.5 Input restrictions

The only restriction used in the current EIAA model to predict the economic performance of the fleet is the TACs. However, for some of the European fleets, effort restrictions have been used for some time already, in addition to TAC restrictions (e.g. some of the Spanish NE-Atlantic fisheries). Moreover, in recent years recovery plans have put increasing restrictions on inputs in different European fleet segments, e.g. for the Dutch beam trawl fishery the maximum number of fishing days has been set at 181 in 2005, whereas most of the vessels used more than 181 days before. In cases where these input restrictions become more restrictive for the fishing opportunities than the quota, the current EIAA model will overestimate the catches and effort, and thereby the economic performance. This might lead to serious bias in the model outcomes.

In order to solve this problem, restrictions in inputs should be part of the model as well. A fairly simple approach would be to estimate total activity (sea days) needed to catch the quota (from sea days estimates based on SSB forecasts) and scale the catch down based on the restrictions on sea days. The problem with this approach is that the reaction of the fishing industry to the restrictions is not taken into account.

There are, however, some problems connected to the implementation of such restrictions.

- In the EIAA model landings are assumed to be equal to the quota corrected by the up-take ratio, but as input becomes restrictive, this assumption cannot be used. The EIAA could be developed to include that issue, although on a more crude level.
- In order to accurately model the restriction in sea days, a more extensive model will probably be needed to take into account restrictions for certain gears and the reaction on these by shifts in fishing strategy, even within the year (e.g. gear use, fishing area). This will also have consequences for the data needs of the model (e.g. catch and effort information needed for different areas, gears, mesh sizes etc.). It is a question of the desired level of aggregation.
- It requires an iterative process to show which of the two (inputs or outputs) are most restrictive, given the legislation. This will have consequences for the model structure.

1.1.6 Dynamics, feedback, and aggregation

A dynamic bio-economic model should include feedback between the stocks and effort of each fleet in order to evaluate alternative future regulations by forward projecting. This would allow for the prediction of the effect of reducing/increasing F in the short, medium and long term for each species in order to assess the effects on the stocks over time (and correspondingly the economic impact over time). As an example, including a link between the biological models and the fleets would require that the relationship between fishing mortality (or harvest) and effort is specified, either in the form, $F = q*E$ or specified as a production function (e.g. Cobb-Douglas function, although other possibilities exist).

If the situation was one where only a single fish stock was targeted with an output (TAC) constraint then the fishing effort would relate directly to that stock. The problem of estimating effort in an output-constrained model that has more than one stock (multi-stock,i.e. mixed fisheries with technical interactions) has been highlighted by Sparre (2004). The problem is (stated as a simplification for clarity): if the biological component of the model requires as input the fishing mortality (or catch) for each stock in some future year, the estimated effort associated with each stock will not be the same value across/for all these stocks. For a series of output constraints (the TACs set for each species) the estimated effort in some future year that relates to each one of these separate TACs will be a different amount. Total effort is assumed to be species independent, and some estimate of effort is required. In order to allocate effort across all the stocks targeted, Sparre (2002) provides some advice in terms of choices:

1) the total effort will be the minimum effort of the estimated series (i.e. min ($Effort_{species(1)}$, $Effort_{species(2)}$, $Effort_{species(n)}$))
2) the total effort will be the maximum effort of the estimated series (i.e. max($Effort_{species(1)}$, $Effort_{species(2)}$, $Effort_{species(n)}$))
3) the total effort will be the arithmetic (or weighted) mean effort of the estimated series (i.e. mean($Effort_{species(1)}$, $Effort_{species(2)}$, $Effort_{species(n)}$)).

This mean could be weighted by yield, stock or the value of the yield of each stock.
Sparre (2004) notes that (1) above, would mean that the fishing is stopped as soon as the precautionary approach (a TAC) is exceeded for one stock, and (2) above would mean fishing is stopped only when the precautionary approach (a TAC) is exceeded for all stocks (except for the stock that the maximum relates to). Table 2 above uses a weighted mean by use of the fish prices and reflects option (3).

Since the best "choice" between the above mentioned cannot be derived theoretically, the selection relates to a management issue. However, it is critical to make a decision as to the choice (of assumption) above as it has major implications for the outcome.

The problem of determining effort in a mixed fishery, and/or the problem of combining input controls (days at sea) with output controls (determining what are the implications for harvest control rules), is highlighted again in section 2.1.1 and section 2.1.2.

1.1.7 Short run and long run

Bio-economic analysis and models should be used to derive long run target reference points for e.g. fishing mortality, effort and TAC, to show the potential economic benefits of each stock or fishery for industry and society at large. The annual advice from economic expert bodies, including STECF economists, should comment on the actual path proposed by the TAC recommending bodies – does it lead in the right direction or not? For biologically and/or economically overused stocks it is important to have a long run target, based on sound economic analysis, to strive for.

1.1.8 Sensitivity testing and thresholds

In general, bio-economics models should run on a regular, pre-agreed, basis in order to facilitate an environment where new ideas and data can feed into the scientific process. It is also important to run assessments and bio-economics models on a regular basis since input information is often in the form of very noisy time series which improve or change direction with time.

The question of how often bio-economics model should be modified has two elements that should be considered.

- A practical element – The modelling work is often a tedious and time-consuming process.
- In principle, the model output will probably influence the political and economic decision making process so its output cannot be changed too often.

New science or insight expresses itself in terms of basic assumptions which are underlying the model structure or in a form of a newly constructed model which produce a more robust or reliable output with the same data and/or basic assumptions. Also it needs to be recognised that modelling work is an ongoing process, introducing new models as they became available and so improving on the existing model.

New data can come in the form of updated existing data or as new data which were not used before.

A possible approach to the issue of how often one should run such a model and provide new advice is to run a set of sensitivity tests with two objectives:

- To present different outcomes under different input scenarios in order to highlight some of the uncertainty associated with the bio-economic model.
- More relevant to the discussion to assess the model robustness to certain input data or model assumption. Input information to which the model seems to be very sensitive should then be singled out as a possible trigger for new model runs.

If new assumptions to which the model are sensitive to are to be introduced, they should be motivated not simply by their possible impact on the model but also have some realistic/empirical basis. New assumptions that simply produce a better model fit should not be the sole justification to be included in the model, but should also reflect a certain empirical reality.

If new or updated data to which the model are sensitive to become available, these should justify a model rerun only if such data are crossing a threshold from which the model output is proved (using sensitivity tests) to be affected. Such thresholds should not only be set according to their possible impact on model output but also with regard to associated variance, in order to prevent overreaction to short term noise in the data. A possible approach to prevent overreaction is to use changes in the average of recent data (for example a moving mean of the last three years) as a trigger instead of the actual change in recent data points.

1.2 Methodologies on bio-economic advice with input control models

1.2.1 The inclusion of non assessed stocks into the biological component

The inclusion of a biological component in bio-economic models is justified when the end-user of the model wants to investigate the effect of management measures on the stocks, or more generally on the dynamics of the marine living resources.

A bio-economic model of a fishery should include a set of state variables describing the evolution of some quantity related to the stocks, assuming that the relationship between the biological and the economic boxes are mediated by fishing mortality (F). Fishing mortality is usually made proportional to effort (E), which can be considered an output of the economic box.

In the particular case of fisheries regulated by effort and selectivity (most Mediterranean fisheries but also some coastal fisheries in the Atlantic) the biological part needs to include necessarily a biological model describing the dynamics of the population and how these dynamics are affected by changes in E, q or S (irrespective of whether the dynamics of E, q and S are endogenous or exogenous to the model).

Several types of biological models are available, from “simple” surplus production models to more data demanding age-structured models. The choice of the biological model is justified by the management measures to be tested, but also by data availability. If the end-user wants to test selectivity related measures, the model must necessarily be age (or size) structured. In this case, the biological data must include some sort of population assessment, usually of the VPA type.

Considering the difficulty in obtaining reliable assessments for some stocks, the input-driven models presented or known to the group (e.g., MEFISTO, MOSES, BIRDMOD and COBAS) propose different approaches to modelling the biological box.

The MEFISTO model assumes that one or more stocks are assessed[3] (in the fishery being analyzed) and these stocks are considered “main species”. Other species making up the entire catch for a fleet are considered “secondary species” and their dynamics are endogenised simply as *catch(second species) = f(catch(main species))*. The functional form is estimated from data series on catches by fleet.

The COBAS model assumes equally that one or more stocks are assessed, but the dynamics of the non-assessed species are described by surplus production models, with parameters empirically determined from catch-effort series.

[3] In the sense of VPA-type assessment

The MOSES model does not use assessed stocks, but describes the dynamics of all species as a surplus production model or a partially age-structured model (Deriso-Schnute), with parameters estimated from catch-effort data.

The BIRDMOD model uses an age-structured model for the target species, and the Schaefer model for the group of accessory species. In the last case, parameters are empirically estimated from catch-effort series.

As an extension, even more complex biological models can be built in a bio-economic model if we were to include the ecological interaction among species (basically, predator-prey relationships), including non-fisheries species. This will be necessary for ecosystem-based bio-economic models.

1.2.2 Some stocks subject to assessment

In EU waters, not all species are subjected to regular assessment. This happens especially on species with a low economic value. This also occurs with non-quota species such as shellfish and cephalopods (some of which have a high commercial value, e.g. scallops, lobster, cuttlefish) but where there is difficulty in assessing age-structure. In the Mediterranean Sea this tends not to be the exception but the common tendency.

In Northern European waters, fleets target mostly quota species. However, in the English Channel and Western Approaches there are a significant number of regularly caught and important commercial species that are not subject to quotas. Fleets report catches relating to up to 50 species in this area, with only 15 under quota. This is addressed in the COBAS model (see Appendix).

In the Mediterranean Sea there are a low proportion of stocks assessed and routinely monitored. Furthermore, there is lack of connection between assessment and management, and lack of adaptive management.

This current situation is the result of the physical constraints of the Mediterranean (low productivity that turns into an overall low economic importance of fisheries) and its behaviour of a sub-tropical sea with high diversity of commercial species (100+) in “low” quantities, and the large quantity of small “artisanal” fishing fleets and many landing points.

However, some stocks e.g. hake, small pelagics, and valuable crustaceans are well studied and assessed; and there are fairly good data sets on landings since 1970, but not so good for effort or capacity.

Current knowledge is the result of scientific research projects (funded by EU, National and Local Administrations) rather than continued monitoring programmes, although this has been changing for the last 10 years.

Before 2000, stock assessments were carried out by Technical Consultations General Fishing Committee for the Mediterranean (GFCM, since 1949), the ICCAT, the CIESM-DYNPOP (1992-1999) and some others, as research projects. They wer not carried out on a regular basis, however.

But 2000, the GFCM, through the SCSA of the SAC, has been in charge of doing periodical assessments of several fisheries, as well as the ICCAT, the CIESM-Fisheries Science and some others, like research projects.

For the 27 species that should be assessed (***Merluccius merluccius***, *Micromesistius poutassou*, *Merlangius merlangus*, ***Mullus barbatus***, *Mullus surmuletus*, ***Pagellus erythrinus***, ***Boops boops***, *Psetta maxima*, ***Engraulis encrasicolus***, ***Sardina pilchardus***, *Sardinella aurita*, *Sprattus sprattus*, ***Trachurus trachurus***, *Trachurus mediterraneus*, <u>*Thunnus thynnus*</u>, <u>*Thunnus alalunga*</u>, <u>*Xiphias gladius*</u>, *Coryphaena hippurus*, *Lamna nasus*, *Prionace glauca*, *Isurus oxyrhinchus*, ***Aristeomorpha foliacea***, ***Aristeus antennatus***, *Parapenaeus longirostris*, ***Nephrops norvegicus***, *Eledone cirrhosa*, *Acipenser sturio)*, the assessment of three of them is done by ICCAT (underlined), while for the rest just ten of them are done on a somewhat regular basis (in bold), but not always in all areas.

1.1.3 Non-assessment stocks related to assessment stocks

This lack of stock assessments becomes of high importance when working with the biological component of the bio-economic models, especially if we take into account that almost all fisheries in the Mediterranean are considered multi-species. However, some multi-species fisheries can also be found in the Atlantic.

So, bio-economic modellers face that stock assessments for all the catch species are not available.

One solution to this problem is the one that the MEFISTO model uses, that is to divide the species between main species and secondary species. The main species are the ones that a stock assessment is available, so an analytic model can be used (growth model (length/weight; von Bertalanffy), Vector of individuals by age class, Vector of Natural mortality; Fecundity index, Reproduction and recruitment functions, etc. are known).

While catches of secondary species (sometimes also called accessory species) are classified by groups (e.g. small pelagics, crustaceans, etc.), which are put as a function of the main species catch, and the catches of the secondary species are then multiplied by a mean secondary species price. The relationship between catches of main and secondary species and the secondary species price are obtained through time series regressions.

Another solution is used in the COBAS model, where mostly age-structured models are used. However, for all shellfish and cephalopods surplus production models are implemented. In these cases, time series of catch and effort data are collated from which a dynamic projection model is constructed.

1.2.4 Catch-Effort Models

The use of a surplus production model is based on the relation between catch and effort data defined for each species. Generally, these models are used in a single-specific and single-gear fisheries. The most common catch-effort models are:

Schaefer model: $C_i = k_0 E_i - k_1 E_i^{\ 2}$

Exponential model: $C_i = k_0 E_i e^{-k_1 E_i^2}$

Pella and Tomlinson model: $C_i = k_0 E_i - k_1 E_i^{\ m}$

where E is the effort, C is the catch, and k_0, k_1 and m are parameters.

In the Mediterranean, most of the species are exploited with different fishing gears, consequently it is very difficult to define the total amount of effort exercised on a single stock. A possible solution is to define an equivalent effort independent from the different gears used to catch the same species.

An equivalent effort $E_{eq,i}$, can be defined as the weighted sum of the effort E_j of the N fishing systems competing for the same catch. This approach is used in the MOSES model (see Appendix III) to estimate both logistic (Schaefer and Exponential) and partially age-structured (Deriso-Schnute) models. The weights used to define the equivalent effort are computed endogenously, from catch and effort time series, via non-linear least squares techniques.

Also the BIRDMOD model uses a catch-effort model (Schaefer model) for the group of accessory species. In this case, the equivalent effort is estimated by a non-parametric approach.

1.2.5 Utility of the most recent information

It is always best to use the most recent information in a modelling framework, as long as temporal consistency is maintained in the data throughout. This ensures the most up to date advice. However, data updates on a regular basis (e.g. yearly) can be prioritised with knowledge about important changes. For example, if a specific stock status changes or an economic variable changes such as fuel price then inclusion of the most recent information must be aspired to.

There are two (linked) key issues with respect to no ICES co-ordinated stock assessment being available: non-quota species and species where there is a lack of knowledge about age-structure. For the most part, these issues occur together, although they may occur independently. There are many examples of highly important non-quota stocks for commercial fishing fleets throughout Europe. These include both finfish (demersal and pelagic), cephalopod and shellfish stocks. Generally, a lack of knowledge about stock age-structure is related to shellfish and cephalopods, although stocks in all categories may not be assessed at the ICES level (or may only be assessed sporadically) for given fisheries. However, member states do undertake stock assessments for non-quota stocks that are important to their country's fleets, which are not presented through ICES.

In such a situation, there are obvious impacts on the current state of knowledge regarding the stock status of non-quota species. Further, because of the very nature of non-quota species, the collection of data (particularly catch and effort data) by member states is not necessarily as rigorous as for the quota species.

GFCM (General Fisheries Committee for the Mediterranean) is having a similar function for the Mediterranean as ICES for the North-east Atlantic.

For these reasons, the following order of preference regarding the inclusion of non-ICES and non-GFCM assessed stocks in a bio-economic modelling framework is suggested:

(i) If available, an independent member state assessment should be used;
(ii) If time-series of catch and effort data are available then surplus production models or time-series production function models (e.g. Cobb-Douglas) can be used;
(iii) If recent catch and effort data are available then a constant CPUE (or perhaps a moving average based CPUE) or basic production function models (e.g. Cobb-Douglas) can be used;
(iv) Otherwise a constant catch (perhaps average or moving average) can be used.

1.3. Set bio-economic indicators that could be used as basis for the advice

A list of indicators and applicability to the short run and long run is provided below. Each year Member States are required to submit to the Commission a report on their efforts during the previous year to achieve a sustainable balance between fleet capacity and available fishing opportunities, Council Regulation 2371/2002[4], Article 14, and Commission Regulation 1438/2004[5], Article 12. In this respect bio-economic models and the development hereof is of utmost importance. Continued over-capacity and over-capitalisation will tend to maintain over-exploitation, which is likely to result in unviable fisheries.

The objective of managing the fishing capacity of the EU fleet is to achieve a balance between the capacity and available fishing opportunities. It is how the capacity that exists at a particular time is deployed and the availability of resources at the same time that will achieve the correct balance. Depending on the objectives of the managers, the desired balance between exploitation rates and resource availability could be achieved by a large capacity fleet being deployed for a small amount of time or a smaller fleet for a longer amount of time.

What information do we want from models? And how do we link this to our decision of where we want to go? Short run options are: economic impact, social impact, while long run options include: optimal fleet structure, resource rent and Maximum Economic Yield (MEY), and Maximum Sustainable Yield (MSY) commitment for all fish stocks (World Summit of Sustainable Development 2015).

The multi-objectives of CFP (Council Regulation 2371/2002) comprise goals that are in some sense contradicting:
- Biological/environmental
- Economic
- Social
- Sustainable development/exploitation

Bearing in mind that short run and long objectives may be in conflict as well, the challenge is to formulate trade-offs between short run and long run concerning:
- Stock levels (biological)
- Catches (consumers, downstream industries, e.g. processors, services)
- Fleet profits and NPV (economic)

[4] Council Regulation (EC) No 2371/2002 (OJ L 358 of 31 December 2002, p.59 -80)
[5] Commission Regulation (EC) No 1438/2004 (OJ L 204 of 13 August 2004, p.21-28)

- Fleet sizes/fishing activity/employment/harbour infrastructure (social)

1.3.1 Short-run indicators/input factors

1.3.1.1 What reference point do we use in the biological advice

Management advice from ICES is primarily based on biological reference points framed within the precautionary approach. The following extract from the Report of the ICES Advisory Committee on Fishery Management and Advisory Committee on Ecosystems, 2004, explains the form of ICES advice and the reference points used in formulating that advice.

The Form of ICES Advice

According to international agreements, including the United nation's World Summit on Sustainable Development in Johannesburg (SA) 2002, the management of human impacts on marine ecosystems should be based on the precautionary approach. Management based on the precautionary approach seeks to be risk averse. Society may furthermore choose to pursue specific benefits from the marine ecosystem such as transport, sustainable harvest of living resources, recreational activities, and deposition of waste. Management for benefit achievement would be bounded by the requirement for risk aversion as stipulated by the precautionary approach. ICES provides advice based on an ecosystem approach to management. In relation to a specific sector this advice will address specific issues arising from the practices within that sector. Beyond that, ICES also advices on the overall state of the ecosystem.

Fisheries advice

The fisheries advice is the result of a three-step process. Single-stock exploitation boundaries are identified first. These are the boundaries for the exploitation of the individual fish stock and are identified on the basis of its status, consistent with the Precautionary Approach and, if target reference points have been defined or management plans which are precautionary have been decided, in relation to targets or plans. The single-stock boundaries also include considerations of the ecosystem implications of the harvesting of that specific species in the ecosystem whenever such implications are known to exist.

Then mixed fisheries issues are addressed. For stocks harvested in mixed fisheries the single-stock exploitation boundaries will apply to all stocks taken together simultaneously. It is thus necessary to identify the major constraints within which mixed fisheries should operate and through this analysis identify the additional constraints that further limit the fishing possibilities. Such major constraints may be stocks in the stock assemblage which is outside precautionary limits and which therefore may become the limiting factor for all fisheries exploiting that stock. This implies that the stocks which are considered to be in the most critical state may determine the advice on those stocks which are taken together with critical stocks.

The second step is therefore to identify which species within mixed fisheries have the most restrictive catch limits, because these constraints, when applied across all species in mixed fisheries, further limit the fishing possibilities.

The final consideration regards those ecosystem concerns which are not related to one specific stock, but rather to mixed fisheries or to groups of stocks. Such concerns may for instance include habitat and biota impacts of dragged gear, incidental bycatches of non-commercial species, and food chain effects when such impacts are known to occur. Ecosystem concerns may represent further boundaries to fisheries beyond those implied by single-stock concerns and mixed fisheries issues.

The overall advice for mixed fisheries is thus threefold: 1) limit the harvest of a critical stock as bycatch or targeted catch to the limit applying to that stock across all fisheries; 2) harvest within single-stock exploitation boundaries for all other stocks; and 3) in the event that further ecosystem impacts of fisheries beyond removal of the stocks included in the assessments have been identified, such concerns may restrain specific fisheries further. The consequence may be that a fishery may fish less than the single-stock exploitation boundary for its target stocks if a critical stock is taken as a bycatch or other ecosystem concerns are to be addressed.

Single-stock upper boundaries on exploitation

The incremental introduction of the Ecosystem Approach supplements the Precautionary Approach implemented in the ICES advice on fisheries management since 1998. The single-stock upper exploitation boundaries that are fundamental building blocks of the ICES advice on fisheries management remain based on the Precautionary Approach biological reference points. These reference points are stated in terms of fishing mortality rates or biomass. They are predefined benchmarks (limit reference points) that should be avoided to ensure that stocks and their exploitation remain within safe biological limits and against which assessments should evaluate the status of the stock.

Risk aversion, based on the precautionary approach, defines the boundaries of management decisions for sustainable fisheries. Within these boundaries society may define objectives relating to benefits such as maximized long-term yield, economic benefits, or other ecosystem services. The achievement of such objectives may be evaluated against another set of reference points, target reference points, which may be measured in similar dimensions as limit reference points, but which may also relate to money, food, employment, or other dimensions of societal objectives. Target reference points will always be bounded by limit reference points and their associated uncertainties.

Reference points for risk aversion

For risk aversion ICES advises within the following framework. The single-stock exploitation upper boundaries are aimed at restricting the risk that the spawning biomass falls below a minimum limit. The minimum spawning stock biomass benchmark is described by the symbol B_{lim} (the biomass limit reference point). The value of B_{lim} is set on the basis of historical data, and chosen such that below it, there is a high risk that recruitment will be impaired (seriously decline) and on average be significantly lower than at higher SSB. When information about the dependence of recruitment on SSB is absent or inconclusive, there will be a value of SSB, B_{loss}, below which there is no historical record of recruitment. B_{lim} is then set close to this value to minimize the risk of the stock entering an area where stock dynamics are unknown.

Below B_{lim} there is a higher risk that the stock could collapse. The meaning of collapse is that the stock has reached a level where it suffers from severely reduced productivity. Collapse does not mean that a stock is at high risk of biological extinction. However, recovery to an improved status is likely to be slow, and will depend on effective conservation measures.

The fishing mortality rate should not be higher than an upper limit F_{lim} which is the fishing mortality that, if maintained, will drive the stock to the biomass limit. Spawning biomass and fishing mortality can only be estimated with uncertainty. Therefore, operational reference points are required to take account of this. To keep the true risk low that spawning biomass falls below B_{lim}, the estimated spawning biomass should in practice be kept above a higher level to allow for this uncertainty. Therefore, ICES applies a buffer zone by setting a higher spawning biomass reference point B_{pa} (the biomass precautionary approach reference point). As long as the estimate of spawning biomass is at or above B_{pa}, the true biomass should have a low probability of being below B_{lim}. Therefore, ICES advises that when the spawning biomass is estimated to be below B_{pa}, management action should be taken to increase the stock to above B_{pa}. Because B_{pa} is a mechanism for managing the risk of the stock falling below B_{lim}, the distance between these reference points is not fixed, but will vary with the uncertainty of the assessment and the amount of risk society is prepared to take. For example, if the quality of catch data were to decline, or multi-year forecasts were required for catch advice, a higher B_{pa} would be needed for the same B_{lim}. The same is true if society will only accept a very low risk that the true biomass is below B_{lim}.

Similarly, to be certain that fishing mortality is below F_{lim}, fishing mortality should in practice be kept below a lower level F_{pa} that allows for uncertainty as well. ICES advises that when fishing mortality is estimated to be above F_{pa}, management action to reduce it to F_{pa} should be taken. Such advice is given even if the spawning biomass is above B_{pa} because fishing mortalities above F_{pa} are not sustainable.

ICES stresses that these precautionary reference points should not be treated as management targets, but as lower bounds of spawning biomass and upper bounds of fishing mortality. Good management should strive to keep SSB well above B_{pa} and fishing mortality well below F_{pa}. If management keeps stocks very close to their precautionary reference points, then annual scientific advice will be altering conclusions on stock status and necessary management actions on the basis of assessment uncertainty as much as on the basis of true changes in stock status. Managing stocks to achieve targets well removed from the risk-based reference points would result in more stable scientific advice, as well as healthier stocks and more sustainable fisheries. The spawning stock should always be kept above B_{pa}. The fishing mortality should be kept below F_{pa} in order to achieve this. If a management plan exists which ensures that the SSB will be kept above B_{pa}, F_{pa} may temporarily be above F_{pa} as long as there are mechanisms ensuring a downward adjustment before SSB approaches B_{pa}.

ICES gives advice on many stocks for which there are no analytical assessments and accordingly no basis for setting reference points as described above. In these cases ICES also uses a precautionary approach, but alternative models are applied, with reference points referring to properties of the stock or fishery that can be estimated, for example catch per unit of effort instead of biomass.

Target reference points

The ICES advice is primarily risk-averse, i.e. it aims at reducing the risk of something undesirable happening to the stocks. Biological target reference points are also part of the

Precautionary Approach, but setting targets for fisheries management involves socio-economic considerations. Therefore, ICES does not propose values for Target Reference Points, and until recently Management Agencies had not identified management targets based on socio-economic benefits. Hence, Target Reference Points have not been used directly in the advice. This means that even if the ICES advice is followed and therefore the stock should be protected from impaired productivity, exploitation of most stocks is likely to be sub-optimal, i.e. the long-term yield is lower than it could be.

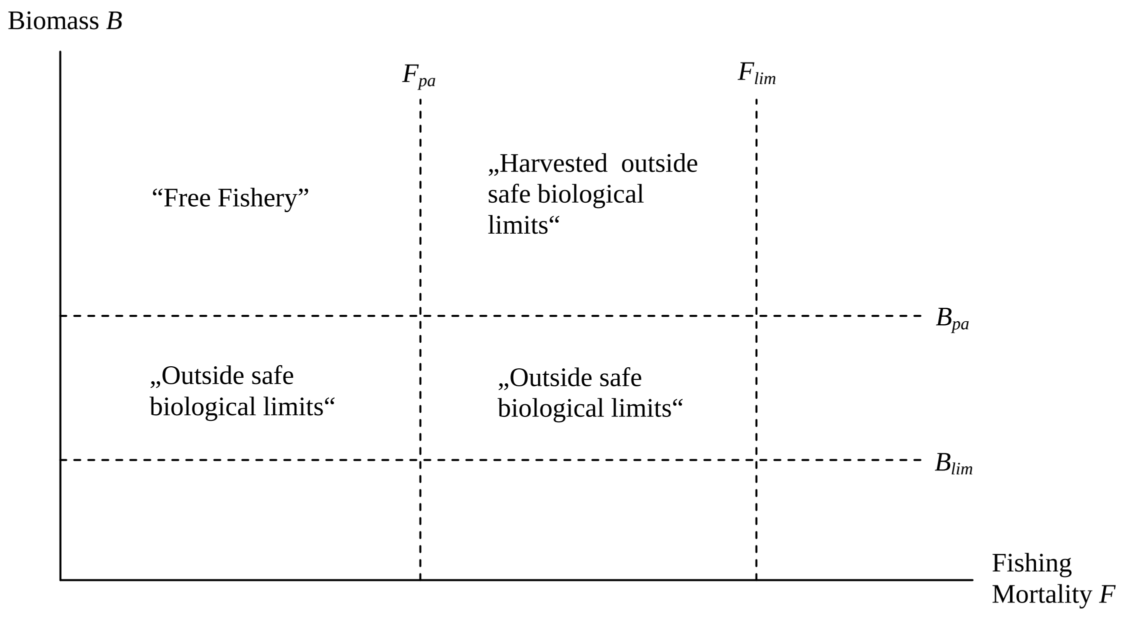
When societal objectives or targets have been identified ICES can provide advice relating to these targets. ICES may advise on the likeliness of achieving targets under different management regimes and may propose parameters and values for target points if a basis for such choices has been defined in fisheries policies.

Managers are invited to develop targets and associated management strategies. ICES will comment on these and consider if they are consistent with the precautionary approach. If they are, ICES will frame the advice to be consistent with the adopted management targets.

Language of fisheries advice

The framework used to phrase the advice in relation to the precautionary approach relies on the assessment of the status of the stock relative to precautionary reference points. When an assessment estimates that the spawning biomass is below B_{pa} ICES classifies the stock as being outside safe biological limits, regardless of the fishing mortality rate.

Figure 2. Target reference points following the precautionary approach



Source: Hubold (2002)

When a stock is below B_{pa} ICES will provide advice to increase the spawning biomass above B_{pa}, which may involve reducing fishing mortality to levels below F_{pa}, possibly by a large amount. If B_{pa} cannot be achieved in the short term, ICES will recommend the development of a recovery plan specifying measures to increase SSB above B_{pa} in an appropriate time scale, depending on the biological characteristics of the stock and other relevant factors.

When an assessment shows that the stock is above B_{pa} but that the fishing mortality is above F_{pa}, the stock is classified as harvested outside safe biological limits. ICES will then recommend that the fishing mortality be reduced below F_{pa} in the short term. However, referring to safe biological limits has in some cases misled clients and other stakeholders to consider stocks described as being outside safe biological limits to be biologically threatened (i.e. close to extinction). The term outside safe biological limits is used in international agreements and has been used by ICES in the past to classify stocks for which the spawning biomass is below B_{pa}. While ICES considers this language to be perfectly justified and in accordance with international practices, the attention of ICES has also been drawn to instances of confusion in the public debate where outside biological limits has been equated to biological extinction. ICES has therefore from 2004 used a phrasing which more specifically refers to the concept on which this classification is based, by referring to the reproduction capacity of the stock in relation to spawning stock biomass, and sustainable harvest in relation to fishing mortality. It should be emphasized that the expressions outside safe biological limits and being at risk of reduced reproductive capacity, or suffering reduced reproductive capacity, are considered entirely equivalent by ICES and that the change in language does not imply any change in judgement of the seriousness of the situation when a stock is outside safe biological limits, and thereby outside precautionary limits. The present ICES classification scheme is equivalent to the terminology used before:

- Biomass:
    - stock having full reproductive capacity is equivalent to inside safe biological limits;
    - stock being at risk of reduced reproductive capacity or suffering reduced reproductive capacity is equivalent to outside safe biological limits.

- Fishing mortality:
    - stock harvested sustainably is equivalent to harvested inside safe biological limits ;
    - stock harvested outside precautionary limits is equivalent to harvested outside safe biological limits.

The following terminology for the State of the stock is used in this report:

For the status relative to SSB: Based on the most recent estimates of SSB, ICES classifies the stock as

- $SSB > B_{pa}$: having full reproduction capacity.
- $B_{lim} < SSB < B_{pa}$: being at risk of reduced reproductive capacity.
- $SSB < B_{lim}$: suffering reduced reproductive capacity. OR at a level where the stock dynamics is unknown and therefore risking reduced reproductive capacity (in the case where B_{lim} is the lowest observed).

The two last categories were earlier referred to as outside safe biological limits.

For the status relative to fishing mortality: Based on the most recent estimates of fishing mortality ICES classifies the stock to be

- $F < F_{pa}$: harvested sustainably.
- $F_{lim} > F > F_{pa}$: at risk of being harvested unsustainably.
- $F > F_{lim}$: harvested unsustainably.

Also here the two last categories were earlier referred to as outside safe biological limits.

1.3.1.2 Economic indicators in the Concerted Action EAEF

The economic indicators used in the Concerted Action EAEF (Economic Assessment of European Fisheries) apply to both the data collection of the AER and to the EIAA model. Emphasis has been put on a few well defined indicators that have been divided into indicators of known concepts from vessels accounts (economic indicators) and indicators of interest from a socio-economic point of view (other economic indicators), see table below concerning the AER and the EIAA. Difficulties as to how to assess investments, although included in the list, have caused that an indicator such as 'return on capital' have been avoided. Result from EIAA calculations are basically presented by use of the same indicators as in the AER, see Table 3.

Table 3. Indicators used in Concerted Action EAEF (Economic Assessment of European Fisheries)

AER (Annual economic report)		EIAA	
Report text	**Appendix (time series)**	**Summary (over time)**	**Extended (one year)**
Economic indicators mEUR			
Value of landings Gross value added Gross cash flow Net profit	Value of landings Fuel costs Other running costs Vessel costs Crew share Gross cash flow Depreciation Interest Net profit Gross value added	Value of landings Crew share Gross cash flow Net profit Gross value added Op.profit margin (%) Classification (words)	Value of landings Fuel costs Other running costs Vessel costs Crew share Gross cash flow Depreciation Interest Net profit Gross value added Op. profit margin (%) Classification (words)
Other economic indicators			
Employment on board (FTE) Invested capital (mEUR) Fleet - number of vessels Fleet - total GT (1000) Fleet - total kW (1000)	Employment on board (FTE) Invested capital (mEUR) Effort (1000 days at sea) Volume of landings (1000t) Fleet - number of vessels Fleet - total GRT (1000) Fleet - total GT (1000) Fleet - total kW (1000)		See below

The 'Op. profit margin' and 'Classification' indicators are based on Operating profit margin defined as net profit in proportion to gross revenue, see Table 4. The indicator is well known from business economics and is often used instead of 'return on capital' which is defined as gross revenue minus variable costs in proportion to invested capital.

Table 4. Classification criteria used in EIAA

Classification	**Operating profit margin** (Net profit / gross revenue)		
Profitable	5%	and more	
Stable	-5%	and up to	5%
Unprofitable	-5%	and below	

In the EIAA reports the classification is elaborated in the presentation of projected results. The operating profit margins of the base line years and the projected year are compared to show the impact of the proposed quotas for the projected year. The interval from minus 5 % to 5 % indicates that the fishing activity would continue in the short, medium and long run even if the fixed costs (interest and depreciation) cannot be covered (negative net profit). In the long run these costs must be covered and the economic performance is deemed unprofitable if the operating profit margin is minus 5 % and below. The criteria are arbitrarily fixed.

Further to highlight the economic repercussions in the short run an 'impact indicator' has been defined.

'Impact' = Impact of the TAC in YEAR+1 on operating profit margin compared to current YEAR

- 'Worsened' = Segment was making losses, losses now greater
- 'Improved' = Segment was making losses, losses now smaller
- 'Lower' = Segment was making profits, profits now lower
- 'Higher' = Segment was making profits, profits now higher
- ' – ' = No significant change.

1.3.1.3 Break-even as reference point on fleet segments and species volume

The break-even concept shows the required landings value to cover fixed cost, given the contribution to the margin per unit landings value. The break-even landings value is then the value that breaks even between contribution margin and fixed cost entailing zero net profit. The break-even landings value in proportion to the realised landings value is an indicator of overcapacity or undercapacity respectively in business terms. In an overcapacity situation the fixed costs are too high to be covered by the contribution margin from the landings, and indicate that capacity ought to be reduced and *vice versa*.

The extended list of indicators in the EIAA, cf. Appendix I.3, includes estimates of the 'break-even' value of landings, partly to show the demand to the value of landings to break even i.e. cover fixed costs, and partly to estimate ‘overcapacity’ by use of the ‘break-even’ information in combination with the actual or projected value of landings.

The definition of break-even is: *Break-even Revenue = Current Fixed costs / (Current Cash Flow/Current Revenue).*

If Break-even revenue and the actual revenue is compared an indication of the change of the fixed costs in order to comply with break-even is obtained. Assuming that fixed costs are a proxy for capacity an indication of over and under capacity is provided. The result does not indicate whether a required change in fixed cost actually is possible, only that it is necessary.

The applied definition of overcapacity is: *Over-capacity = 1- (Revenue / Break-even Revenue)*

A potentially informative use of the break-even indicator would be to estimate, for each fleet segment, the catch required to break even assuming the status quo catch composition for each segment. The break-even catches for each stock could be summed over fleet segments giving an indication of the degree of imbalance between the fishing capacity at break-even and resource availability.

1.3.1.4 Value added indicators

From a socio-economic point of view remuneration of capital and labour is of interest. The Gross Added Value expresses the Added Value that the segment contributes to the National Economy. This includes: salaries, profits, opportunity cost of capital and depreciations. It can be obtained by deducting the fixed and costs related to fishing (except the labour costs) from the total landing value.

Another interesting indicator is the value added per kg of fish, which consists of dividing the Gross Added Value by the total kg of fish landed. This indicator offers a view of the economic importance of the landings in volume terms. Both indicators are complementary, and in need of each other, for a robust analysis.

1.3.2 Long-term indicators

1.3.2.1 Production surplus models, Length of time to recover, NPV comparison

Production surplus models such as the Gordon-Schaefer model predicts a long run bio-economic equilibrium where Catch Per Unit of Effort (CPUE) equals the ratio of the cost per unit effort a to price per unit harvest p, i.e. $CPUE = a/p$. Time series for catch and effort, as well as for effort costs and fish prices, are important sources of information that may be used in cases where fisheries independent stock assessment is not undertaken. CPUE time series should be used with great care as indicators of stock changes due to the unknown stock-output elasticity and efficiency changes.

In the short term (i.e. the following year), constant assumptions can be made about the structure of a given fleet and that fleet’s activity. The longer term is indicated by either a static equilibrium solution or a dynamic solution. In the former, as used to indicate a "recovered state" in the EIAA model[6], no information can be given as to the length of time it would take to achieve that state, or even if that state can be achieved (especially given assumptions about a constant fleet). Hence, an indication of profitability of a fleet at a snapshot in time (i.e. "now") for any potential future scenario carries obvious misinterpretations. In the dynamic solution, a path (typically by year) to some future situation is given. This can account for changes in activity (i.e. changes in effort allocation by gear/species/area) and can take account of changes in fleet structure. These will clearly be dependent on the management options modelled and assumptions made. However, in the dynamic case, economic indicators over time can be presented that allow the assessment of the full effects of management measures on fleets to be ascertained. With respect to the biology, time to recovery given scenarios for alternative fishing mortalities (or time to some other target) can be provided (e.g. North Sea Cod recovery evaluations). These can indicate the probability of recovery at each time step and as such the uncertainty associated with recovery.

In the dynamic case, typical indicators can be used such as gross revenue, intermediate consumption, gross cash flow and net profit, as a yearly path is evident. In addition, a comparison of net present values (NPV) is possible in the dynamic case. In comparing the present values of alternative management strategies in order to achieve a policy objective (e.g. a recovery program or MSY for stocks), it is common to discount net benefits that will accrue in the future compared to net benefits that can be achieved at present. Discounting is included because investment in fisheries must compete with other investment opportunities with a positive rate of return. A second argument is the assumption that future generations are better off. In the case of fisheries this means at least constant catches, in an overuse situation an expectation of higher stocks and catch possibilities in the future. This needs to be addressed by the social planner. Typically, a cost–benefit analysis will discount streams of net benefits and compute the NPV as a single number. The theory is that standard discounting is meant to ensure that the present value of net benefit calculations provides a meaningful indication of whether the efficiency criterion is satisfied or not.

There are many arguments for and against discounting future benefits and costs, especially controversial is the choice of the discount rate (as the outcomes are highly sensitive to the rate). When evaluating policies, the market interest rate can be used as the discount rate but didn't really reflect all long-term effects. High discount rates favour myopic policies that continue to exaggerate unsustainable resources whereas discount rates that are too low can fail to capture the efficiency argument because other opportunities to invest the capital are more profitable. Sensitivity of the outcomes of a range of discount rates (e.g. 2-7%) can be undertaken in order to illustrate the possibilities. The alternative management strategy that achieves the highest NPV (with constraints for other criteria – such as sustainability) is as such the "best" choice.

1.3.2.2 Economic Sustainability Indicator

The economic sustainability depends on the capacity of the sector to attract money. To guarantee the investment of financial resources in the long term, it needs to protect the fishery investment profitability. So, the economic sustainability could be measured by comparing the

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[6] The "recovered state" in the EIAA model indicates the quotas of each individual stock where they have reached an equilibrium level at which they can be fished at F_{pa} (i.e. the fishing mortality at which levels of recruitment give a 95% probability of avoiding stock collapse).

profitability of the fishery investments in vessel capital and fish stocks on one hand and in alternative sectors on the other.

Of course, the possibility to invest in more profitable economic sectors, or with the same profitability with less risk, determines a reduction in the investments in the fishery and compromises its sustainability in the long term.

Based on the considerations exposed above, it is possible to define some specific indicators which allow measuring the sustainability level from the economic point of view.

A feasible indicator to measure the economic performance of a fleet segment could be the ROI (Return on Investment). The ROI indicates the percentage ratio of net profit plus the opportunity cost in relation to the investment.

In order to effectively interpret the information obtained through the indicator, some reference values can be applied (RPs, reference points). These values can be associated with either a difficult or an optimal (or sub-optimal) situation. The former identifies a limit which is necessary to avoid (LRPs, limit reference points), while the latter represents a target to be attained by the system (TRPs, target reference points).

The indicator suggested to measure the economic sustainability is calculated by comparing the investment profitability rate (ROI) for a specific fleet segment within a specific geographical area with the theoretical risk free rate, for example the long-term treasury bonds rate. By using a difference as indicator, the LRP equals to zero and remains constant over time.

The difference between the two rates allows us to evaluate the profitability of an investment in the fishery with regards to a risk free investment. When the ROI value is lower than (or very close to) the long-term treasury bonds rate, i. e. when the economic sustainability indicator is negative or very close to zero, it is not profitable to invest in the fishery and the financial resources will be directed to public bonds or to more profitable alternative investments. Such a situation can be defined as unsustainable from an economic point of view.

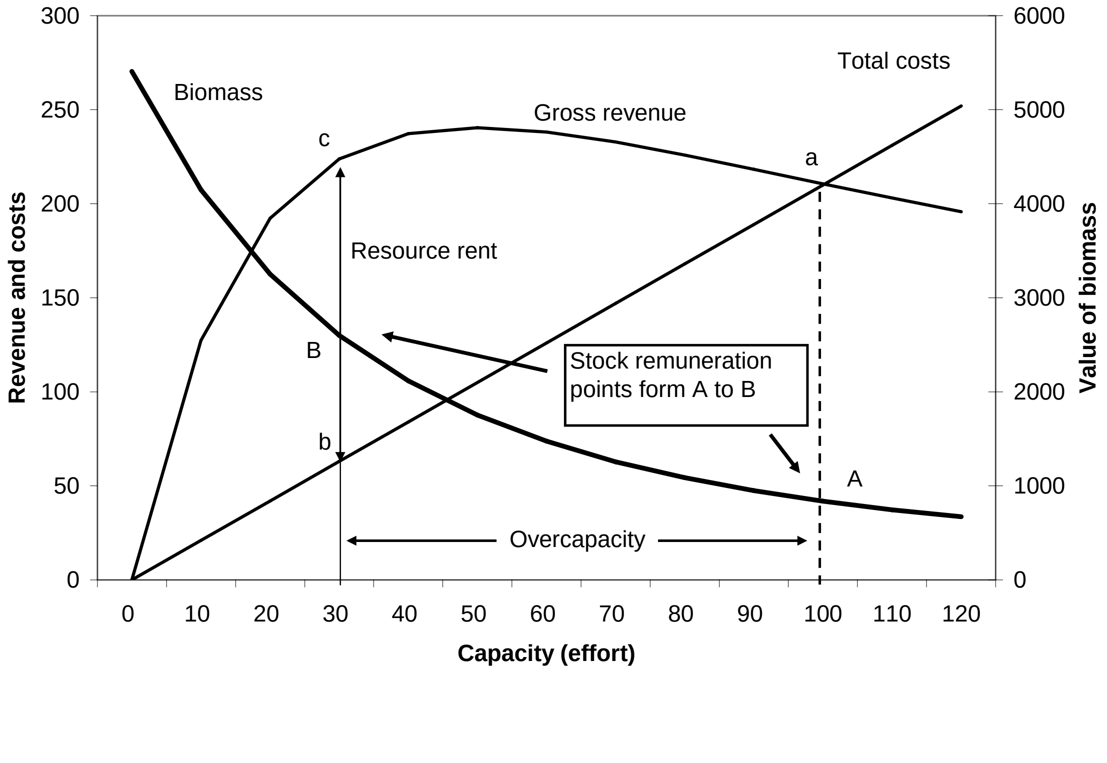
In case of limited information on invested capital it is possible to use other more easily available information's from vessel owner statements to create an indicator for economic sustainability. The development of own capital (equity) reflects the stability of a company. It is not possible to stay in business in the long run with decreasing own capital over many years. Additionally, huge amounts of external capital compare to low amounts of own capital mean high risks of bankruptcies in case of lower catch possibilities than expected.

1.3.2.3 Remuneration of spawning stock biomass (SSB)

Remuneration of the biomass (resource rent), e.g. the spawning stock biomass (SSB), is parallel to remuneration of man made capital. Information about SSB is extracted from ACFM reports and allocated to specific fleet segments according to the share of their catch relative to total EU catch. The biomass value (VSSB) is determined via the net profit, if this information is available. Otherwise one could use a share of gross value. The interest rate could correspond to the level used in public investment projects (e.g. roads, bridges). These interest rates differ between countries (e.g. Denmark 6 %, Norway 8 %).

An indicator evaluating the current VSSB(current) relative to VSSB(precautionary), determined according to the precautionary approach SSB, should be aimed at but elaborated further with respect to multi-species versus single species stock recovery and optimal fleet adaptation, cf. Figure 3, points *A* and *B*, respectively. In well-managed fisheries the resource rent *b* – *c* reflects the remuneration of the biomass of a single species. In fisheries characterised by overcapacity e.g. the intersection between gross revenue and costs at point *a* the resource rent is dissipated. Ideally the resource rent should be estimated and included as an opportunity cost of fishing, but such an exercise is data demanding. An alternative is to use VSSB multiplied with a socio-economic interest rate. Two possible options are indicated in Figure 2 – a rent dissipated option at *A* and a 'maximum resource rent' option at *B*. None of these, however, coincide with ideal resource rent *b* – *c*. Using the VSSB indicators, for a well managed fleet segment or stock $\frac{VSSB(current)}{VSSB(precautionary)} = 1$, while $\frac{VSSB(current)}{VSSB(precautionary)} < 1$ in a fishery that is not managed in an optimal way.

Figure 3. Remuneration of the biomass, the concepts of resource rent and overcapacity



The EIAA model is prepared for possible estimates of remuneration of the fish stocks i.e. includes measure for resource rent. The value share VSSB of the fish stocks allocated to each fleet segment is calculated in proportion to the segment's quota share of the total TAC. The issue requires further development and is not presented as part of the EIAA results in published reports for example SEC (2004) 1710.

1.3.3 Aggregation

There are two different aspects on the level of aggregation that are used for economic indicators: the level at which economic indicators is used within the models and the level at which the results are presented.

The level needed for the use of economic indicators in the models depends on the type of model used. In the EIAA model, only totals per fleet segment are used to predict the effects of TACs on the economic performance of fleets, but some reaction of the fishermen to prices, TAC levels and availability of the species is accounted for. In dynamic simulation models a fisherman’s behaviour is modelled by means of comparison of economic indicators of different fishing strategies. Therefore, average economic indicators are needed to model the behaviour of the fishermen in such models.

Since all of the models are used for management purposes, the output indicators should fit the data needs for managers. For biological purposes total economic indicators are best (assessing fishing mortality), and are used to present averages per vessel group. In case of stable fleets, total economic indicators will be more indicative for developments in the economic performance, but in case of changing fleet structure, other levels of aggregation (per vessel, per kW, per GT) might be more indicative for the actual developments.

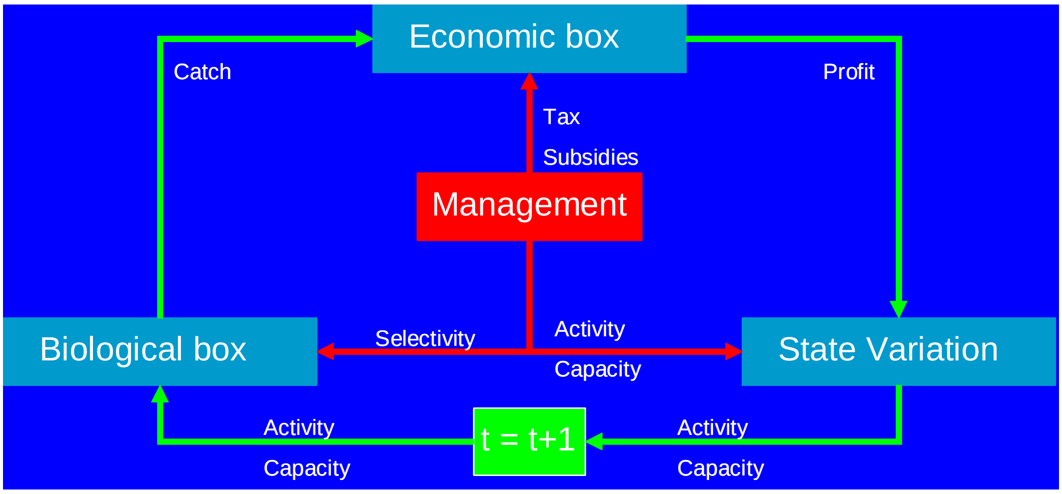
2. Types of models

2.1 Production systems

2.1.1 Model approach and model causality in a single period

The intention of this brief introduction and discussion is to show that the model structure must reflect the aim of the model. A very general structure of a dynamic simulation model is represented in the following figure 4:

Figure 4. The structure of the BIRDMOD model



The model structure is composed by four main components: The biological; the economic; the state variation; and the managerial box. The first three components are useful to simulate the natural dynamics of fisheries:

- a biological box simulates the evolution of the biomass state within the stocks affected by the fishing activity;
- an economic box simulates the evolution of the fleet state in terms of economic variables;
- a "state variation" box outlines the dynamic relations among the endogenous variables of the model by using some predetermined behaviour rules.

The management box exogenously determines variation in the model variables. Within a HCR-input context, the management measures can be directed to modify the level of effort, in terms of activity, capacity or selectivity, exercised on the natural resources. More specifically economic measures also can be implemented, in terms of tax rate variations and subsidies.

In fisheries production systems where the number of stocks is different from the number of fleets, harvest control rules (i.e. restrictions) require that choices have to be made outside the model if several restrictions in terms of limited catch or effort have to meet. These choices are *inter alia* about the permitted discard, the permitted deviation from certain revenues per fleet segments, etc.

Fisheries production systems require the presence of fish stocks and capital in terms of fishing vessels including crew. If the biological box and the economic box of figure 4 is illustrated in a table format, the production system could be described as three-dimensional problem as in Table 5. The interior of the table could be landings measured in either quantity or in value.

Table 5. 3-dimensional table format of species, vessels, and landings

		Segment 1	Segment2	Total landings
Fish species (stocks)	Species 1	$Landings_{11}$	$Landings_{12}$	l_1
	Species 2	$Landings_{21}$	$Landings_{22}$	l_2
	Species 3	$Landings_{31}$	$Landings_{32}$	l_3
Gross revenue		r_1	r_2	

If such a table is expanded to show more explicitly the interaction between fish stocks and fishing vessels, the implication is the following production system that is augmented with cost *c* (a function of days and vessels) and profit π, which is the difference between revenue and costs see Table 6.

Table 6. A fish production system displayed in table format

		Fleet segments (days/vessel * vessels)		Landings	Discards	Harvest
		d_1*nv_1	d_2*nv_2			
Fish stocks	sb_1	a_{11}	a_{12}	l_1	u_1	h_1
	sb_2	a_{21}	a_{22}	l_2	u_2	h_2
	sb_3	a_{31}	a_{32}	l_3	u_3	h_3
Revenue		r_1	r_2			
Costs		c_1	c_2			
Profit		π_1	π_2			

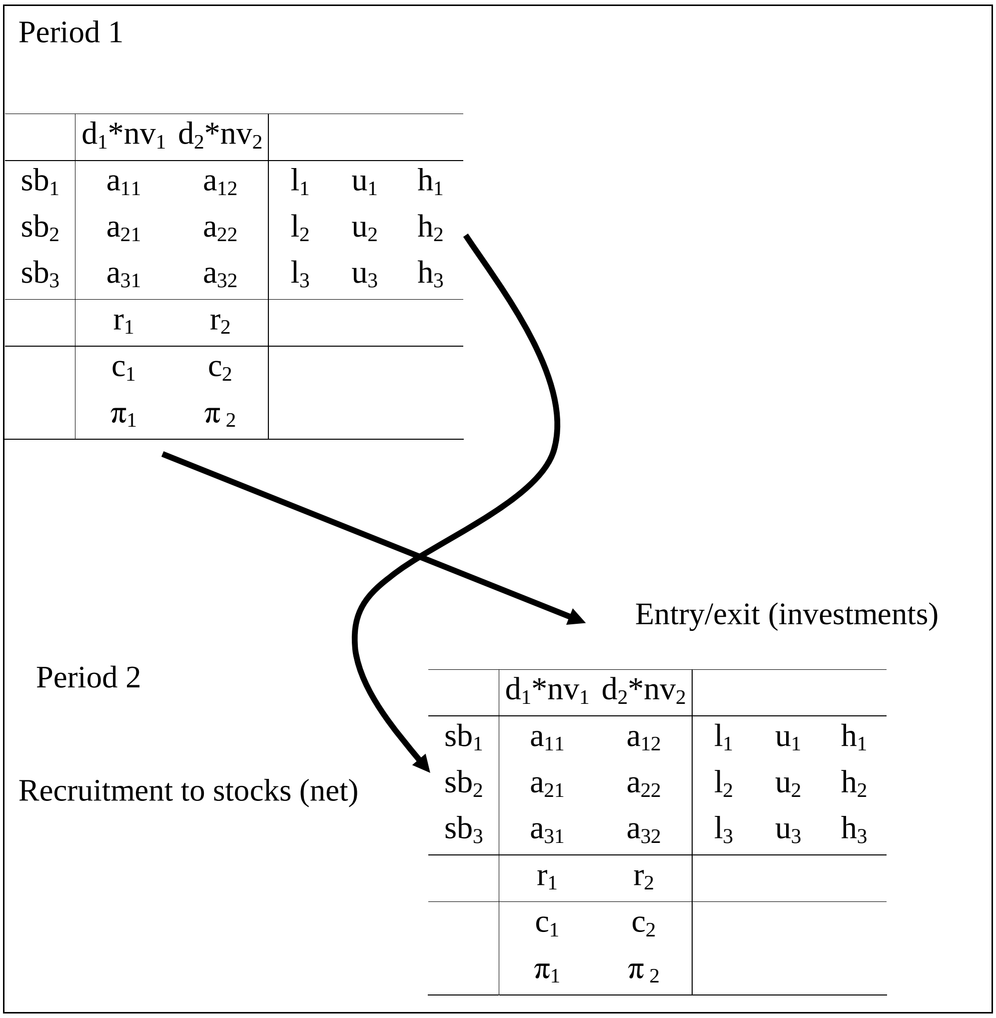
sb is the stock size and *a* relate effort to harvest for a given stock (catchability coefficients), and *nv* and *d* denote number of vessels and sea days.

2.1.2 Inter-temporal interaction

Further complications arise **when** the production system is turned into a dynamic system working over time, see figure 5. The harvest together with recruitment to the stock in one period determines the stock size in the next period. However, profit per segment in one period also determines the size of the segment by the number of vessels (and days) in the next period through an investment function.

The catch rates *a* are assumed to be constant but the stock biomass and the effort in terms of days * vessels will change over time. Harvest control rules applied in one period will impact landings and profit in this period, and fish stocks and effort in the following period.

Figure 5. The inter-temporal relationship in a bio-economic production system



The cycle of a bioeconomic model is practice more complicated than illustrated in figure 4. The implication of this is that in one type of models the cycle works one way round, and in other types of models the cycle works the opposite way round. It is not possible to shift direction in the same model.

The core of the problem can be illustrated for a single fishing area and a single period in time to avoid complications with many areas and time periods, which will not change the basic feature. A simple set of equations based on table 6 will illustrate the problem.

In a system consisting of two fleet segments catching three species the harvest *h* of each species, i.e. landings *l* plus discards *u*, per stock *sb* is determined by the product of sea days, number of vessels, fish stock, and catch per day. The revenue of each fleet segment is composed by several species and is calculated by aggregating the landings for each fleet segment. For "input driven" models box 1 shows the set of equations. "Input driven" models are controlled by effort (vessels * sea days per vessel) and influenced by stock biomass (state variable). There are two "output": harvest and revenue calculated in different ways. These two "outputs" influence the next period in different ways. But that can be handled in one model.

Box 1. A 'fish production' system shown in equations. The "input driven" approach of MEFISTO, BIRDMOD and TEMAS

Harvest per species:

1. $h_1 = (a_{11} * d_1 * nv_1 + a_{12} * d_2 * nv_2)sb_1$
2. $h_2 = (a_{21} * d_1 * nv_1 + a_{22} * d_2 * nv_2)sb_2$
3. $h_3 = (a_{31} * d_1 * nv_1 + a_{32} * d_2 * nv_2)sb_3$

This approach can be formulated in terms of fishing mortality *f* as:

4. $h_1 = (f_{11} + f_{12})sb_1$
5. $h_2 = (f_{21} + f_{22})sb_2$
6. $h_3 = (f_{31} + f_{32})sb_3$

The revenue *r* per fleet segment (landings per species multiplied with prices *p*) is determined by:

7. $r_1 = (p_{11} * a_{11} * sb_1 + p_{21} * a_{21} * sb_2 + p_{31} * a_{31} * sb_3)d_1 * nv_1$
8. $r_2 = (p_{12} * a_{12} * sb_1 + p_{22} * a_{22} * sb_2 + p_{32} * a_{32} * sb_3)d_2 * nv_2$

In multi-species fisheries, the revenue *r* of each segment is determined by the sum of the shares of each stock taken by the segment. For simplicity, prices are assumed to be one and cost to be linear in days and vessels.

It should be observed that a multi-species and multi-fleet production system includes a number of 'weighting' procedures represented by the *a*-coefficients that can be handled in different ways according to the assumption about the production system - e.g. are the species caught separately or are they caught jointly, and which species are target and non-target species? The weighting procedure is of great importance; see the discussion in paragraph 1.1.6.

Contrary to above, “output driven” models are controlled by landings (or harvest if possible) and influenced by the state variable stock biomass. The “output” from this model is effort *e* (the product of number of vessels and days per vessel), in which the number of vessels in the short and medium-long run are less flexible and therefore leave the no of sea days per vessels to adjust. This is shown in box 2. Therefore, it is often convenient to construct a new model where effort is a function of the biomass and the landings with a different set of ‘catchability coefficients’ *b*, rather than try to derive results by use of the system 1-8.

Box 2. The “output driven” approach of the EIAA

Fishing effort e is sea days multiplied with number of vessels for each fleet segment

9. $$d_1 * nv_1 = e_1 = \left(b_{11} * \frac{h_1}{sb_1} * + b_{21} * \frac{h_2}{sb_2} + b_{31} * \frac{h_3}{sb_3} \right)$$

10. $$d_2 * nv_2 = e_2 = \left(b_{12} * \frac{h_1}{sb_1} * + b_{22} * \frac{h_2}{sb_2} + b_{32} * \frac{h_3}{sb_3} \right)$$

Harvest in proportion to the stock is also the fishing mortality rate in a simple form

11. $$d_1 * nv_1 = e_1 = \left(b_{11} * f_1 * + b_{21} * f_2 + b_{31} * f_3 \right)$$

12. $$d_2 * nv_2 = e_2 = \left(b_{12} * f_1 * + b_{22} * f_2 + b_{32} * f_3 \right)$$

The same type of ‘weighting’ problems arise as above represented by the *b*-coefficients with respect to jointness or non-jointness, target and non-target species as discussed above. And it is noted that the fishing mortality rates and the catchability coefficients have different interpretations.

2.1.3 Implications of harvest control rules

Management is implemented by different rules often called harvest control rules (HCR). A number of cases is touch upon below. If the harvest control rule is based on setting fishing mortality rates *f*, each segment must be assigned a rate, cf. equations 4-6. Further, *f* is a function of or in the simplest form equal to the product of the catch rate, the number of fishing days per vessel and the number of vessels, cf. equations 1-3. Hence, *f* has to be determined by setting the catch rates *a*, number of days and the number of vessels.

If the harvest control rule in the system is days, number of vessels and costs (for example charges or subsidies), the landings can be calculated if the stock size and catchability rates are known. Changes in technical measures will change *a*.

If the harvest control rule is in terms of days, the number of vessels and/or costs (charges or subsidies) the gross revenue *r* per segment can be calculated if prices, stock size and catchability rates are known, cf. equations 7-8. If the aim by harvest control rules is to obtain certain revenue per fleet segment, the effort (product of days and vessels) can be calculated for the segments if prices, catch rates and stock sizes are known. If, however, the aim is to determine the size of quotas to satisfy given gross revenues for given efforts, this is in most cases not possible**.**

If the harvest control rule, however, is maximum harvest, e.g. determined by a quota, and if the stock biomass and the catch rates for each stock and fleet segment are known, then effort (equal to the product of number of vessels and sea days per vessel) of the segments cannot in most cases be calculated in the input driven system cf. box 1; 1-3. It is not possible to find an effort value for the two segments that 'match' all three species quotas. Either discards will occur, or some of the quotas are not taken.

If the harvest control rules are set in terms of number of vessels and fishing days per vessel, and initial stock sizes are known, the system works. But if harvest control rules in terms of quotas are introduced, there are two options: 1) Augment the model with restrictions and tell the model what to do if a restriction becomes binding; 2) Turn the model procedure upside down so that effort is a function of the quotas.

If harvest control rules are set in terms of both input control and output controls: 3) Augment the model with restrictions and let the model find a solution subject to a goal that has to be laid down in advance.

The model approach presented in Box 1 is input based. This approach also includes TEMAS, ECONMULT, MEFISTO, and COBAS. Option 2) shown in Box 2 is handled by quota based models such as the EIAA, and option 3) is handled by optimisation models EMMFID, MOSES, and SRRMCF.

2.2 Review of models used

Several bio-economic models have been developed concerning different aspects of EU fisheries. Central contributions are:

1. EIAA: Economic Interpretation of ACFM Advice
2. TEMAS: Bio-economic model to assess the effect of technical management measures
3. MOSES: Bio-economic models for Mediterranean fisheries
4. BIRDMOD: Methodological Support for a Bio-Economic Model of Population Analysis of Demersal Resources
5. MEFISTO: MEditerranean FISheries Tool
6. EMMFID: Economic Management Model of Fisheries In Denmark
7. SRRMCF: Swedish Resource Rent Model for Commercial Fishery
8. COBAS: A dynamic bio-economic model of the fisheries of the South-West to determine the costs and benefits of sustainable fisheries management
9. ECONMULT: Bio-economic multispecies models of the Barents Sea fisheries

A brief review of the models is presented below, and a more detailed description of the models is found in the Appendix. A full understanding of the models and how they operate would require an explicit exposition of the equations, the dataset, and ideally various tests of the models for robustness. This is, however, outside the scope of this report.

2.2.1 Objectives

MEFISTO is a bio-economic simulation model developed with the aim to reproduce the bio-economic conditions in which Mediterranean type fisheries occur (excluding large pelagic species). By Mediterranean type of fisheries are understood input managed fisheries, so the model has been possible to be used outside the Mediterranean Sea, as it has been proven in Pernambuco (Brasil) modelisation.

Once the bio-economic conditions are reproduced it is possible to simulate alternative management strategies and predict the bioeconomic implications on the fishery (for both fleets and stocks).

Likewise, BIRDMOD is a simulation model. Focus is on Italian fisheries and the general objective is to provide a modelling framework capable to address population analysis of demersal resources. The EIAA model is constructed to assess the economic consequences of the TAC proposals formulated by ACFM, by making use of the data collected and disseminated in the annual economic reports (AER) produced by the Concerted Action EAEF. Consequences of TAC proposals and other management initiatives can also be evaluated by use of EMMFID. The model is an optimization programme that determines a detailed allocation of effort, and is developed for the fisheries in Denmark. SRRMCF is similar to EMMFID and developed for the Swedish fishery. MOSES is also similar to EMMFID and concerns Italian fisheries. It is an optimization programme with biological constraints that estimates optimal allocation of fishing effort by gear and area. COBAS is a simulation model for the English Channel and the Western Approaches (ICES division VII d-j) and takes a stakeholder perspective. The model is under development and is to be used to assess a range of management options for stock recovery for the South-West, over a 15 year time horizon. TEMAS is also a simulation model with a generic frame to evaluate the effect of technical management measures to fisheries, with focus on management of fleet capacity rather than management of SSBs by TACs. ECONMULT is a simulation model that includes species in the Barent Sea that have high commercial value. Structure variables relate to the structure of the fleet and decision variables describe the existing regulation systems.

2.2.2 Scope

The EIAA model operates at EU level. Based on cost and earnings data and the biological advice for TACs from ACFM (Advisory Committee for Fisheries Management of ICES) it projects[7] the economic situation for a given fleet segment. It is a one-year calculation and does not directly incorporate biological repercussions, since there is no biological module inside the model tracking stock dynamics over time. Stock abundance is used in the model to calculate changes in catch per unit effort. Stock assessment is indirect in the sense that it is carried out outside the model and then used as input (in form of proposed TACs and estimated SSBs, or alternatively long run sustainable SSBs and TACs). The EIAA model currently covers eleven Member States, and 113 management areas. It is fully flexible with respect to the number of fleet segments. EMMFID comprise the entire Danish fishery and approaches

[7] Projection is defined as a calculation where all variables and parameters are fixed except the TAC/quotas, while a forecast includes changes in several variables e.g. oil prices and fish prices.

the fishery from the producer side, i.e. the dimensions are 26 fleet segments, 118 species, 34 management areas, and 14 regions. It is fully flexible with respect to the dimension of these variables. With the proper adjustments and data it can include fishing fleets from other EU member states than only the Danish. Optimal allocation of fishing effort, in terms of fishing days and number of vessels (with respect to fleet segment, geographical origin, area and month), is determined when an objective is pursued (e.g. overall industry profit) subject to biological and technological constraints. Stock assessment is carried out outside the model, as is the case with EIAA. Both models are continuously updated with available data. MOSES also determines optimal allocation of effort (with respect to area and gear type). Profit (value added) is maximized subject to biological constraints. The model concerns the areas surrounding Italy and focus on bottom trawlers and multipurpose vessels. SRRMCF in its current version operates with 14 fleet segments. The area dimension is determined by the gear and species, and season is included as it operates on month.

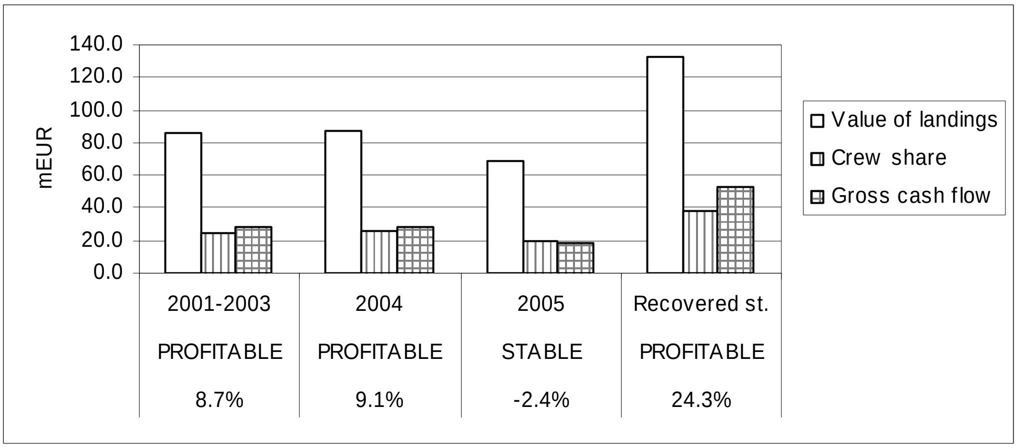
TEMAS, BIRDMOD, MEFISTO, ECONMULT and COBAS all include a biological module that model stock dynamics over time. It is simulated how fishing activities, stocks and economic outcomes interact. TEMAS is a generic framework that models the effect of technical management measures in fisheries. The model can be divided into the operating system and the management regime. The operating system includes the biological and the production (economic) module, where the biological part involves a multi-species age structured setup. The "true" system is simulated (stocks and fisheries) with the operating system, which will produce input data to the management regime. This management regime reflects the advising and management process, where the input data will be used in a traditional assessment, which in turn will be used to generate management advice.

BIRDMOD models the Italian demersal fisheries. The simulation is conducted within four "boxes", the biological box, the economic box, the state variation box and the managerial box. As for TEMAS the biological part involves a multi-species age structured setup. The economic box calculates prices, cost and gross profit. Based on the economic outcome the state variation simulates the fishermen behaviour assuming (individual) profit maximization. Finally, the management box enables us to choose from a pool of management measures usually adopted by the Public Administration. The pool includes restrictions of fishing effort, such as temporary withdrawal or capacity reduction plans, and technical measures, such as changes in the mesh size of trawls. MEFISTO simulate the particular behaviour of Mediterranean fisheries (specifically excluding large pelagics fisheries) in biological and economic terms. It allows for multi-species dynamics with technical interactions and multi-fleet dynamics, where the control variable is effort (not the catch). The model has a "Fisherman" module where fishermen can increase the capital invested in fishing. Effort and catchability is then fed into a "Stock" module that simulates resource dynamics. From the stock module catches are fed into the "Market" module where catches are converted into economic performance, which then serves as input to the fisherman module. COBAS simulates key fisheries of the fisheries English Channel and the Western Approaches. Concerns about recreational fisheries and environmental impacts associated with fishing activities (damage index for 'habitat' and impact on cetaceans) are included. Stock dynamics are simulated in a biological module and economic consequences and effort are simulated in an economic module. The fisheries are defined in terms of metiers (gear, species and area). ECONMULT is a multi-fleet simulation model for fisheries in the Barents Sea. A vector of biomasses links the biological part of the model to the economics. In ECONMULT the stocks are exogenously given, but in recent applications it has been coupled to the biological models PROST[8] and AGGMULT[9]. There are two types of variables in ECONMULT: Structure variables and Model variables. The Structure variables define the resolution of the specific fleet model (vessel groups, target species, biomass units, bolean switches and time units), while the Model variables represent ordinary variables in the fleet model that have been defined (decision and endogenous variables).

2.2.3 Output

EIAA is programmed in MS Excel and outputs several standard tables and bar charts. Due to the use of excel it is possible see the code directly, make changes and track consequences. An example of an output bar chart is shown in Figure 4. An output table is found in Appendix 1. The model is operated by FOI, but can be attained on request.

Figure 4. EIAA. Standard output chart for a fleet segment



TEMAS is, like EIAA, also programmed in MS Excel. Visual Basic applications are integrated to ease the use, e.g. via a menu for inputs and a menu for choice of scenario. TEMAS can provide extensive amounts of output (as many of the other models) and divides output into 1) stock structures output, 2) fleet structured output and 3) economic output. No standard output is defined. TEMAS is available on request from DIFRES. As for TEMAS, no standard output is defined for COBAS. Output is tailored for the specific analysis. COBAS is implemented in GAMS (www.gams.com) which requires specific programming skills to operate, but explicitly shows the equations of the model. The model is operating at CEMARE. EMMFID is also implemented in GAMS, while SRRMCF is programmed in LINGO, which is freeware. A standard table, cf. Table 7, that can be used to evaluate output is depicted below. Additional output can be generated on demand. The model is operating at FOI, and the

[8] See: Bogstad, B., A. Aglen, D.W. Skagen and M. Nygaard Åsnes, IMR, Bergen, Norway, and Y. Kovalev and N.A.Yaragina, PINRO, Murmansk, Russia (2004). Evaluation of the Proposed harvest control rule for Northeast Arctic cod. Working document no.3, AFWG 2004, ICES. Copenhagen 4-13 May 2004. Åsnes, M. (2005). PROST Users Guide, Institute of Marine Research, Bergen, April 2005.

[9] Tjelmeland, S. and B. Bogstad (1998). Biological modelling. In T. Rødseth (ed.) Models for Multispecies Management, Springer-Verlag, Berlin, pp.69-91.

source code is available if requested. However, the (very detailed) input data are generally not available due to confidentiality.

Table 7. EMMFID, Standard output table

	Number of vessels	Revenue	Contribution margin	Gross profit	Return on capital
Fleet segment 1 ------------------- 2 Fleet segment 26					
Total					

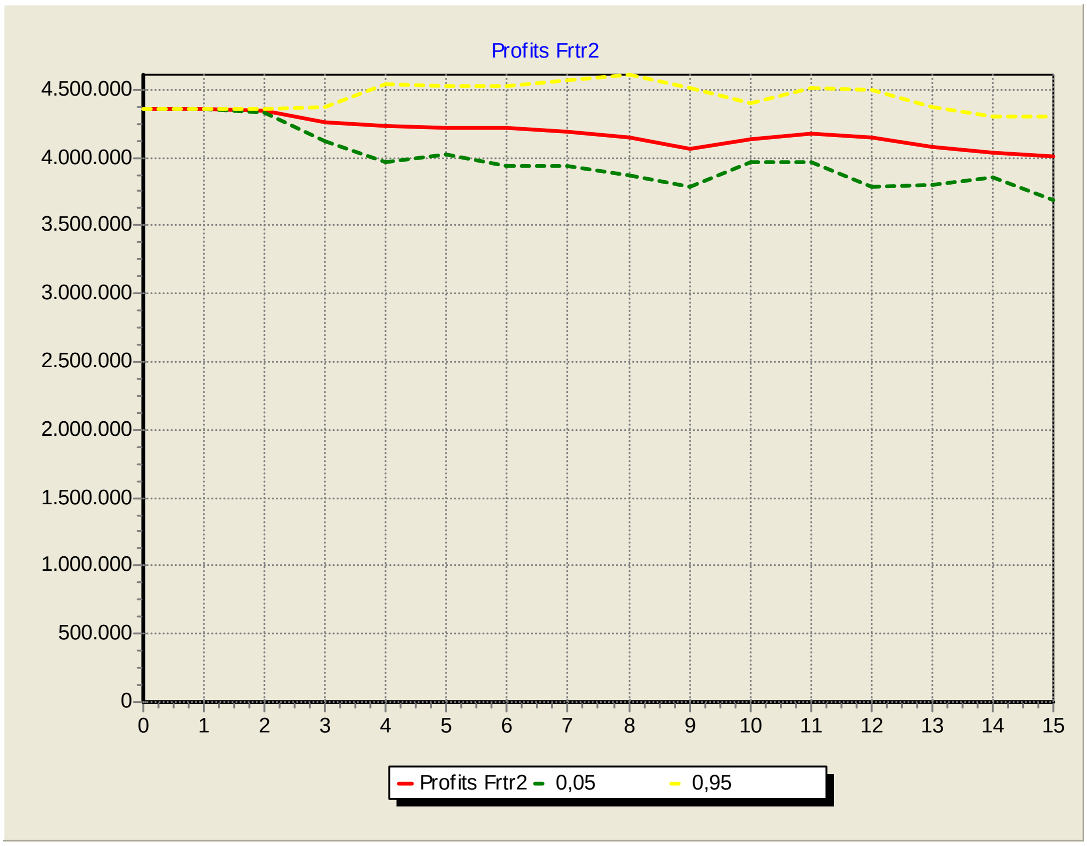
The last version of the MOSES (IBEM model) is programmed in Matlab. Two kinds of output are produced by the model, biological outputs and economic outputs. The biological component outputs long-term landings based on the Schaefer logistic curve for each species and area, and the economic component outputs the long-term added value. Biological and economic results are displayed for different levels of effort: the current level, the simulated levels (effort simulation), and the optimal level (effort optimization). The last output (effort optimization) is produced following four different scenarios: no constraints, biological constraint, inertia constraint, and biological and inertia constraints. All the outputs are displayed with standard graphs, and the data are easily exportable to excel spreadsheets. The IBEM version of MOSES is operating at IREPA and the software is available if requested.

In MEFISTO a range of standard graphs (e.g. stock, effort, recruitment, catchability, capital, vessels, profit) and custom graphs (stock, cohort, fleet, vessels) can be generated. All the output data values can be exported to a spreadsheet. MEFISTO is programmed in Pascal with a user friendly stand-alone application for Windows 98 or higher. No programming skills are needed to operate it and input data are imported from a spreadsheet. The software is free and the last version of the MEFISTO model is available at:
http://www.gemub.com/GEM2/emodelos_bioecomicos.htm.

The actual calculations are hidden from the end-user because MEFISTO was designed with the objective of being used by non-scientists, including industry and fisheries managers. However, the equations have been fully reviewed in workshops and articles (Lleonart et al., 1996, 1999, 2003 and Guillen et al., 2005). Furthermore, they are fully explained in the manual accompanying the software MEFISTO_userguide.pdf.

A standard output graph from MEFISTO is shown in Figure 5.

Figure 5. MEFISTO, Standard output graph – profit for a fleet segment



ECONMULT is implemented in Mathematica and operated at NFH. Programming skills (in Mathematica) is a necessary prerequisite to work with the model. The software is free and can be downloaded from http://www.nfh.uit.no/prosjektvis.aspx?id=60. ECONMULT is flexible with respect to output

BIRDMOD is programmed in Matlab. Its main output is an overall evaluation of the management measure simulated by the model. The evaluation is performed by considering the general economic outcome. This is calculated in terms of net profits, management expenses met by the Public Administration to impose the measure, social costs due to the measure adopted and, particularly, to the possible reductions of the sector workforce. The result is then compared to the trend of specific biological parameters, evaluated using appropriate Reference Points. All the outputs are displayed with standard graphs, and the simulation results are automatically saved on excel spreadsheets. BIRDMOD is operating at IREPA and the software is available if requested.

2.2.4 Structure

EIAA is a short term projection model. It is capable of calculating the economic performance on a fleet segment basis (for all EU member states), given the expected catch (TACs). It is output driven in the sense that it incorporates TACs that translate into landings. Output in terms of TAC/quota is determined outside the model and used as input in term of exogenous variables to the model. The activity, cost and economic outcome is then calculated accordingly. EMMFID, SRRMCF and MOSES are the other models that include TACs

(MOSES works with biological constraints) in this manner, but the catch is endogenously determined. On one hand, the optimal allocation of effort is dependent on the TACs, but on the other hand the output is determined via the effort. However, output could be fixed by inclusion of appropriate constraints, meaning that these models (uniquely) can be considered as either output- or input driven. EMMFID, SRRMCF and MOSES are optimization models. The optimal allocation of effort is determined when certain objectives are pursued, subject to biological and technological restrictions. TEMAS, ECONMULT, MEFISTO and COBAS can be considered as input driven.

MEFISTO is a simulation model for the economic and biological behaviour of selected fisheries in the Mediterranean. Indicators of the current situation are projected into the future. Alternative management policies can be simulated by changing the initial conditions: e.g., changing maximum fishing time, adding or removing taxes, increasing or diminishing the fleet size, etc. In all these cases the impact on the indicators of each boat, stock, price, etc. can be analysed.

BIRDMOD, ECONMULT, COBAS and TEMAS are also simulation models. In BIRDMOD dynamics of selected Italian fisheries are considered within four modules. These are the managerial, the biological, the economic and the state variation. Scenarios are formulated in the managerial module in terms of, for example, fishing effort, capacity reduction plans and technical measures. Operators are assumed to maximize profit (at individual operator level) and based on this the state of the system varies. ECONMULT simulates the effect of management on high value commercial fisheries in the Barents Sea: effort per vessel, quota (total or per vessel), taxes, closed seasons, closed areas, number of vessels and catch (total and per vessel). COBAS differs from the other models by being stakeholder driven. A steering group that is comprised of stakeholder representatives will determine the final strategy. The stakeholders represented each have a direct interest in the management and use of the fish stocks in the South-West, and they represent: statutory and conservation agencies, commercial fishing, fish processors, retailers, restaurateurs, regional development, recreational sea anglers, and environmental NGOs and conservation organisations. TEMAS provides a generic frame to simulate the effect of technical management measures to fisheries. It is made up of various modules describing the stocks dynamics, the harvesting process, the catchability dynamics, the economic analysis, the assessment procedure, the fisheries management, the implementation of the management tools, and the fishing strategies.

Simulation and optimization are different conceptual approaches. In optimization an optimal solution is found within the boundaries of a feasibility area defined by parameter values and model constraints. Simulation also relies on assumptions about parameter values, but in contrast to optimization it is a set of rules that determines the dynamic consequences (e.g. biological and economic) for the fishery in focus.

3. Relevant projects

The list of research projects including bioeconomic modelling or aspects of bioeconomic modelling is not exhaustive. Quite a few models have been developed over time, but many of them have been developed for specific tasks, are not well documented and even abandoned after use. The group has not carried out any serious attempt to trace all possible models, in particular, not those developed in third countries. The project or models listed subsequently are primarily included on basis of the immediate knowledge of the member of the working group.

Projects and models that seem worth noticing are:

- EFIMAS (extract from http://europa.eu.int/comm/research/fp6/ssp)
- COMMIT (extract from http://europa.eu.int/comm/research/fp6/ssp)
- PROTECT (extract from http://europa.eu.int/comm/research/fp6/ssp)
- BECAUSE (extract from http://europa.eu.int/comm/research/fp6/ssp)
- CAFÉ (extract from project proposal)
- MTAC (description from available references)
- LEM (description from available references)
- Resource rent in Norwegian Fisheries (description from available references)
- FEMS (extract from project proposal)

The following four project under EU's sixth framework programme: EFIMAS; COMMIT; PROTECT; and BECAUSE all include bio-economic modelling while CAFÉ comprises estimation of the relationship between capacity, effort and fishing mortality; and capital utilization.

3.1 Short description of EFIMAS, COMMIT, PROTECT, BECAUSE and CAFÉ

EFIMAS will develop a robust framework within which to simulate and evaluate the biological and socio-economic consequences of a range of fishery management options and objectives. That comprises development of a common programming platform in the programming language R: Fisheries laboratory using R (FLR) that will help researcher to run various bio-economic models. This project will end in Spring 2008. 29 pan-European institutes are involved.

COMMIT is closely linked to EFIMAS where the difference seems to be that in COMMIT more emphasize is placed on bio-economic modelling and short term biological and economic advice rather than on the programming platform. This project will end in Spring 2007. 12 pan-European institutes are involved.

PROTECT is directed towards investigations in marine protected areas, and the project is as such focussing on a specific management area. However, bio-economic models are developed in the project with the aim to assess the protection of sensitive species and the economic repercussion thereof. The project will end in Summer 2008, and comprises 17 partners.

BECAUSE is a modelling approach to assess sustainable management of entire marine ecological system. No bio-economic modelling is foreseen, however. The project will end in Spring 2007, and comprises 16 partners.

CAFÉ comprises estimation of relationships between capacity, effort and fishing mortality. In this respect the project will serve as information input when parameter values are being determined in bio economic models. The project will end in Spring 2009, and include 14 partners.

A more detailed exposition of these five projects is found below after the short presentation of other relevant models or projects.

3.2 FEMS (Framework for the Evaluation of Management Strategies)

This project and the associated projects mentioned in the description have been concluded or are close to conclusion. They are, however, included in the list to document the purpose and the link to other projects of relevance.

FEMS (as extracted from the project proposal) will develop a computer simulation framework for the evaluation of management strategies by undertaking a variety of case studies for stocks of importance to community states. The framework will consider sources of uncertainty not currently considered by International fisheries fora with the intention of developing methods that provide robust advice to managers consistent with the precautionary approach.

The impacts of human or socio-economic aspects on management systems is being considered by other EU projects and therefore to address these important issues FEMS was be part of an informal cluster of three projects ‘European fisheries management evaluation network’ dealing with the implementation of fisheries management strategies. The three proposed projects Policy and Knowledge in Fisheries Management (PKFM QLRT-2001-01-01782), European Advisory System Evaluation (EASE QLRT-2001-01693) and Framework for the Evaluation of Management Strategies (FEMS QLRT-2001-01824). This will help to eliminate overlaps, reduce costs and facilitate synergies, with the aim of having a bigger research impact. In addition it is proposed that a current project, Bio-economic modelling of Mediterranean Fisheries (BEMMFISH QLRT-2000-01533) be part of the cluster as well.

The main achievements will be to
(i) quantify the benefits of a variety of management strategies in terms of yield and probability of exceeding sustainable limits
(ii) develop alternative assessment/management strategies where appropriate,
(iii)compare management strategies of ICES and ICCAT,
(iv)contrast the responses of a variety of stocks (from data rich to data poor, from tropical to temperate species and from pelagic to demersal fish) to exploitation
(v) provide flexible free software that can be used by fish biologists to address a wide range of stocks and management questions.

(vi) to review the relevant biological and bioeconomic models used in the formulation of fisheries advice.

FEMS will provide software and methodology that will be used by other current EU proposals (e.g. PKFM, EASE, BEMMFISH and RASER) to evaluate the consequences of improving our understanding of fishery systems.

The project is be led by CEFAS, and partners include ICCAT, ICES, IEO, IFREMER and the Universities of the Azores and Miami.

1. Departamento de Oceanografia e Pescas/ Universidade dos Açores (DOP/UA)
2. Centre for Environment, Fisheries & Aquaculture Science (CEFAS)
3. The International Commission for the Conservation of Atlantic Tunas (ICCAT)
4. International Council for the Exploration of the Sea (ICES)
5. The Instituto Español de Oceanografía (IEO)
6. Institut Francais de Recherche pour L'eploitation de la mer (IFREMER)
7. The University of Miami (RSMAS)

The project is financed by the EU Programme Quality of Life and Management of Living Resources, Framework for the Evaluation of Management Strategies, Key Action 5 Sustainable agriculture, fisheries and forestry, and integrated development of rural areas including mountain areas.

3.3 MTAC

Although MTAC has been abandoned by ICES since 2005 a brief introduction is included here. The “Mixed Fisheries” working group of ICES is currently developing models suited for fleet based management, and a review of MTAC and other management models is found in Anon (2006). Mixed fisheries problem has been addressed by STECF at least since 2002 STECF (see STECF reports 2002; 2003; 2004) by the use of MTAC (Mixed Fisheries TAC) proposed by Vinther et al. (2004).

The MTAC advice seeks to make explicit the terms of the mixed fisheries problem, the nature of the trade offs necessary to be made by management. It points at the need for a political management decision before scientific advice can proceed in using it for specific advice. The STECF WG on mixed fisheries did not directly address the questions on effort regulation, but looked only into the problems of defining TAC’s which accounted for the mixed nature of most fisheries, in particular the demersal fisheries. The MTAC model as used by STECF to calculate TAC-advice, can also be used to calculate the effect of both fleet capacity reductions and limitations on sea-days. The STECF, however did not use the model for those purposes. The MTAC quota proposals have, formed basis for scenarios carried out in the EIAA model, see for example SEC (2004) 61.

3.4 LEM

The LEM Fishery Simulation Model is developed by professor Lee G. Anderson, University of Delaware, USA, and Excel programme is written by **L**ee G. Anderson, **E**miko Maruyama, and **M**aryjane Middelkoop in 2003. The model is available on request from Professor Anderson, lgafish@udel.edu.

The basic purpose was to provide a tool that Management Councils could use to show the economic effects of their management actions.

The general model is called LEM41a. The simulation models the joint commercial and recreational exploitation of a fish stock with 12 age classes where recruitment is a function of spawning stock size in numbers. The basic parameters of the model are the initial stock size and composition, the initial number of boats and recreational participants, the coefficients on the recruitment and individual growth equations, the age of sexual maturity, the catchability and natural mortality coefficients by age class, values for prices and costs and the parameters of the marginal willingness to pay function for recreational participants.

The model is capable of considering the effects of the following types of regulations.
1) commercial season length; 2) recreational season length; 3) commercial gear restrictions 4) commercial mesh restrictions 5) commercial size limits 6) recreational size limits 7) recreational creel limits 8) commercial limited days at sea programs 9) license limitations 10) commercial TAC 12) ("perfect") individual transferable quotas; 13) commercial annual fishing mortality controls

The spreadsheet which comprises LEM41a is made up of seven worksheets. The biological and economic parameters are set on the Data worksheet. The various regulations are turned on or off on the Regulation worksheet. The output of the model is presented on the Analysis worksheet. The simulation is produced by the interactions between the worksheets entitled Simulation and Fishing Mortality Coefficients with inputs from the Data and Regulation worksheets. The worksheet entitled Popdy provides some preliminary analysis of the stock recruitment relationship but it is not part of the actual simulation model. A description of the various parameters and other terms is provided in worksheet entitled Glossary.

The CD with the model contains the following files:

- LEMnew (Microsoft WORD) User guide and description of the model, which is applied to the Red Snapper and Red Grouper fisheries in the Gulf of Mexico.
- LEM41a (Microsoft EXCEL) This file contains the basic qualitative simulation model.
- LEMsnapper (Microsoft EXCEL) This file contains the modified LEM model that was calibrated to the red snapper fishery.
- Snappertemplate (Microsoft EXCEL) This file contains a template for displaying the results from runs of the LEMsnapper model.
- LEMgrouper2 (Microsoft EXCEL) This file contains the modified LEM model that was calibrated for the red grouper fishery using the most recent stock assessment.
- Groupertemplate (Microsoft EXCEL) This file contains a template for displaying the results from runs of the LEMgrouper2 model.
- Grouper (Microsoft Powerpoint) This file contains a powerpoint presentation that uses the results of the grouper model to analyze the biological and economic effects alterative regulation considered by the GMFMC.

3.5 Resource rent in Norwegian Fisheries

In 2005 a study about resource rent in Norwegian fisheries were accomplished the Institute for Research in Economics and Business Administration, Bergen Norway, cf. Steinshamn (2005). In this study was used an optimization model very similar to the EMMFID and the SRRCF models, but less detailed. It was (is) programmed in GAMS. The purpose of the study was to calculate the resource rent in Norwegian commercial fisheries under various assumptions, and assess consequences for employments, the value added, and the distribution of the resource rent.

The model comprised 10 species and 25 fleet segments according to the classification of the Norwegian Fisheries Directorate. Landings, costs, and earnings statistics of the Norwegian Fisheries Directorate was used. When the results are presented, the segments are, however, aggregated to 11 groups, which comply with the 'managements groups' of Norway. The model calculates the best possible composition of vessels in the fleet in order to maximize the resource rent, subject to the restrictions that the quotas must not be exceeded and each vessel is not allowed to catch more than its capacity.

3.6 Extended description of EFIMAS, COMMIT, PROTECT, BECAUSE and CAFÉ

3.6.1 EFIMAS: Operational Evaluation Tools for Fisheries Management Options

Overview:

EFIMAS will develop a robust framework within which to simulate and evaluate the biological and socio-economic consequences of a range of fishery management options and objectives. The project will:

Use models that will run stochastic simulations incorporating data from selected EU fisheries

Compare range of management options generated with the current management of the test fisheries

Compare the performance of a range of management options under alternative management systems and objectives

Contribution to policy development:

EFIMAS will provide more reliable scientific management advice to fishery managers, including robust management evaluation tool and framework driven by numerically defined harvesting rules

The project will develop an evaluation framework of existing and new interactive fishery advice and management models that identify the socio-economic, as well as the biological, consequences of given management decisions

The project will help restore the somewhat shaken trust of stakeholders by incorporating a wider range of variables to illuminate the decision-making process and make it more accessible to them.

Project deliverables

- Review of present management and decision-making processes – April 2005
- Preliminary software package with documentation – October 2006
- Final software package with documentation – June 2007

Dissemination

- Project website launch – June 2004
- Mid-term reports and newsletters – October 2005, April 2007
- Final project reports and documentation – April 2008

Technical information

Research priority: Modernisation and sustainability of fisheries, including aquaculture-based production systems
Specific webpage: http://www.efimas.org
Proposal/contract no: 502516
Start date: 1/4/2004
Completion date: 31/3/2008

Coordinator:
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10. Institute of Marine Biology of Crete (IMBC) Greece
11. National Centre for Marine Research (NCMR) Greece
12. Marine Institute (MarInst) Ireland
13. Institute of Marine Research (IMR-No) Norway
14. Institute of Marine Research, National Board of Fisheries (IMR-Se) Sweden
15. Swedish Nat. Board of Fisheries, Institute of Freshwater Research (NBF) Sweden
16. Sea Fisheries Institute (SFI) Poland
17. Instituto Tecnologico Pesquero y Alimentario (AZTI) Spain
18. Institute for Fisheries Management and Coastal Community Development (IFM) Denmark
19. University of Portsmouth (CEMARE) United Kingdom
20. Agricultural Economics Research Institute (LEI) Netherlands
21. Danish Research Institute of Food Economics (FOI) Denmark
22. Institute for Research in Economics and Business Administration (SNF) Norway
23. Istituto Ricerche Economiche Pesa e Aquacoltura (IREPA) Italy
24. Imperial College of Science, Technology and Medicine (IMPERIAL) UK
25. Consejo Superior de Investigaciones Cientificas (CSIC) Spain

26. Universitat de Barcelona (U.Barcelona) Spain
27. Universidad de País Vasco / Euskal Herriko Unibertsitatea (U. Basque C.) Spain
28. Departamento de Economía y Empresa. Universidad Pablo de Olavide (UPO) Spain
29. University of Helsinki (U.Helsinki) Finland
30. University of Newcastle (UNEW) UK

3.6.2 COMMIT: Creation Of Multi-annual Management Plans for CommITment

Overview:

COMMIT aims to improve the scientific basis for the long-term sustainable planning of fishery management, while identifying any short-term biological and socio-economic consequences. The project will:

- Evaluate management plans that reduce annual fluctuations in exploitation and encourage stakeholder commitment
- Base these strategies upon harvest rules and develop them explicitly to recognise various uncertainties
- Carry out a socio-economic analysis to identify mechanisms affecting the commitment of key stakeholders

Contribution to policy development:

- COMMIT will support the main elements of the Common Fisheries Policy, such as sustainable fisheries and an economically viable fishing industry
- COMMIT will identify robust management strategies that reduce the uncertainties currently besetting fishery management
- The project will involve greater stakeholder recognition of and compliance with the management framework
- Management decisions based on the COMMIT models will provide greater security to fishermen

Project deliverables

- Specification and implementation of robustness trial operating models – August 2005
- Specification and implementation of final trial operating models for each of the principal case studies – December 2006
- Completed harvesting and management strategy software with full documentation – March 2007
- Final report on specification of the final trials – April 2007

Dissemination

- Detailed report on the specifications of the robustness trials – October 2005
- Report on the current management procedures for each case study – April 2006
- A series of reports and draft papers on the various aspects of the project – April 2007

Technical information

Research priority: Modernisation and sustainability of fisheries, including aquaculture-based production systems
Specific webpage: Details not yet available
Proposal/contract no: 502289
Start date: 1/4/2004
Completion date: 31/3/2007

Coordinator:
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6. Finnish Game and Fisheries Research Institute (FGFRI) Finland
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8. Imperial College of Science, Technology and Medicine (IMPERIAL) UK
9. Instituto de Investigação das Pescas e do Mar (IPIMAR) Portugal
10. Agricultural Economics Research Institute (LEI) Netherlands
11. Netherlands Institute for Fisheries Research (RIVO) Netherlands
12. National Centre for Marine Research (NCMR) Greece

3.6.3 PROTECT: Marine Protected areas as a tool for ecosystem conservation and fisheries management

Overview:

PROTECT seeks to provide European policy-makers with improved tools for the identification, design and management of MPAs. It will bring together the collective expertise of 17 leading European marine research institutes who will:

- Evaluate the potential of MPAs as a tool to protect sensitive species and habitats against the effect of fishing
- Develop scientific methods and information products to design and evaluate the effect of MPAs
- Co-operate with other EU-funded projects, such as EMPAFISH
- Organise a series of thematic workshops and compile reports that will draw from experience and lessons learnt from specific case studies

Contribution to policy development:

- PROTECT directly addresses the policy priority for assessing the potential of marine protected areas for marine environment protection and fisheries management, as expressed in Elements of a Strategy for the integration of environmental protection requirements into the Common Fisheries Policy (COM 2001.143)

- PROTECT will support the EU in pursuing its objectives for the conservation of marine biodiversity and the establishment of MPAs, as agreed in the Convention on Biological Diversity in Rio de Janeiro (1992), at the UN Environment Summit in Johannesburg (2002) and at the OSPAR-HELCOM Ministerial conference in Bremen, June 2003

Project deliverables

- Initial review of MPAs as management measures – July 2005
- A series of scientific tools and knowledge products to design, monitor and evaluate MPAs, including:

1. Strategies to monitor and assess MPAs
2. Meta-database on MPA information
3. Ecosystem indicators
4. Stock specific spatial models; multi-species and multi-fleet models; bio- and socio-economic models

- Case specific information through studies on specific ecosystems in the Baltic Sea (top-down controlled ecosystem); the North Sea (a wasp-waist ecosystem); and the North East Atlantic (deep sea coral reefs) – ongoing
- Synthesised information for EU policy support, including:

1. Improved scientific advice on MPAs to achieve their objectives with respect to target species and ecosystems
2. Improved scientific advice on MPA impacts on fisheries and socioeconomic consequences
3. Recommendations on legal strategies to be adopted for establishing MPAs

- Policy Implementation Plan, June 2008

Dissemination

- Project website – Project leaflet – Project newsletter – CD-ROM of all project information and reports compiled
- Thematic workshops on MPAs – Dialogue meetings with non-project stakeholders - International symposium on MPAs
- Proceedings from thematic workshops – Scientific papers in peer-reviewed journals and presentation at international meetings – Articles for popular scientific journals - Annual project report – Policy Implementation Plan - Final Project report

Technical information

Research priority: 1.3. Modernisation and sustainability of fisheries, including aquaculture-based production systems
Proposal / contract no: 513670

Start date: January 2005
Completion date: June 2008

Coordinator:
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3.6.4 BECAUSE: Critical Interactions BEtween Species and their Implications for a PreCAUtionary FiSheries Management in a variable Environment – a Modelling Approach

Overview:

The sustainable management of European fisheries requires an adaptive approach that takes into account the long-term dynamics of the entire marine ecosystem so as to protect the biodiversity of our seas.

- BECAUSE investigates the interaction between predator and prey, and the shifts in their relative populations
- The project also looks into how fishing affects the balance of the marine food chain
- The interactions targeted for investigation include sandeel/predator fish, predators and prey of cod, and hake/prey fish

Contribution to policy development:

- BECAUSE will help integrate a sustainable ecosystem approach into the EU's Common Fisheries Policy (CFP)
- The project will help the EU meet its global fishing commitments and underwrite the sustainability of ecosystem services

- It will improve multi-species fisheries assessment and propose optimal policy and management measures to replenish fish stocks and ensure high yields
- It will result in an integrated and holistic approach to fisheries management and conservation

Project deliverables

- Revision and development of consumption rate models – March 2005
- Food web models and time series of diet overlaps between key predators – April 2005
- Development of various process models – October 2005
- Integration and validation of BECAUSE-enhanced process sub-models into existing multi-species models – February 2006
- Quantification of various multi-species models – June 2006
- Assessment of multi-species fisheries management strategies – January 2007

Dissemination

- Website launch – March 2004
- Project newsletter – August 2004
- Mid-term activity report – August 2005
- BECAUSE final report – March 2007

Technical information

Research priority: Modernisation and sustainability of fisheries, including aquaculture-based production systems
Specific webpage: http://www.rrz.uni-hamburg.de/BECAUSE/
Proposal/contract no: 502482
Start date: 1/03/2004
Completion date: 28/2/2007

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3.6.5 CAFÉ: Capacity, Fishing mortality and Effort

Extract from the project proposal states that there have been numbers of measures to reduce both the fleet capacity and to limit fishing effort. It is often assumed that a reduction of capacity will lead to a reduction in effort. Most previous research in this area has attempted to link fishing effort to mortality e.g. TECTAC (QLRT-2001-01291). The project comprise the fleet capacity, and the links to effort and then to mortality.

Therefore, this project is designed to analyse and quantify these relationships. It will examine the links between capacity and effort using state of the art modelling tools. The concept of “capacity utilization” will be central to determining the links to fishing effort.

The project will work with four case studies;

1. North Sea pelagic fisheries targeting herring and mackerel
2. Biscay pelagic fisheries targeting anchovy, sardine, mackerel and horse mackerel
3. North Sea mixed demersal fisheries targeting gadoids and flatfish
4. Biscay & Celtic Sea mixed demersal fisheries targeting hake and *Nephrops*

The project will collate and analyse data within each case study on:

- the physical characteristics of the fleet and vessels e.g. power, size, gear size, number of vessels
- The behaviour of the fleet e.g. landings, fishing location and time, effort in terms of hours fished and days at sea and CPUE. Information on fishing tactics will also be collated and will be examined for a subset of vessels using fine scale directed studies within the project
- economic data on fleet costs and earnings;
- biological data such as abundance distributions (and changes in distribution) and the calculated stock structure and fishing mortality

An explicit element of the project is to define and use capacity and effort metrics based on their utility in the models used to analyse their inter-relationships and with the resultant mortality. The aim is to identify meaningful measures of capacity with definable and robust links to effort via utilization. Fishing mortality information will be derived from the outputs from ICES assessment working groups.

The project will use a variety of analytical tools such as Data Envelopment Modelling to explore capacity and it’s utilization. A key component of the project will be an analysis of the factors and processes that cause changes in fleet capacity.

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4. Data requirements

4.1 The Data Regulation and the models

The bio-economic models have different demands for data. This is related to the Commission Regulation (EC) 1639/2001. The two tables, Table 9 and 10, below concern the minimum and the extended data collection programme respectively.

Table 9. Data collection – minimum programme (EC 1639/2001)

Appendix XVII (section J)
Economic information per fleet segment as defined in Appendix III (MP)

General description	**Minimum programme First priority (annual)**
Income (turnover)	Total and per species
Production costs: — crew (include social cost) — fuel — repair and maintenance — other operational costs	Total and per production cost category
Fixed costs	Average cost, calculated from investment
Financial position	Share of own/foreign capital
Investment (asset)	
Prices/species (*)	Value, tonne
Employment	Full time/part time/FTE
Fleet	— No — gt — kW — age — gear used
Effort	Relevant unit accounting for technology and time

(*) Quarterly basis everywhere. Aggregated on a regional level 3 in Mediterranean in Appendix I.

Table 10. Data collection – extended programme (EC 1639/2001)

Appendix XVIII (section J)
Data needs for basic economic evaluation per fleet segment (EP)

General description	Extended programme Second priority
Landings per species	Seasonal (monthly) Stock (by ICES areas) Market category Regional differentiation (level 3, Appendix I)
Income (turnover)	Subsides (annually) Regional differentiation (level 3, Appendix I)
Production costs: — crew — fuel — repair and maintenance — other operational costs	Further subdivision of operational costs Regional differentiation (level 3, Appendix I) Differentiation of remuneration to crew according to position
Fixed costs	Regional differentiation (level 3, Appendix I)
Financial position	Rents to external institutions Regional differentiation (level 3, Appendix I)
Investment (asset)	By type of investment: hull of vessel, various engines and refrigeration/freezing, storage and lifting equipment
Prices/species	Monthly By market category Regional differentiation (level 3, Appendix I)
Employment	Skill/education Distinction per vessel size, regional differentiation
Fleet	Size categories of fleet segments regional differentiation (level 3, Appendix I)
Effort	Regional differentiation (level 3, Appendix I)

The EIAA is fully flexible to handle different fleet segments but requires data on EU TACs per management area and stock assessments, landings composition of species per fleet segment and costs and earnings, see Table 11. TEMAS and EMMFID are particularly data demanding models. TEMAS includes detailed multi-stock and multi-fleet aspects. Therefore, it caters for full ‘VPA-type’ stock information (as used by ICES stock assessments) and full fleet definitions including structure and economic data. EMMFID requires a detailed disaggregation of the fleet, TACs per management area and detailed information regarding landings and effort with respect to area, month and species. COBAS is also quite data demanding. Data are obtained from a number of different sources: through survey for economic, regional and environmental data; through logbooks for structure and activity of the commercial fishing fleets; and through ICES and CEFAS for stock relationships. The breakdown of costs is remarkably detailed. The BIRDMOD model needs biological and economic data. The economic data are disaggregated by fleet segment, and are obtained from the IREPA monitoring system for the Italian fisheries. Some biological parameters are estimated by means of trawl surveys (MEDIT and/or GRUND programmes); while some others are obtained or generated by experimental data or hypotheses formulated according to the conditions in the Mediterranean and reported in the literature. BIRDMOD needs also specific information on the activity of the commercial fishing fleets. This information is collected by the sampled vessels within the IREPA monitoring system. Time series data on catches for each species and effort for each fleet segment are the minimum data required by the MOSES model. The number of observations used to estimate the parameters of this model determine the level of "goodness" of the results.

The extent to which the models run with the data specified in Commission Regulation 1639/2001 is shown below. Technically all the models can run with these data.

Table 11. Can the model run with these data?

Model	1639 (MP)	1639 (EP)	Needs
EIAA	Yes	Yes	TAC/quota and stock assessments for extensive use
TEMAS	No	No	Comprehensive biological model component
MOSES	Yes	Yes	If time series data are available.
BIRDMOD	Yes	Yes	If the fleet segments use more than one fishing gear, the model needs information on the activity distribution among the fishing gears.
MEFISTO	Yes	Yes	Economic data disaggregated by vessel is desirable to take full advantage of the model capabilities
EMMFID	No	Yes	Extensive use needs catch per day/species/segment/area
SRRMCF	No	Yes	Extensive use needs catch per day/species/segment/area
COBAS	Yes	Yes	If analysis identifies activity not captured by extended 1639/2001 (e.g. fleet disaggregation), additional technical and economic data may be required
ECONMULT	Not relevant	Not relevant	Comprehensive biological model component

4.2 BIRDMOD and MOSES model particulars

Data are collected within each management area through three levels of aggregation: by species, by fleet segment, and by fishing gear within each fleet segment.

The source of data on landings, costs, prices and activity is the IREPA monitoring system. Some biological parameters are estimated by means of trawl survey (MEDIT and/or GRUND); while some others are obtained or generated by experimental data or hypotheses formulated according to the conditions in the Mediterranean and reported in the literature.

For BIRDMOD, the technical and economic data by fleet segment for the base year is:

- Number of vessels and GT/GRT
- Activity: total number of days at sea
- Crew: total number of men employed
- Landings: total landings in weight by species, by month, and by gear
- Prices: price by species
- Costs: a) commercial costs; b) fuel costs; c) other variable costs; d) maintenance costs; e) other fixed costs; f) depreciation; g) interest.

For BIRDMOD, the Biological data must be collected by species:

- Stock-Recruitment parameters or number of recruits by month
- Von Bertalanffy growth model parameters
- Length-weight relation parameters
- Total mortality (Z)
- Natural mortality (M)
- Maturity ogive model parameters
- Selectivity parameters by fishing gear

For MOSES, data are collected within each management area through two levels of aggregation: by species and by fleet segment e.g. 1) Time series on total landings by species; 2) Time series on total effort by fleet segment in terms of GRT and activity; and 3) Other data as a matrix of prices by species and by fleet segment for the base year, and a vector of costs per unit of effort by fleet segment for the base year.

4.3 MEFISTO model particulars

The MEFISTO model can be run with the data obtained from the regulation 1639/2001, but it works best with data individualized by vessel.

Additionally, for the economic data, MEFISTO uses the daily fuel consumption, which can be obtained indirectly from the total fuel consumption costs and price. We can then extrapolate to the vessel level knowing the horse power and the GT.

For the Mediterranean, it is also useful to know the percentage of the share for wages, but not essential.

For the biological data on main species the regulation data are used indirectly through stock assessments (e.g. from GFCM), including fishing mortality, and literature on growth, natural mortality parameters, or stock-recruitment relationships.

For species whose data are not obtained in the regulation (secondary species), time series analysis of their catches are required.

4.4 Data availability and readiness in time for advice

Exemplified by Spain, in the framework of the Concerted Action EAEF, exhaustive data series have been provided on costs and earnings for Galician purse seiners, coastal trawler, 300´s trawlers fleet and Atlantic longliners. In 2005, a new segment has been introduced, namely NAFO freezing trawler fleet.

The sampling strategy applied in the framework of the EAEF in Spain has been satisfactory in coverage and data reliability. This strategy has been based on:

1. Accounts
2. Surveys/questionnaires

One relevant feature of the Spanish fleet for implementing an operative system of economic data collection is its composition of high percentage in number, of small vessels, and the importance of the small-scale fishery, very significant in several Spanish costal communities depending on fisheries. Also it should be noted that the EC regulation requires the segmentation for the whole fleet.

On this issue, limited information on fishing activities for vessels less than 10 metres has been found. At this stage, and to achieve the segmentation required by the regulation, it must be useful to implement observatory systems to assess the intensity of use of each gear for each vessel during a year. Current projects aimed to implement observatory systems to assess the intensity of use of each gear for the artisanal sector, such as OCIPESCA (in the framework of Interreg III B program) could provide a better understanding of Spanish artisanal fishing vessels operations.

It is noted that the present data collection regulation (Commission Regulation 1639/2001) does not give sufficient information, in some cases, for a fishery based approach as outlined by the ICES study group. The main elements lacking are the target stocks and the geographical dimension. These lacking elements will delay the practical use of bio-economic modelling for fisheries in which some Spanish fleets are involved, as well as the implementation of advances in the fishery based forecasts.

Also, from the experience accumulated in the CA, it is important to include value of fishing rights, as a separate item if possible. This is especially important in the *300`s trawler fleet* as there are current investments in accumulating fishing rights.

The sampling strategies can be summarized under the following three items:

-Time for submitting economic data is limited by availability of economic accounts of fishing vessels:
The experience accumulated during the CA indicates that economic data would require a minimum of two months to be collected and processed adequately.

-The regulation requires the availability of average economic indicators per fleet segment based on a specific segmentation:
For homogeneous fleet segments this is not generally a problem, such as NAFO freezing trawlers and Atlantic surface longliners. However, it could be inconvenient where vessels have a number of alternative fishing strategies, and as a result move around fleet segments,

such as the Spanish artisanal fleet and costal purse seiners. Fleet segmentations should be introduced that are in line with the conclusions of the ICES and GFCM study groups.

-Readiness for bio-economic advice for fisheries in which Spanish fleets are involved:
The Spanish fleet is composed of several fleet segments that may not be wholly consistent over time, as vessels may change strategy in a given year. This may need to be qualified with respect to fleet structure in terms of the average effects of TAC on that segment for the forthcoming year. The EIAA model is totally flexible with respect to fleet segments. It therefore fits to the minimum programme of the data collection regulation (1639/2001) and to the extended programme.

With the exception of the financial information provided for under the minimum programme, which does not include interest payments, the list of variables included under the regulation, and their proposed specification provide, adequate input for running the EIAA simulations.

5. Adjustments of data regulation

The group has not addressed this item explicitly with respect to required changes in the data regulation in order to run the bio-economic models. However, the presentation of the models in this report indicates that most of the models are flexible with respect to fleet segmentation and economic indicators. Some of the models require more detailed information to be run at their best, e.g. catch per unit effort information and costs and earnings information on vessel level. The following discussion addresses the conceptual problem to what extent the fleet segmentation is appropriate to identify vessels unequivocally for comparison of economic performance.

According to the Appendix XVII of the Commission regulation 1639/2001, the vessel segmentation that has to be followed for the collection of the economic data has two dimensions, cf. Appendix III. Firstly, a horizontal dimension that takes into account the vessel length, which is common for both the minimum and extended programmes, and a second vertical dimension which separates vessels in terms of the gear used (with a higher disaggregation for the EP), see Table 12 . The difference between the minimum and the extended programme is that level 4 in Table 12 is omitted in the minimum programme, and the four length groups below 24 metres at level 1 are aggregated to two, leaving only four length groups in the minimum programme.

Table 12. Detailed disaggregation of vessels for capacities (Extended Programme) Appendix IV of 1639/2001

Vessel length (level 1)			< 10 m	10 - 12 m	12 - 18 m	18 - 24 m	24 - 40 m	≥ 40 m
Type of fishing technique								
Level 2	**Level 3**	**Level 4**						
Mobile gears	Beam trawl	North Sea < 221 kW						
		North Sea ≥ 221 kW						
		Outside North Sea						
	Demersal trawl and demersal seine	Bottom trawl						
		Danish and Scottish seiners						
		Polyvalent						
	Pelagic trawl and seiners	Pelagic trawl						
		Pelagic seiner and purse						
		Polyvalent						
	Dredges							
	Polyvalent mobile gears							
Passive gears	Gears using hooks	Longlines						
		Other gears using hooks						
	Drift nets and fixed nets							
	Pots and traps							
	Polyvalent passive gears							
Polyvalent gears								

Source: Commission Regulation (EC) no 1639/2001 Appendix IV (section C)

Even if it is interesting to have common disaggregation levels in order to do comparisons, some problems are encountered:

- The horizontal dimension can separate vessels with almost the same technical characteristics, creating artificial groups. In fact, the precision levels cannot be met only because of this separation affecting the posterior application of the bio-economic models.
- The vertical dimension ensures that many vessels that on a seasonal basis change the gear used should be placed in the "polyvalent gear" box in order to avoid overlapping of the same vessels in different boxes. This situation creates a box with a mix of different vessels, which complicates the analysis and the posterior comparison.
  Furthermore it has also some problems when defining the gears. For example, all the hooks are not passive gears and seiners and trawlers are not differentiated.
- In general, the small scale vessels are all mixed in one or two boxes. Furthermore, the threshold of 12 metres separate vessels with the same fishing strategy.

Finally, there is a wish to define a segmentation that facilitates integrated economic and biological analyses. As biological analyses often focus on stocks or 'fisheries' (metier), constituting certain catch compositions and fishing patterns, the fleet segmentation in Appendix III and IV (1639/2001) does not accommodate such analyses. However, ‘fisheries’ are not well defined as they can change rapidly. Therefore, a segmentation based on ‘fisheries’ is hardly useful for regular economic analyses. A useful further amendment to the segmentation, could take the format of descriptions of the segments’ activities over the year combined with information of the catch composition. Information about the catch composition of the fleet segments, however, is compulsory in order to be able to run economic models. The description would allow for a distinction for example between beam trawlers fishing for plaice and sole on one hand and shrimp on the other, or vessels fishing for pelagics and demersal in the Mediterranean and in the Atlantic.

Another problem found is that the disaggretation proposed in Appendix III (1639/2001) does not take into account the segmentation that is currently being applied in some EU areas, such as in the Mediterranean Sea. According to the GFCM, the segmentation used in the Mediterranean includes a new category in the horizontal axis (vessels between 6 and 12 metres), and a more detailed (and *ad hoc*) description of the gears, in the vertical axis, see table 13.

Table 13. GFCM Fleet Segmentation

Groups	< 6 metres	6-12 metres	12-24 metres	More than 24 metres
1. Minor Gear without engine	A	⇐		
2. Minor Gear with engine	B	C		
3. Trawl	⇒	D	E	F
4. Purse Seine		G	H	⇐
5. Long line			I	
6. Pelagic Trawl		⇒	J	⇐
7. Tuna Seine			K	⇐
8. Dredge		⇒	L	
9. Polyvalent			M	

Segments Description

A- Minor Gear without engine. All vessels less than 6 metres in length without an engine (wind or oar propulsion). Exceptionally, vessels without engine longer than 6 metres can be included.
B- Minor Gear with engine less than 6 m. length. All vessels under 6 metres length with engine, excluding trawl vessels.
C- Minor Gear with engine between 6 to 12 metres. All vessels between 6 to 12 metres length with engine, excluded specific gears as demersal trawl, purse seine, pelagic trawl and dredge.
D- Trawlers less than 12 m. length. All demersal trawlers less than 12 metres. Exceptionally, trawl vessels under 6 metres can be included.
E- Trawlers between 12 to 24 m. Demersal trawl between 12 to 24 metres.
F- Trawlers of more than 24 m. Demersal trawl with length of more than 24 metres
G- Purse Seines between 6 to 12 m.

H- Purse Seines between 12 to 24 m. Excluded Tuna Seine. Exceptionally, Purse Seines vessels of more than 24 metres, can be included
I- Long line of more than 12 m. Long line as exclusive gear more than 12 m. Exceptionally, vessels more than 24 metres, can be included.
J- Pelagic Trawlers. All Pelagic Trawl vessels, but normally this group is between 12 to 24 metres.
K- Tuna Seine. All Tuna Seine vessels.
L- Dredge. All Dredge vessels. Normally this group is between 12 to 24 metres, but exceptionally dredges under 12 metres can be included.
M- Polyvalent (and Other) longer than 12 m**.** All vessels longer than 12 metres, that use different gears along the year or use a gear not already listed in this classification.

6. Advice procedures and organisational framework

To provide criteria that form the basis for the advice, procedures in terms of the required human resources and institutional framework are much dependant on the type of problem to be investigated.

First of all a distinction must be made between regular tasks, *ad hoc* tasks and long term strategic tasks. The regular tasks require a very swift and firm format including sufficient human and financial resources, while the ad hoc and long term strategic tasks could put more emphasis on the human resources.

6.1 Regular tasks

Hitherto to advice has been put forward to Commission services by ICES with respect to stock assessment, TACs and other topics within the biological field. The work of ICES is an on-going procedure that is activated in various forms by the EC.

One (important) form of short run biological advice is the annual preparation by STECF and the EC for the Council meeting in December, where next year’s quotas have to be agreed. For the last four years this has been supplemented by assessments of the economic repercussions. This work has been supported financially through a Concerted Action that was discontinued at the end of 2004. For 2005, an EC grant was been provided to make it possible to continue the work for a further year. It is uncertain what will happen in 2006 and beyond.

The biological and economic advice is channelled into the STECF committee by use of two subgroups. The economic advice depends on the biological advice with respect to TACs and the cost and earnings information provided hitherto by the Concerted Action EAEF. Preparation of the economic advice is subject to strict time restrictions in terms of data collection and provision, and in term of using the EIAA model, which is developed to account for these restrictions.

Ideally, the model should be used *before* next year’s quotas are agreed, i.e. before the Council of Ministers meets in December and *after* the quota proposals have been forwarded. This time restriction leaves very little time in late October and early November to carry out calculations and present results. Therefore, the model set-up ensures that it is very easy and quick to use. The process in October/November is shown in Table 14:

Table 14. Projections and data availability for projections

Data type	**Baseline** (3 years average)	**Current year (October/November)**	**Coming year**	**Long run**
Economic	Costs and earnings Landings of species in volume and value	Not known i.e. calculated by the model	Not known i.e. calculated by the model	Not known i.e calculated by the model
TAC/quota	Known	Known	Known	Estimated
Stock abundance	Estimated for certain stocks	Estimated for certain stocks	Estimated for certain stocks	Estimated for certain stocks

In the future (from 2006) the procedure of economic data collection will be based on Commission Regulation 1639/2001, and the Joint Research Centre (JRC) will carry out the secretariat function of the STECF.

The regular tasks, i.e. the annual economic evaluation of the ICES advice, require a firm structure that can be put quickly into operation, and this would require that the human and financial resources necessary to carry out the work may not (cannot) be secured safely only by relying on ad hoc working group meetings.

There is a need to build a stable framework for the collection, processing and evaluation of economic data on an annual basis. Furthermore, it is the opinion of the Sub-group that the annual economic evaluation of the ICES advice should only be undertaken by appropriate experts from each member state. Such experts need to be able to make an annual commitment to undertaking the evaluation which should be timetabled well in advance. Expert participants will only be able to make such a commitment if they are supported financially.

6.2 Ad hoc and long term strategic tasks

Given that the EIAA model is not designed primarily to handle economic repercussion of input regulation such as sea days, and given that input regulation in certain fisheries are introduced together with output regulation, model development to deal with that needs attention. Input regulation in terms of sea days requires information about catch per day. The EMMFID and the SRRMCF models may serve as an appropriate starting points, as they are well developed. The MOSES and COBAS models are similar to EMMFID, although COBAS is still under development. These models are, however, data demanding and may not be possible to use with a view to the strict time limits confronting the STECF. Therefore, these models are suitable tools for less urgent tasks.

The models TEMAS, MEFISTO, BIRDMOD, and ECONMULT are models mainly designed for analytical purposes. They may serve as appropriate tools for less *ad hoc* tasks, and especially long term strategic task, which also implies that the data availability is not a restriction in the same way as for the urgent tasks.

MEFISTO can be used to analyse a range of fisheries management scenarios, based on input control. The management tools available to the user are effort control, i.e. control of fishing activity in terms of time at sea, or capacity in terms of vessel withdrawal and incentives to decommission, as well as selectivity changes and control of fuel price, subsidies and changes in market prices of the target species.

BIRDMOD is able to simulate a pool of management measures usually adopted by the Public Administration. The pool includes restrictions of fishing effort, such as temporary withdrawal or capacity reduction plans, and technical measures, such as changes in the mesh size of trawls. The model can simulate also economic measures, such as variations of taxes and subsidies. An overall evaluation of the management measure simulated by the model is foreseen by output. The evaluation is performed by considering the general economic outcome. This is calculated in terms of net profits, management expenses met by the Public Administration to impose the measure, social costs due to the measure adopted and, particularly, to the possible reductions of the sector workforce.

Currently the main (only) model that is used by the European Commission as an aid (in principle at least) to assist in evaluating management proposals in the ICES area is the EIAA. While the EIAA has been accepted as a useful aid to fishery managers for a number of years, the developments in the way that managers have asked for advice and the ensuing changes in the way that ICES has produced its advice, means that an additional bio-economic approach is desirable.

The EIAA model essentially takes an estimate of the TACs available for the forthcoming year and assumes that these will be the realised landings by the Community fleets. In summary, the EIAA provides an answer to the question, “If the fleets fish in the same way next year as they have done for the past three years, and their landings next year are the same as the proposed TACs, what will their economic performance next year be relative to their average economic performance over the most recent three years? The EIAA also provides an estimate of the potential economic performance of the existing fleet segments assuming that all stocks exploited are being fished at a rate corresponding to the precautionary fishing mortality rate (Fpa or a proxy) under long-term equilibrium conditions.

The changes to the way that management advice has been given by ICES have been driven by a number of factors:

1. The introduction of recovery plans (RPs) for some stocks that show reduced reproductive capacity.
2. The introduction of management plans (MPs) for some stocks, notably those under joint management agreements e.g. EU/Norway.
3. The desire for the implementation of harvest control rules (HCRs) for some stocks.
4. The drive to develop long-term management strategies (LTMS).

While ICES has taken steps to try to address the above, and to devise a framework within which the performance of each of the above can be evaluated from a biological (stock response) perspective and to estimate the development of yield from the fishery, only limited attention has been given to the development of economic models that can inform the decision making process. Hence, at present, managers are only able to use stock development and yield as a basis for proposals and decisions. It also follows that in the absence of any other criteria, the success of management can only be measured against these two criteria, irrespective of any explicit or other management objectives.

There are a great variety of potential objectives for managers, and while in the situation where stocks are depleted or harvested unsustainably, the primary concern for managers is to focus on achieving increases in stock size to levels where recruitment is not impaired and to reduce fishing rates to sustainable levels. Both of these focus on stock development and yield. However, commercial fishing is an economic activity, i.e. commercial fishers do what they do to make money, and inevitably, the true objectives for managers have an economic basis. It follows, therefore, that to make informed decisions that will help to achieve economic objectives, the performance or likely performance of those decisions with respect to those objectives also need to be evaluated.

There is therefore a need for development of tools that can provide economic evaluations of each of the above categories: HCRs, MPs, LTMSs, and RPs.

The development of tools within ICES to evaluate these are largely restricted to modelling the development of the stock and yield from the stock on an annual basis, assuming specific exploitation patterns, overall levels of fishing mortality and predicted recruitment derived from a stock-recruit relationship. The modelling can be deterministic or stochastic. Such an approach permits a year-on-year prediction of the developments of the stock and overall yield under different management scenarios. The economic evaluation tool that is currently used only addresses the potential impact in the immediate future (assuming a catch for next year) and in the long-term equilibrium situation where the stocks are each fished at F_{pa} (or a proxy for F_{pa} where this is not defined). However, to better inform managers of the potential economic development of the fleets under different management scenarios, an alternative approach is desirable. For example, when you deal with a multi-stock (mixed fisheries) problem you avoid the complication of aggregating the stocks.

Long run socio-economic objectives include: optimal fleet structure, resource rent and Maximum Economic Yield (MEY), cf. Maximum Sustainable Yield (MSY) commitment for all fish stocks (World Summit of Sustainable Development 2015). The multi-objectives of the CFP (Reg. 2371/2002) comprise 1) biological/environmental 2) economic 3) social and 4) sustainable development/exploitation goals, which are contradicting and therefore extremely demanding to pursue.

Last but not least, the fishermen’s objectives are to make money from fishing. Making money in the short, medium and long run involves the risk of depleting the stocks, while closure of fisheries ‘depletes’ the fishing fleet. There is a trade off, and the demanding task is to find a common indicator. One possible route is to put more emphasis on fleet development reference points parallel to what has been done for the stocks. An example of this long run strategic task is found in the result presented for the ECONMULT model, which could serve as inspiration for the development in this field.

Two types of development of economic models could be considered for the immediate future.

1. Assigning the degree of risk to the economic effects of proposed TACs. History has shown that the proposed TACs may not be adopted and that the TACs adopted are often not achieved or are exceeded. The degree of error for each stock could be calculated from the historic series of TACs and catches. This would be of limited use for taking management decisions but it would inform managers of the potential range of consequences of those decisions.
2. Application of a model to the projected annual yields arising from the evaluation of envisaged HCRs, MPs etc. and provision for changing the behaviour of the fleet segment to take account of effort restrictions, for example, and feed back to biology.

At present, for many stocks, the priority is to get back to a healthy state with sustainable harvest rates. Hence biological objectives are the primary concern which can be achieved through exploitation rates, which have a direct influence on yield from the fisheries (2015 objective). If this state is achieved, what kind of economic indicators will be required and how should they be calculated so that managers can take appropriate decisions based on criteria that will achieve their economic objectives without returning stocks to a perilous state?

The Green Book of the European Commission states that the Mediterranean fisheries have to be regulated by effort control, not TACs. Current management regimes for Mediterranean fisheries are based on effort and technical measures, such as selectivity control. So, there is a need for scientific advice, not in quotas terms, but in effort units. With respect to fisheries not subject to TAC it is recommended that the input driven models such as MEFISTO be considered as a practical tool for evaluating the outcome of management measures proposed by the sub-committee of Stock Assessment of the General Fisheries Council for the Mediterranean and in the long-term management of Mediterranean fisheries resources. Fisheries are important in the Mediterranean Sea in employment and social terms, even though catches are lower than in Atlantic waters.

7. Task force groups

To prepare the road for long term, ad hoc and strategic advice, and to secure short term regular advise is continued, it is recommended that task forced are established.

The objective of a task force is produce detailed information in terms of user manuals about the operational models identified in this report. The aim is to provide information that increases the assessability and applicability of the models to a broader group of people and institutes. It should be noted that for example that the EIAA and the MEFISTO models were developed in projects financed by EU programmes, while the other models have been developed by national grants..

The manual produced by the task force should address as minimum the following items:

1. Model language

2. Model objective and scope
3. Type of advice and time range (simulation over years, static comparative, optimisation)
4. Model overview - diagramme
5. Full specification of the equations of the model
6. Full specification of the variables of the model
7. Full list of the parameters of the model (including parameter values)
8. Data requirements to initialise the model; i.e. a complete list of indicators (often the same as the variables)
9. Description of the required time to run the model and to produce and disseminate the advice.
10. Format of output of the model
11. Procedure of how to run the model
12. Where has the model been used, outcome, validation and references
13. Institute and key personnel

The models that are recommended for further elaboration in terms of user manuals are listed in the following table 15.

Table 15. Models recommended for elaboration in terms of user manuals

Acronym	Type	Institute	Contact person	Home page	E-mail
EIAA	Output driven	FOI/LEI	Hans Frost	www.kvl.foi.dk	hf@foi.dk
MEFISTO	Input driven	GEM/ICM-CSIC	Jordi Guillen & Francesc Maynou	http://www.gemub.com	jordi@gemub.com
BIRDMOD /MOSES	Input driven/ optimization	IREPA	Paolo Accadia	www.irepa.org	accadia@irepa.org
EMMFID	Optimization	FOI	Jens Kjaersgaard	www.kvl.foi.dk	jk@foi.dk
SRRMCF	Optimization	F-Verket	Aanton Paulrud	www.fiskeriverket.se	Anton.Paulrud@fiskeriverket.se

The criteria for selection are that the model has been operated and verified with respect to robustness and data assessability. It should be noted however that the model have been constructed subject to the problems addressed and the available data and data formats.

The EIAA model has been used for the last four years (2002-2005) to assess the economic impact of the biological advise in terms of TACs. In 2006 a transition takes place, due to the adoption of the data regulation that becomes effective with respect to costs and earnings statistics from 2006. To secure smooth transition and continued regular advice it is recommended that an EIAA task force is established as soon as possible having in mind that the advice is due before the STECF plenary meeting in November.

With respect to the input driven model the nature of input control rules implies that the time restrictions are not as strong as for the output regulated fisheries. However it is recommended that task forces are set up soon to ensure continuity and further development. Even though these models do not face the same time restrictions with respect to STECF advice, they are very useful not least with respect to ad hoc questions and long term advice given by STECF. It should be noted that although the input driven models often are used for long run simulations the results can be up-dated as soon as data are up-dated both on a year by year basis as well as on a long run basis.

Further, it is noted from the review of models in this report that a third type of models, optimization models, has been developed and is operational. So far, they have been applied on a national scale, but can potentially be used more widely, in particular in areas where output- and input controls are both in use at the same time. These are characterised by being useful for analysing long term strategic advice. Therefore a task force producing user manuals for this type of models considered very useful and is recommended to be established soon.

The models chosen above are well described mainly with respect to the equations of the models. The availability of this information facilitates the work with the user manuals. Although it differs what amount of resources is required to produce the manuals it is the opinion of the group that such manuals could be prepared within a rather short period of time that could take the format of working group meetings including tutorials in their use.

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Appendices I-IX

I. EIAA

Economic Assessment of ACFM Advice

Hans Frost (FOI)

I.1 Objective

The EIAA model is constructed to pursue the objective: to assess the economic consequences of the TAC proposals formulated by ACFM by making use of the data collected and disseminated in the annual economic reports (AER) produced by the Concerted Action EAEF.

The first versions of the model were developed in the Concerted Action: Economic Interpretation of ACFM Advice that came into existence under FAIR CT97-3541, 1998-2000. The model was gradually improved and the layout was changed in 1999 with the aim to make the model more transparent. It was further developed in the subsequent Concerted Action 2002 – 2004: 'Economic Assessment of European Fisheries' (QLRT - 2000 – 01502) where the EIAA model reached the format it has now.

The model is developed with respect to certain demands in terms of time restrictions. Ideally, the model should be used *before* next year's quotas are agreed, i.e. before the Council of Ministers meets in December and *after* the quota proposals have been forwarded. This time restriction leaves very little time in late October and early November to carry out calculations and present results. Therefore the model set-up takes into account that it should be very easy and quick to use. The process as it is viewed in October/November is shown in table I. 1:

Table I.1. Projections and data availability for projections

Data type	**Baseline** (3 years average)	**Current year (October/November)**	**Coming year**	**Long run**
Economic	Costs and earnings Landings of species in volume and value	Not known i.e. calculated by the model	Not known i.e. calculated by the model	Not known i.e calculated by the model
TAC/quota	Known	Known	Known	Estimated
Stock abundance	Estimated for certain stocks	Estimated for certain stocks	Estimated for certain stocks	Estimated for certain stocks

I.2. Scope

At the EU level, clear priorities are given to stock conservation and recovery. To improve the grounds for empirically based economic advice, the EIAA model is constructed as a projection model with the aim to calculate the economic repercussions of the biological advice. The ACFM is the Advisory Committee for Fisheries Management of ICES. The EIAA model is based on costs and earnings statistics of the fleet segments, and uses biological input about stock levels and TACs. On the basis of a number of assumptions and using the biologically-defined precautionary approach, the model can be used for short and medium term projections, in particular of the effects at the fleet segment level of changes in stock levels and TACs.

For the EU, more than 130 TAC management areas (defined as species-area combinations) are applied in order to restrict catches, and these are used in the EIAA model. Around half of these are subject to assessments of fish stock abundance, while the others are set as a precaution. After the TACs are fixed for these management areas they are allocated to the 20 Member States as quotas according to a predetermined allocation key ('the relative stability'). Of the 20 Member States, some are subjected almost completely to quota restrictions, while others are subjected only to a few restrictions. Since 1998, assessment of economic performance has been currently carried out for 62 fleet segments defined within the EU(15) and 73 within the EU(25). These segments cover 62 % of the landings value for the EU. In the EIAA model a sample of 25 of these segments has been subjected to projections of economic performance, taking the pertinent quota changes into account.

I.3. Model output

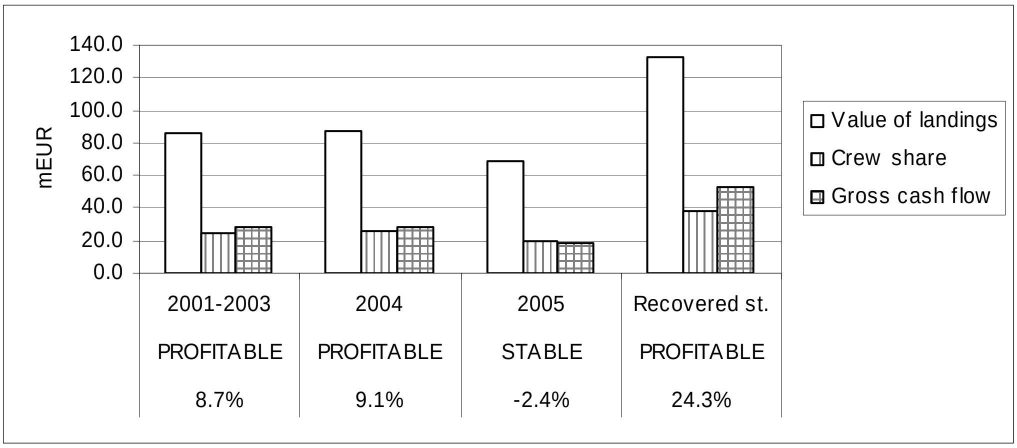
The results of the model calculations are presented for fleet segments – and not 'fisheries' or species, as the economic performance of the fishing vessel is the main interest of fishermen and the industry.

The EIAA model uses a fixed format of output to show results of the calculations. The economic indicators displayed in Table I.2 are considered the most useful to provide a short summary of the economic situation for the years in question.

Table I. 2. Extract from the EIAA model showing the format of the model output

PS and trawlers ≥ 40 m		**mEuro**		
Operating profit margin	**8.7%**	**9.1%**	**-2.4%**	**24.3%**
Performance	PROFITABLE	PROFITABLE	STABLE	PROFITABLE
	2001-2003	**2004**	**2005**	**Recovered state**
Value of landings	86.5	86.9	69.1	132.2
Crew share	25.2	25.3	20.1	38.4
Gross cash flow	27.8	28.2	18.7	52.5
Net profit	7.5	7.9	-1.6	32.2
Gross value added	44.2	53.5	38.8	90.9

The results in Table I.2 are displayed in the figure below. The purpose of this is to make it possible for the reader to obtain a quick overview of the development of the main economic indicators.



Finally, the fixed format provides more detailed tables of the results in terms of economic indicators combined with estimates of ‘break-even’ value of landings, partly to show the demand to the value of landings to break even e.g. cover fixed costs, and partly to estimate ‘overcapacity’ by use of the ‘break-even’ information in combination with the actual or projected value of landings.

There is a table for each year for which the EIAA model calculates results. These tables have mainly been used as background information, and not often used in final reports.

Table I.3. Detailed output from the EIAA model

2005		**mEuro**	
	Purse seiners and trawlers ≥ 40 m	Trawlers 24 - 40 m	Trawlers < 24 m
Value of landings	69.1	66.6	72.3
Fuel costs	7.3	10.2	10.0
Other running costs	7.2	9.6	9.9
Vessel costs	15.9	21.0	19.4
Crew share	20.1	22.9	35.0
Gross cash flow	18.7	2.9	-2.0
Depreciation	13.9	17.2	14.8
Interest	6.4	10.1	5.9
Net profit	-1.6	-24.3	-22.7
Gross value added	38.8	25.8	33.0
Net profit / Gross revenues	-2.4%	-36.5%	-31.4%
Classification	STABLE	UNPROFITABLE	UNPROFITABLE
Invested capital	148.3	164.8	128.6
Required cash flow	20.3	27.2	20.7
Remuneration of SSB	27.7	6.2	3.5
Break-even revenue	75.1	627.1	-741.8
Break-even revenue incl. SSB remuneration.	177.7	768.7	-866.8
"Over-capacity"	**8%**	**89%**	**100%**
"Over-capacity" incl. SSB remuneration.	**61%**	**91%**	**100%**

I.4. Model structure

The causality of the EIAA is that the model is driven by changes in output. The model is static in the sense that it runs over time with exogenous TAC inputs for each year. Effort becomes an endogenous variable. Effort in terms of days at sea on an annual basis is included in the EIAA as an endogenous variable. The maximum number of sea days per fleet segment is an exogenous variable from which fleet capacity components of effort, e.g. number of vessels, GT and kW are calculated for future periods.

The EIAA model does not operate with fishing effort as such but with a fleet activity variable. The model operates with variable costs as a function of estimated fish prices, landings and fish stock abundance, so that variable costs in future years are calculated from the variable costs in the base years. Changes are considered only within fleet segments, not between segments.

The rationale behind the fleet activity variable is an inverse Cobb-Douglas type production function, which for a single species, single fleet and single stock is:

$$A = a * \frac{p(TL)L^{\chi}}{X^{\beta}} \tag{1}$$

Where:
A: fleet activity (effort), *a*: coefficient, *p*: price as a function of aggregate landings *TL* on EU level, *L*: landings per segment, *X*: spawning stock biomass, *chi* and *beta* are parameters (landings activity and stock-catch flexibilities)

In the EIAA model the calculation of the fleet activity variable consists of three elements. First an index is constructed by use of the landings of each species of the fleet segment in the base period multiplied with the predicted future price of each species set relative to the total landings value in the base period (Laspeyres index). The future prices are calculated by use of an inverse demand function including a flexibility exponent (inverse price elasticity). This procedure redistributes the fleet activity on species in accordance with the price estimated for the future period. The rationale behind this is that the fisherman is allowed to react to price changes. The second element calculates an index for the future period taking future landings per species in volume and relates that to current landings per species in volume. The proposed TAC/quotas determine future landings. The third element calculates an index of spawning stock biomass per species in the future period related to spawning stock biomass per species in the current period. The coefficients of each step are multiplied with each other, per species. Finally, this index is aggregated over species and the coefficient is multiplied by the variable cost of the baseline.

The fleet activity expression in terms of time, species and fleet segment in the EIAA model is as follows:

$$A_{t,j} = \sum_i \left(\frac{L_{0,i,j} \cdot P_{t,i,j}}{\sum_i L_{0,i,j} \cdot P_{0,i,j}} \cdot \left(\frac{L_{t,i,j}}{L_{0,i,j}} \right)^{(\chi_{i,j})} \cdot \left(\frac{SSB_{t,i}}{SSB_{0,i}} \right)^{(-\beta_i)} \right) \tag{2}$$

$\chi \geq 0$; and $\beta \geq 0$

$A_{t,j}$	'Activity coefficient' as a function of quota species at year *t* of fleet segment *j;* $A_{0,j}$ = 1 (endogenous variable) calculated for the baseline
$L_{t,i,j}$	Landings in volume in baseline period 0, and TAC in period *t* of species *i* by fleet segment *j*
$P_{t,i,j}$	Prices in period *t* of species *i* by fleet segment *j*
$SSB_{t,i}$	Spawning stock biomass at year *t* of species *i* (exogenous variable)
$AA_{t,j}$	'Activity coefficient' as a function of quota and non quota species at year *t* of fleet segment *j;* (endogenous variable)
$\chi_{i,j}$	'Technology flexibility rate' of quota species *i* by fleet segment *j*
β_i	'Stock – effort' flexibility rate of quota species *i*
$RC_{t,j}$	Running costs at year *t* of fleet segment *j*, include fuel and other fishing days dependent costs (endogenous variable)
$RC_{0,j}$	Running costs at base years of fleet segment *j*, include fuel and other fishing days dependent costs (exogenous variable)

The *first element* accounts for incentives to reallocate effort as a function of changes in relative prices. Note that future prices depend on the price flexibility rates.

The *second element* accounts for technological accessibility. If χ is zero the fish are easily accessible, and when χ increases accessibility becomes harder. The default value in the model is $\chi = 1$. The inclusion of the element makes it possible to distinguish between different accessibilities in particular for demersal and pelagic species and different fishing technologies.

The *third element* accounts for accessibility caused by stock abundance. $\beta = 0$ implies there is no stock abundance effect on activity. With full effect $\beta = 1$. Default values are between 0.6 and 0.8 for demersal species and between 0.1 and 0.2 for pelagic species

When the *A* variable is calculated for each fleet segment the recorded variable costs for the baseline period are multiplied with *A* to obtain variable cost for the future period. The model contains two options for calculating *A*. One option takes into account only the effect of changes in the quota species. The second option denoted *AA* is adjusted for the share of the value of the quota species relative to the total landings value.

By use of that procedure it is assumed that each species in the landings composition could be caught separately which makes it possible to add the cost share of each species. However, in many fisheries joint production prevails entailing that species are caught in fixed proportions. These fixed proportions are however changed in future periods by the change of the quota compositions.

Further to the variable costs the crew share is calculated in the model for the baseline period by taking the costs of the crew relative to the gross revenue.

I.5. Data requirements

The EIAA model uses data from the CAClient database at www3.lei.dlo.nl/ca/. Three groups of input are required:

1. EU TACs per management area and stock assessments
2. Landings composition of species per fleet segment and on national level
3. Costs and earnings

The EIAA model requires input consistent with the EC regulation 1639/2001 (appendix XVII), as well as the proposed revised heading, definitions and specifications adopted during the Paris workshop (Report of the workshop 'Economic Indicators' Paris 10-14 May 2004, IFREMER). The various variables and indictors are summarised in Table I. 4. With the exception of the financial information provided for under the minimum program, which does not include interest payments, the list of variables included under the regulation, and their proposed specification, provide adequate input for running the EIAA simulations.

Table I. 4. Economic variables and indicators used in the EIAA compared to the EC data regulation and the revisions proposed by the Paris workshop

Cost and earnings input to the EIAA from the AER	**Review of economic indicators (Paris workshop)**	
	Indicator required by EC 1639/2001	**Proposed revised heading by the workshop**
Gross revenue/value of landings	Income – Turnover	Gross revenue (of which gross value of landings)
Fuel costs	Fuel costs	
Vessel costs	Repair and maintenance	
Crew share	Crew (incl. Social costs)	
Other running costs	Other running costs	Other costs
Depreciation	Fixed costs	Capital costs
Interest	n.a. under the minimum program	
Invested capital	Investment (asset)	The value of capital
Prices/species	Prices/species	

Source: Commission Regulation (EC) no 1639/2001, appendix XVII (section j) and Report of the workshop 'Economic Indicators' Paris 10-14 May 2004, IFREMER.

Enhancement of economic indicators for the future as proposed by the Workshop "Economic Indicators" could slightly change the input to the model. For example, taking into account of gross revenue from non-fishing activities and accepting the proposed definitions of employment, labour costs, prices, capital costs and the division between fuel and oil costs.

Implementation of improvements of the model as suggested by the group, e.g. modelling changes in segment share and 'jointness' in output will require collection of data that is not currently provided by the data collection regulation.

The foremost assumption of a fleet segment, as used in EIAA, is homogeneity. That is, vessels incorporated into a segment must have similar operating characteristics, not only with respect to how and where they fish, but also, and more importantly in EIAA, through unit (variable) costs experienced.

It is also noted that a fleet segment may not be wholly consistent over time, as vessels may change strategy in a given year. For homogeneous fleet segments, this is not generally a problem. However, where vessels have a number of alternative fishing strategies, and as a result move between fleet segments, this may need to be qualified with respect to fleet structure in terms of the average effects of TAC on that segment for the forthcoming year. The EIAA model is totally flexible with respect to fleet segments. It therefore fits to the minimum programme of the data collection regulation (1639/2001) and to the extended programme.

I.6. Institutional base

The current institutional arrangement is that the EIAA model is run as part of the work of the Concerted Action. It has been used to produce assessment reports submitted to STECF in 2002-2004.

It is constructed in an Excel workbook composed of 19 sheets (2005 version). Each workbook contains 11 Member States, 113 management areas of the EU, and 4 fleet segments. The number of fleet segments is expanded by use of more workbooks.

Updated with TACs, only costs and earnings data and landings composition data in terms of volume and value per fleet segment, are required.

II. TEMAS

Bio-economic model to assess the effect of technical management measures

Per Sparre, Clara Ulrich, Holger Hovgaard, Youen Vermard (DIFRES) [10]

II.1 Objective

The primary objective of the TEMAS model (simply noted as TEMAS from hereon) is to evaluate the effect of technical management measures on fisheries. The primary aim of technical management measures is to reduce the fishing mortality on juvenile fish which links directly to the reduction of discarding. Technical management measures, however, cannot be evaluated in isolation, so the model covers (more or less) all aspects of fisheries management. TEMAS contains a generic model of ICES fish stock assessment and the advice given by the ACFM of ICES, as a module. TEMAS can be used to evaluate alternative management measures within a full feedback fisheries evaluation framework (operating model and management procedure – see 'model structure' below). The TEMAS model is composed of modules, which can be selected or de-selected. The software implementation of TEMAS is a toolbox for creation of fisheries models rather than a single model. The toolbox allows you to create a suite of different models belonging to a family of models that originate from the traditional ICES forecast model (i.e. Thompson and Bell, 1934).

In contrast to the traditional ICES approach of single species, annual, single areas model with no account of fleet-aspects, bio-economics and fleet behavioural aspects, the TEMAS model contains modules accounting for the mixed nature of fisheries, behaviour of fishermen and fisheries managers. As a consequence of this, the TEMAS model accounts for fleet/gear/vessel size –features, multi-species fisheries, multi-area and seasonal variations. Behaviour of fishers can be modelled only in a bio-economic context, and TEMAS contains modules for costs and earnings and other features from fisheries economics.

The TEMAS model performs three simulations of population dynamics in parallel. A simulation producing the input data to the simulation of ICES fish stock assessment/advice, the population dynamics estimated by the ICES assessment working groups/ACFM, and the population dynamics of ICES forecasts. TEMAS does not only model the behaviour of ICES experts [what does this mean?], it also attempts to model the reaction of the fleets to management measures. Management measures are technical ones as well as quota (effort and catch) regulations. To do this in a meaningful way, the economics of fishing is accounted for.

II.2 Scope

[10] Note that this is not necessarily the all-encompassing list of developers. Also note that at this time this overview has not been validated or accepted by the developers. This overview has been put together using accompanying TEMAS documents and manuals.

TEMAS is not a specific model – it is a generic framework. The current version is a long suite of models, starting with the "BEAM"-models (Bio-Economic Analytical Model) developed originally by IFREMER scientists decades ago.

It is implemented in EXCEL/Visual Basic (Sparre, 2003a) and is a collection of four ordinary workbooks (no installation procedure, - just click on it and it starts).

One basic idea is that the TEMAS model should be used in the same context as the ICES models, and that it should "improve" the ICES model.

One major idea behind the TEMAS model is that it should focus on management of fleet capacity rather than on management of SSBs by TACs, as is the current situation with ICES advice. The idea is that management of capacity is far more important than management of the SSB. Furthermore, management of fleet capacity is feasible in practice, whereas management of SSB involves the "will of god".

Thus, TEMAS is an extended ICES model, aiming at solving the problems that can be handled by man, and "handling" the decisions of god by stochastic simulation.

That implies that TEMAS includes the option to make a conventional single species, single fleet ICES forecast. The reasons for this is that we hope to make ICES use the model when giving management advice.

The traditional TEMAS model extends the ICES models to cover:

1) Multi species (mixed fisheries)
2) Multi fleet (technical interaction)
3) Multi area (including migration), based on the Quin-Deriso model. Conversion of area-mortality into stock-mortalities.
4) Seasonal variations (time step optional)
5) Bio-economics (revenue, costs and earnings, net present values, - based on the concepts from "project analysis")
6) Comparison of alternative management regimes (e.g. Effort quotas vs TAC)
7) Conversion of effort into fishing mortality, including modelling of "technical creeping"
8) Modelling of "fleet dynamics", e.g. accounting for the age distribution of vessels, "recruitment and mortality" of vessels.
9) Stochastic simulation (all parameters can be made stochastic)

Currently , the bio-economics is the primary model, and all other models act as sub-models relative to the bio-economics. The primary output is a suite of bio-economic measures for the performance of the system, including the usual ICES measures (SSB and F). The measures of performance are divided according to three stakeholder groups: (i) the industry; (ii) the Government treasury; and (iii) society as a whole.

The current model is under reconstruction to meet the requests from the TECTAC project. These new features are: behaviour models based on the random utility model; fishers' reaction to management measures (e.g. TAC and technical measures); and TAC (including a model of ACFM's behaviour, the harvest control rule) in a mixed fisheries context.

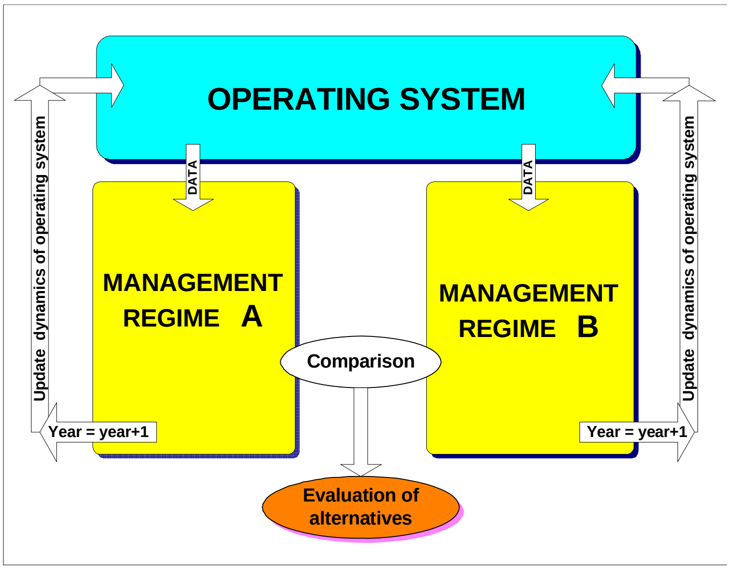
II.3 Model structure

The model is a generic bio-economic and multispecific-multifleet dynamic model. It was developed for the bio-economic and biological comparison of quota and effort management (Ulrich and al, 2002). It is made up of various modules describing the stocks dynamics, the harvesting process, the catchability dynamics, the economic analysis, the assessment procedure, the fisheries management, the implementation of the management tools, and the fishing strategies.

The overall approach uses deterministic and/or stochastic simulation techniques. These are implemented by adding random parameters to various key inputs, and by running several runs of the same simulation.

The TEMAS model is divided into two distinct models: the operating model and the management model. This recent approach consists of simulating the "true" system (stocks and fisheries) with the operating model, which will produce input data to the management model. This second model reflects the advising and management process, where the input data will be used in a traditional assessment, which in turn will be used to generate management advice in the management module.

Figure II. 1: The principal components of TEMAS for one time period of a dynamic process.



The operating system is a model of the stock and the fisheries system. The boxes "Management regime A" and "Management regime B" indicate two models that can simulate the management process (which may include simulation of the ICES working group, setting

TACs, etc…). The arrows indicate the process of one single time period (year, quarter, month…).

TEMAS has been implemented in EXCEL with extensive use of macros written in Visual Basic. The choice of Excel and Visual Basic by the author was only made because of its wide extension, its easy use, and its user-friendliness for presentation and demonstration.

Below follows a list of indices used in the TEMAS model.

Table II. 1: list of indices used in the TEMAS model

INDICE	Explanation	Range
a	Age group	a =0,1,…, Max_Juv_a, Min_Adult_a,…,Max_Adult_a
Ar	Area	Ar = 1,2,…., MaxAr
Ct	Country	Ct=1,2,…, MaxCt
Fl	Fleet	Fl=1,2,…, MaxFl
Q_Age	Time period (as age)	Q_Age = 1,2,…, Maxq (Max number of time period)
Q_Time	Time period (as time)	Q_Time=1,2,…,Maxq
Rg	Rigging of gear	Rg=1,2,…, MaxRg
St	Stock	St=1,2,…,MaxSt
Va	Vessel age group	Va=1,2,…,MaxVa
Vs	Vessel size group	Vs=1,2,…,MaxVs
Y	Year	Y=1,2,…,MaxY

II.4 Model output

TEMAS is divided into two files: the input file, which is used to enter all the inputs used during the simulation, and the calculation file, which performs all the calculations and displays the results. All inputs and outputs are stored as text files, and not as excel cell values.

The output for single simulations (deterministic or stochastic) provides many more details than the output from stochastic simulations. The output from stochastic simulations comprises a set of selected key results only.

Output (produced by workbook TEMAS_CALC) is divided into the groups:
1) Stock structured Output (Output independent of the fleet structure)
2) Fleet structured Output (which may or may not be fleet structured)
3) Economic output

Each output group is further divided into:
1) Results from single deterministic simulation
2) Results from single stochastic simulation
3) Results from multiple stochastic simulation

TEMAS produces large amounts of output for single simulations. The total output for a single simulation is so large that it is not likely ever to be used in full. The idea with the large amounts of output is that the user should select whatever subset he/she considers useful in the context of the case study.

The detailed output from single simulations produced by the TEMAS is rather extensive, and the reader is referred to the demonstration example of TEMAS for further details.

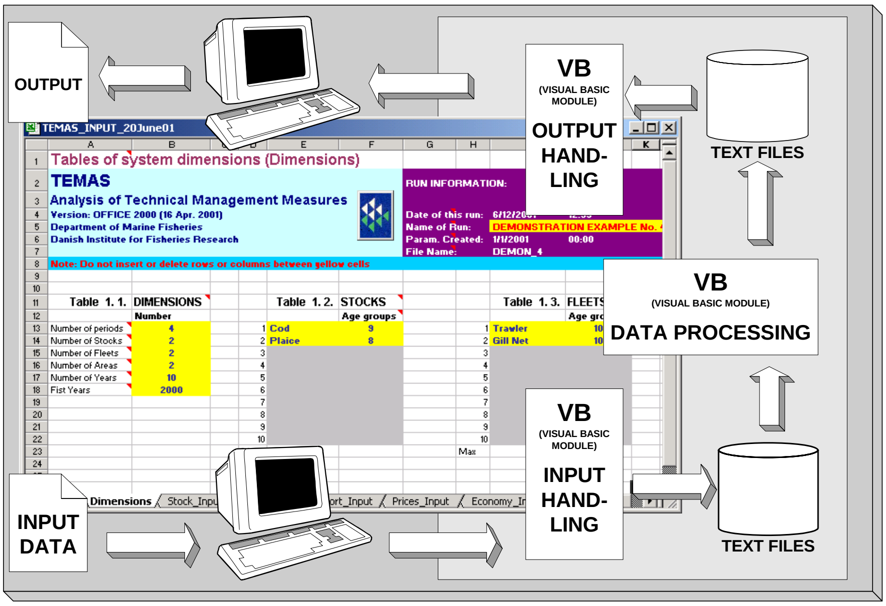
As input to TEMAS, the output is also separated into stock structured output and fleet structured output, as indicated by the names of the 16 output worksheets in workbook TEMAS_CALC:

1) "Summary_output" (cash-flow, NPV, total landings & value, mean value per kg, crew, boats)
2) "Stock_Output" (stock structured output)
3) "Fleet_Output", (Fleet and fleet/stock structured output)
4) "Economy_Output",
5) "Stochastic_Output"
6) "NPV_Output" (NPV = "Net Present Value").
7) "Tuning_Output"
8) "Rules"
9) "Ogives" (gear selection ogive, discard ogives and growth curves, not shown here)
10) "St_Out_Period", "Stock output by time period (summed over areas)"
11) "St_Out_Area", "Annual Stock output by area (summed over periods)"
12) "St_Out_Per_Ar", "Stock output by time period and area"
13) "Fl_Out_Period", "Fleet output by time period (summed over areas)"
14) "Fl_Out_Area", "Annual Fleet output by area (summed over periods)"
15) "Fl_Out_Per_Ar","Fleet output by time period and area"
16) "Table_List","List of all tables produced by TEMAS_CALC"

II.5 Data requirements

The data required for TEMAS is significant – it is a highly developed model based on detailed multi-stock and multi-fleet aspects. Therefore, it caters for full 'VPA-type' stock information (as used by ICES stock assessments) and full fleet definitions including structure and economic data. A flow of the data within TEMAS is presented in Figure II.2.

Figure II. 2. Flowchart for data and results of the TEMAS software.



II.6 Institutional basis

The first version of TEMAS (November 2000) was developed as a part of the research project TEMAS (TEMAS = Technical measures – Development of evaluation model and application in Danish fisheries), a research project funded by the Danish Ministry of Food, Agriculture and Fisheries. The Duration of the project was four years, from September 2000 to May 2004.

The project was jointly executed by two institutes:

1) Danish Institute for Fisheries Research
2) Institute for Fisheries Management and Coastal Community Development

It is based on the open-source concept and is available for use.

III. MOSES

IREPA Onlus (Institute of Economic Research for Fishery and Aquaculture)

III.1 Objective

The Italian model is specifically built in order to represent a management instrument to be employed by public administration. It is a catch-effort model for multi-species and multi-gear fisheries, developed using time series of data of catch and fishing effort. It can be used both for simulation and optimisation analysis. In the former case, the model offers a description of catch and effort data through the estimation of parameters for biological and logistic models. In the latter case, it provides the optimal distribution of fishing effort over areas and gears according to different scenarios (each combining economic objectives and biological and inertia constraints).

III.2 Scope

The MOSES catch-effort model is composed by logistic or biological sub-models applied to each species/areas combination (about 470 different equations for the simulation of Italian fisheries). Most species can be caught by more than one gear. Specification of links among them is given by a technical matrix. Fishing effort for a given equation is defined as a linear combination of effort for those gears competing for the catch of each species. Weights are estimated by means of non-linear regression analyses.
The economic part considers only the harvesting sector and makes use of unit average costs by fisheries (gear/area) and average prices (species/area), as given by the continuous monitoring of the fishing industry.
In the MOSES model, optimal allocation of fishing effort can be carried out for one or more scenarios, and are therefore endogenously determined into the model. A predetermined behaviour of fishermen is assumed: according to the existing external constraints, they are considered as price-takers. Therefore, costs and prices are exogenous.

III.3 Model structure

III.3.1 Biological modelling approach
In the analysis of catch and effort data, two main approach are usually adopted: surplus-production models and age-structured models. The first are non-age-structured

models, require little data and are based on the following assumptions: population dynamics is regulated by density-dependent factors, the effects of the age-structure are neglectable, time delays in production processes are not considered, biomass is homogeneously distributed in the area, there is a balance between immigration and emigration rates, catchability rates and fishing patterns are constant. The second are based on natural equations for an age-structured population, and, unlike the previous class, can make use of auxiliary information coming from biological studies.

The MOSES model makes use of both classes, since it can estimate parameters for Schaefer and exponential models (first class) as well as for Deriso-Schnute model (second class). Regarding the first class, it must be added that the approach is dynamic, in the sense that catch of a given year is considered as a weighted sum of two different terms: a long-period term and a short-period term. This analysis is made possible by the use of a parameter (ranging from 0 to 1) which influences the number of years required to reach asymptotically equilibrium conditions corresponding to a given value of the effort. For high values of this parameters, long-term predictions tend to coincide with short-term predictions.

III.3.2 The economic modelling approach

The economic part of the Italian model reflects the peculiarities of the local marine fishery. The latter is characterised by a high level of artisanality, that becomes evident considering that more than 90% of the fishing firms are individual or familiar firms, and only the remaining part consists of companies. This composition has strong implications on the structure of the economic balance, which must take into account particularly the remuneration of labour, varying in conformity with the contract adopted.

The economic part of the IREPA model aims to the maximisation of the value added. Particularly, the objective is to determine the optimal distribution of fishing effort (obtained from the catch-effort model) that fulfils the maximum economic result (in terms of value added) compatible with the need of species preservation (biological constraint) and of socio-economic aspects, such as a realistic redistribution of the productive structure (inertia constraint). The problem is then:

max VA = R - C ,

where R represents the revenues, given by the sum (for species and area) of the value of the catches (the amount of each of them being multiplied for its own selling price), and C describes the total operating costs, given by the sum (for each fishing system and area) of the products between the fishing unit cost (labour costs excluded) and the total fishing effort. The average prices and the fishing unit costs come from time series of data estimated by IREPA on the basis of the monitoring of Italian fleet developed since 1985 through a sample methodology.

During the procedure of optimisation, the bio-economic model looks for the optimal allocation of fishing effort (and of optimal size of the fleet) for management policy purposes, using prices and unit costs of the reference year and catch and effort time series as well as the time series of catch and effort (indispensable to consider their dynamics in order to avoid over- or under-exploitation). In other words, the model suggests the best effort distribution when prices, unit costs, effort dynamics and catch dynamics are given.

It should be noted that the maximisation of the value added concerns the fleet segments (divided according to fishing system and geographical area), not the individual firms. Therefore, the indirect hypothesis is that all firms behave in the same way and these actions are additive, with the consequence that the sum of these microeconomic behaviour can be now taken into consideration by the optimisation algorithm.

Calculated in this way, the value added represents the remuneration of the factors of productions, namely capital and labour, which are mixed and not easily separable in Italian fisheries, so that it is not correct to apply the mere profit maximisation (unless one is willing to accept arbitrary rules). This means that the MOSES model doesn't consider the income distribution, but only the production aspect. It would be surely possible to introduce the different local systems of income distribution between capital and labour in the analysis, but, because of the considerable heterogeneity of these systems, it should be necessary to add many other parameters in the structure of the model, thus making it more cumbersome and difficult to be solved.

III.3.3 Modelling techniques

The MOSES model is based on a biological sub-model (catch-effort model) and on an economic sub-model.

The former is identified by yearly time series, which are determined after the calculation of the optimal value of the parameters characterising the selected biological model (Schaefer, exponential, Deriso-Schnute).

For each species i an equivalent effort $E_{eq,i}$ is defined: it is calculated as the weighted sum of the fishing effort concurring to the catch of that species.

Given the value of equivalent effort $E_{eq,i}$ for each species *i* (as defined before), the functional form of surplus-production models are:

- Schaefer model: $C_{s,t} = k_0 E_{eq,t} - k_1 E_{eq,t}^2$;
- exponential model: $C_{s,t} = k_0 E_{eq,t}\, e^{-k_1 E_{eq,t}}$.

It has been already underlined that a dynamic approach for the both previous models is considered in the analysis, so that catch in the *t*-th year can be expressed as a weighted sum of an equilibrium term C_s and a short-period term C_c, obtained by catch and effort in the *t-1*-th year, assuming constant CPUE:

$C_t = SC_{s,t} + (1-S)C_{c,t}$, with $C_{c,t} = C_{t-1}\dfrac{E_{eq,t}}{E_{eq,t-1}}$.

By this approach, for each model it is possible to consider all the situations ranging between a purely steady-state model with fast response time (S=1) and a constant CPUE model with equilibrium conditions reachable only at infinite time (S=1).

These models have therefore a memory of one year, and their parameters are k_0, k_1 and S (plus the coefficients necessary to define the equivalent effort).

In order to have significant solutions, some constraints are imposed in Schaefer and exponential models: k_0,>0, k_1>0, $0 \le S \le 1$. In Schaefer model, another condition is set for parameter k_1 (connected to the value of maximum catch of the steady-state curve): $k_1 > k_0/10E_n$, where E_n is the effort corresponding to the most recent year.

The biological model is based on the (partially) age-structured model first proposed by Deriso and then generalised by Schnute. The general form of this flexible model is:

$$\frac{C_{t+1}}{e^{-qE_{t-1}}} = (1+\rho)e^{-M}\frac{C_t}{e^{qE_t}-1} - \rho e^{-2M-qE_t}\frac{C_{t-1}}{e^{qE_{t-1}}-1} + \alpha V\frac{C_{t+1-k}}{e^{qE_{t+1-k}}-1}\left(1-\beta\gamma\frac{C_{t+1-k}}{\left(e^{qE_{t+1-k}}-1\right)}\right)^{\frac{1}{\gamma}} -$$

$$-\rho\alpha v e^{-M-qE_t}\frac{C_{t-k}}{e^{qE_{t-k}}-1}\left(1-\beta\gamma\frac{C_{t-k}}{\left(e^{qE_{t-k}}-1\right)}\right)^{\frac{1}{\gamma}} .$$

It predicts catch C_t at year t as a function both of fishing effort E_t in the same year and of catch and effort for the k previous years (it is a model of order k then).
The following parameters are used in the equation above:
M = natural mortality
q = catchability
ρ = Ford growth coefficient
v = pre-recruitment weight, at age k-1 (kg)
V = recruitment weight, at age k (kg)
α = coefficient of recruitment model
β = coefficient of recruitment model
γ = coefficient of recruitment model
k = recruitment age (years)
In the estimation procedure, parameter k is considered known, while the following 7 independent parameters can be identified: M, q, ρ, αv, αV, β, γ.
The selection of meaningful solutions requires additional constraints on parameter values of the biological model. They are:
$q>0$
$0<\rho<1$
$\beta>0$
$\sigma=e^{-M}<1$
$\alpha v>0$
$\alpha V>0$
$\alpha V>\alpha v$
$\alpha V+e^{-M}>1$
$\left(1-\beta\gamma\frac{C_{t+1-k}}{\left(e^{qE_{t+1-k}}-1\right)}\right)>0$ $t=k+1,...,T$ (T=numbers of years for which effort data are available)
$\left(1-\beta\gamma\frac{C_{t-k}}{\left(e^{qE_{t-k}}-1\right)}\right)>0$ $t=k+1,...,T$ (T=numbers of years for which effort data are available).
The estimation is computed using a non-linear regression analysis (Augmented Lagrangian approach with Quasi-Newton minimisation techniques).
A similar procedure is also used for the solution of the economic model, which aims to the optimisation of the distribution of fishing effort, in order to have the maximum economic result compatible with two constraints. The first is a biological constraint, introduced to avoid overfishing and depauperation for some species connected to the maximisation of profit; the second is an inertia constraint, introduced to select realistic solutions regarding effort redistribution.
In order to insert an index correlated to overfishing, for each catch-effort equation a biological term VB_i has been defined:

$$\begin{cases} VB_i = E_i - E_{m,i} & \text{if} \quad E_i > E_{m,i} \\ VB_i = 0 & \text{if} \quad E_i \leq E_{m,i} \end{cases}$$

Here $E_{m,i}$ represents the effort corresponding to maximum catch in biological equilibrium conditions. For the Schaefer model, it is $E_{m,i} = \frac{k_0}{2k_1}$; for the exponential model, it is $E_{m,i} = \frac{1}{k_1}$.
For each area, a global biological term VB is computed as the ratio of terms VB_i for each species and total fishing effort in the area: $VB = \frac{\sum_{i=1}^{NSP} VB_i}{\sum_{i=1}^{NFS} E_i}$. This index can be interpreted as the fraction of the total effort exceeding the conditions corresponding to maximum catch for each species. Therefore, this formulation is appropriate for areas-oriented policy measures, and is then suitable for input control.
In order to measure the differences between the proposed solutions and the actual ones, for the *i*-th fishing system an inertia constraint VI_i has been defined:

$$\begin{cases} VI_i = \left|E_i - E_i^*\right| - \Delta E_i & \text{if} \quad \left|E_i - E_i^*\right| > \Delta E_i \\ VI_i = 0 & \text{if} \quad \left|E_i - E_i^*\right| \leq \Delta E_i \end{cases}$$

Here ΔE_i represents the maximum allowed variation around the reference value for the effort E_i^*, evaluated by the following relationship: ΔE_i =StDev(E_i)F . The value ΔE_i is then proportional to the standard deviation of the *i*-th fishing effort in the observed period in the given area, and the factor F can be varied according to the scenarios considered in the optimisation analysis, and therefore to the proposed management objectives. This procedure allows to take into account the "elasticity" manifested by each fleet during the previous period, for each area and fishing system, related to the micro-economic reactivity in the fisheries and/or to technological innovation in the long-run.
For each area, a global term VI is then computed as: $VI = \sum_{i=1}^{NFS} VI_i$. By the inertia term it is possible to limit the variations with respect to the present effort distribution, avoiding possible unrealistic solutions and selecting the distribution that, with equivalent economic and biological results, requires less re-conversion effort or cost.
The optimal fishing effort distribution in a given area corresponds to the maximum economic outcome (in the MOSES model it is the value added) satisfying possible biological and inertia constraint:

$\max_x VA(x)$

s.t. $\quad VB(x) < VB_{max}$

$\quad\quad VI(x) \leq 0$

As already said, the solution of this problem is achieved by the Augmented Lagrangian algorithm.

III.3.4 Statistical estimation procedures

Classical testing theory through hierarchical scaling has been used to identify the fisherman objective function (maximisation of value added).
Basic statistical techniques have been used for the treatment of input time series data.
The parameters of catch-effort models, as well as the optimal distribution of fishing effort, are identified by solving a non-linear regression problem, minimising the error sum of squares. Inequality constraints are introduced in order to assure biological meaning to parameters.
For each species-area combination, the following error function has been considered:

$$E = 100 \frac{\left[\sum_{t=1}^{T} \left(C_{ct} - C_{mt} \right)^2 \right]^{\frac{1}{2}}}{\sum_{t=1}^{T} C_{mt}} ,$$

where T is the number of years considered, C_{ct} and C_{mt} represent computed and measured catch in the t-th year.

The optimal value of the parameters x are computed solving the following non-linear optimisation problem:

$\min_x F(x)$

s.t. $G_i(x) \leq 0$ $\quad i=1,...,N_c$,

where the objective function F is composed by the error E, and constraints G (whose number is generally indicated with N_c) have been already discussed before in the analysis of the biological models.

The constrained minimisation problem above is then reformulated as an unconstrained minimisation problem by introducing the Augmented Lagrangian function $L(x,\lambda)$:

$$L(x, \lambda) = F(x) + \sum_{i=1}^{N_c} \xi_i$$

$$\begin{cases} \xi_i = -\lambda_i G_i(x) + \dfrac{\rho}{2} G_i(x)^2 & \text{if} \quad G_i(x) \leq \dfrac{\lambda_i}{\rho} \\ \xi_i = -\dfrac{\lambda_i^2}{2\rho} & \text{if} \quad G_i(x) > \dfrac{\lambda_i}{\rho} \end{cases}$$

The Lagrange multiplier λ_i is a non-negative number associated to the i-th constraint G_i; ρ is a positive penalty factor. This unconstrained minimisation is performed by an iterative Quasi-Newton technique, with the following features: a) linear search based on safeguard inverse interpolation; b) numerical gradient evaluation; c) iterative estimate of the Hessian matrix (second derivatives) using the Davidon-Fletcher-Powell algorithm.

After each minimisation, Lagrange multipliers are updated according to the following relationship:

$$\lambda_i = \lambda_i - \min\left(\rho G_i(x), \lambda_i \right) .$$

A new unconstrained minimisation is then performed, until convergence is achieved. The starting values of vector x in each minimisation are selected by means of a technique of random search.

The Augmented Lagrangian approach is also used for the solution of the optimisation problem regarding the distribution of fishing effort under the biological and inertia constraints.

The economic relationships (examined before) define a classical problem of minimisation of a non-linear function:

$\min_x -VA(x)$

s.t. $\quad G_1(x) = VB(x) - VB_{\max}$

$\quad G_2(\mathrm{x}) = -VI(x)$

Approximated confidence contours at given probability levels are estimated from numerical investigation of the error sum of squares function.

III.4 Model output

The IBEM version of the MOSES model, presented at the BEMMFISH conference on 18th-22nd October 2004, produces two kinds of output, biological outputs and economic outputs.
The biological component outputs long-term landings based on the Schaefer logistic curve for each species and area, and the economic component outputs the long-term added value.
Biological and economic results are displayed for different levels of effort:

- Current level;
- Simulated levels (effort simulation);
- Optimal level (effort optimization).

The last output (effort optimization) is produced following four different scenarios:

- No constraints;
- Biological constraint;
- Inertia constraint;
- Biological and inertia constraints.

III.5 Data requirements

In the Italian model, the endogenous variable of logistic and biological sub-models is catch.
The exogenous variables are:
- time series of fishing effort, for fishing system and area (yearly data);
- technical matrix, specifying fishing systems concurring to the catch of each species;
- recruitment age for each species;
- time series of catch, for species and area (to be used for the determination of the error function).
In the economic sub-model, the endogenous variables are total revenues and value added.
The exogenous variables are:
- unit costs for fishing activity in a given year, for fishing system and area;
- average prices in a given year, for species and area.
In the optimisation and simulation estimates, also the effort becomes endogenous, since the model is able to forecast the optimal effort distribution.

III.6 Institutional base

The last version of the MOSES model (IBEM) was developed by IREPA in the framework of EU project BEMMFISH. The current version is programmed in Matlab.
The MOSES-IBEM model is operating at IREPA and the software is available if requested.

IV. BIRDMOD

IREPA Onlus (Institute of Economic Research for Fishery and Aquaculture)
S.I.B.M. Onlus (Italian Society of Marine Biology)

IV.1 Objective

BIRDMOD-model was developed as a part of a project financed by The General Directorate for Fisheries and Aquaculture (under the Italian Ministry of Forestry and Agriculture Policies).
The "Methodological Support for a Bio-Economic Model of Population Analysis of Demersal Resources" project (BIRDMOD) developed and co-ordinated the activities of two research projects. Presented by SIBM and IREPA partners respectively, the projects focus on the following tasks:

1. To finalise the Bio-Economic Model and analyse its Biological Variables;
2. To provide a methodological support for the BIRDMOD Bio-Economic Model.

In order to perform the co-ordinated project, SIBM was supported by 12 Operative Units from the Evaluation Programme of the Demersal Resources (GRUND) and by the Statistic Methodologies Group established within the GRUND and the FAO Fishery Resources Division. IREPA worked in partnership with Salerno University and the Data Project Company.

The specific objectives of the co-ordinated project were the following:

- To provide a methodological support for the assessment of stocks tailored to the specific features of the Italian demersal fishery;
- To devise a flexible model-prototype that would provide an appropriate description of the state of mono and multi-specific stocks;
- To develop an IT protocol for the processing of data and the formulation of suitable econometric techniques for the evaluation of risk and uncertainties within the population dynamics;
- To provide procedures of simulation for bio-economic model dynamics with methodological protocols and to identify the algorithms for their optimisation; and
- To identify the appropriate IT support that would provide the model with the features of a truly operational work tool.

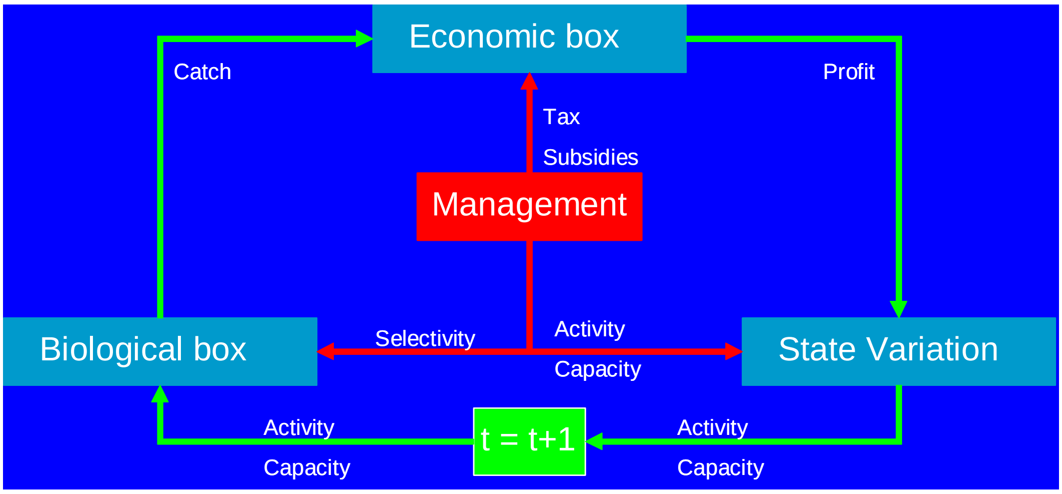
IV.2 Scope

BIRD-MOD is a bio-economic simulation model of the fishing sector. The model is divided into four main modules and four different "dimensions". The managerial, the biological, the economic, and the state variation are the modules considered. The "dimensions" taken into account are the temporal dimension, the fishing systems, the gears employed, the species caught and, for each species, the age/length classes.

The biological module simulates the evolution of the biomass state within the stocks affected by the fishing activity. The economic module simulates the evolution of the fleet state within the geographic area of interest. The management module enables us to simulate the effects of the Public Administration's intervention in the sector and, as a result, to measure the effects of different management policies from a biological, economic and social point of view. Finally, the state variation module enables us to outline the dynamic relations among the endogenous variables of the model by using some predetermined behaviour rules.

IV.3 Model structure

Figure IV.1. The structure of the BIRDMOD model



Biological Box

The general reference framework is represented by an approach based on simulation models that follow the conceptual scheme of "operating models" (Hilborn and Walters, 1992). As for the dynamics, the framework is formulated as a pool dynamic model organized in time intervals.

The evolution of the population is simulated by considering the trend of individuals belonging to a yearly class (cohort) during the subsequent months and years. This method enables us to consider dynamic aspects, such as the different force of the recruitment during different years. This is a particularly important issue for the Mediterranean and the Italian fishery (Caddy, 1993), which are based on the positive outcome of recruitment. Generally speaking, the target of recruitment for the main species are the younger classes.

Nevertheless, the mortality estimations do not depend on the catch coefficient (q) and the fishing effort (f). For this reason, specific assumption on natural (M) and fishing- related (F) mortality rates, the size of recruitment (R) and the dependence of the fishing mortality on the fishing effort and the catches, are formulated in advance. The parameter of input and the dimension of some variables of the BIRDMOD model are obtained or generated by experimental data or hypotheses, formulated according to the conditions in the Mediterranean and reported in the literature.

This method enables us to adjust the results of the model to the “true” outcome (i.e. the catches). Accordingly, in the context of the Italian Seas, it is possible to identify the pool of experimental data essential to verify the hypotheses on which to formulate suggestions for the management of resources.

The main specific objectives concerning the biological box of the BIRD-MOD model are the following:

- To recreate, through simulation, a mono-specific population of a given ichthyic species on the basis of the existing or mutated exploitation scenarios;
- To reconstruct, through simulation, the catches attainable on the basis of the existing or mutated exploitation scenarios.

The variables at stake and the logic pattern adopted were the outcome of two different analyses that addressed the following:

- Variables or sub-models to be used as inputs for designing the BIRD-MOD prototype-model;
- Potential contribution of historical series based on data gathered with methods which have been either direct (e.g., index of plenty, aggregate death rate etc.; source: SIBM) or indirect (e.g., catches and fishing effort; source: IREPA).

The results of both these analyses and the interrelations between variables and sub-models led to the formulation of a biological box whose features will be outlined below.

The BIRDMOD biological box consists of an essentially deterministic simulation model (the stochastic elements are only considered in relation to recruitment) and it is governed by two basic laws:

- Exponential decrease in a natural population either exposed to exploitation or not (e.g., a virgin population or exclusively subject to natural mortality);
- Catch obtained on account of given exploitation rates.

The BIRDMOD biological box is organized in time intervals equal to a month to allow the discreteness of the population and catches in line with management measures possibly, based on monthly adjustments (e.g. temporary withdrawal from fishing activities).

Each cohort, composed of all new individuals joining the population within the year, receives monthly impulses whose extent (number of impulses, periodicity and number of individuals) is simulated on the basis of experimental data and information concerning the biology of the different species (e.g. steady or discreet recruitment, seasonal recruitment peaks, ripening period of gonads and reproduction, stock-recruitment relations, etc.)
Based on the conceptual scheme of an analytical “pool dynamic model”, the model operates under mono-specificity conditions.

Furthermore, by means of a transition analysis based on 30 years, the model is able to verify how the absence or the introduction of changes would influence the structure of the population and catches over time.

The main components of the biological box, all vectorialized are the following:

- Recruitment, which is quantitatively determined on the basis of a priori experimental information or associated to the relation between parental stock and recruits through the Beverton and Holt (1957), Ricker (1954) and Deriso (1908) stock-recruitment relation parameters;
- Growth, defined according to the Von Bertalanffy model;
- Length-weight relation, defined by means of a power model;
- Percentage of mature individuals, by age/size groups and defined through an ogive model;
- Natural mortality *M*, constant or variable depending on age/size parameters and defined according to the Pope *et al.* model (2000) as implemented in Samed (2002);
- Gear selectivity, defined following three main models, particularly an ogive, the product of two ogives and a Gaussian;
- Total mortality *Z*, as estimated by means of trawl surveys (MEDIT and/or GRUND);
- Fishing-related mortality per gear *F*, defined by means of *Z-M* relation and percentage of selection; and
- Total monthly landed catch per gear/fishing system, as estimated using the IREPA sampling system.

The main assumptions of the biological box can be summarized as follows:

- Natural mortality, commonly estimated using empirical formulas or relations based on life history parameters, mirrors the rate of decrease in a population due to natural causes, including predation;
- The process of size selection (basic component of the fishing-related mortality), actually and entirely due to the gears assumed by the model (from 1 to 4 gears), occurs according to the previously identified selection models;
- The proportionality between actual catches and fishing-related mortality, broken down by fishing gear, propagates homogeneously among the different size classes of the population;
- The relation between fishing-related mortality *(F)* and fishing effort *(f)* is a direct one, thus variations on the latter will propagate in a linear and direct way on the former and vice versa;
- As a consequence of the previous statement, a catch coefficient (*q*) assumed as constant over the years (30) is the object of the transition analysis which foresees a variation of the fishing-related mortality and, thus of the effort (e.g., in terms of fishing days). However, as the parameter *q* is unknown, effectiveness is not considered as a variable;
- An aggregate mortality *Z* mirrors the actual condition of all the elements (including the features/performance of different fishing gears) affecting the decrease in the age/size classes of the population;
- Possible variations of the catch coefficient (*q*) are included in the aggregate mortality *Z.* Therefore, if *Z* varies, under conditions of unaltered effort (activity), the effect of an increase in effectiveness (i.e., catches) might be assumed and evaluated.

Economic Box

The BIRDMOD economic box is formulated by fishing systems and constant time intervals equal to a year. As for demersal resources, four fishing systems have been identified: trawl, small-scale, polyvalent and passive-polyvalent. The main elements of the economic box are the prices and costs functions.

Two basic hypotheses relating to the price dynamics are considered by the model. The first case assumes the prices per fishing system and species as constant. The second case assumes the prices as a function of the produced quantity that is the quantity on offer. The dependent variable, i.e. the produced quantity, may be identified either with the production of the single fishing system or the aggregate production of the reference market.
The costs considered for each fishing system are broken down as follows:

- Variable costs;
- Fixed costs;
- Labour costs;
- Interests and amortizations.

On the basis of the structure of the economic account adopted, variable costs are subdivided into three headings: costs of fuel and lubricant, commercial costs and others variable costs. The first and the third are considered as a function of the total fishing days, whilst the commercial costs are estimated as a function of the aggregate catches.
The fixed costs, subdivided into maintenance and other fixed costs, are estimated as a function of the fleet segment considered.
The cost of labour is calculated as a share of the total revenue equal to 50% as in the case of the Italian fishery, that is the difference between profits and variable costs. This approach is justified by the prevalence of the share contract over other means of labour remuneration provided for by the Italian regulations pertaining to the fishery sector.
Gross profit is obtained by subtracting either intermediate costs from profits, that is total fixed and variable costs from labour cost.
Finally, net profit is obtained by subtracting amortizations and interests from gross profit. As well as fixed costs, amortizations and interests are estimated as a function of the dimension of the fishing system considered.
Net profit represents the output of the economic box. Estimated using the catches, prices and costs, net profits are further adjusted by taking into account the effect of management policies, defined in terms of taxes and subsidies.

State Variation Box

The state variation box simulates the operators' behaviour in terms of variations of both average days of activity and number of vessels. The box is aimed at simulating the natural dynamics of the sector by assuming that the operators' objective should be the maximisation of profits. On the basis of this hypothesis, the state variation of the system will be solely a function of the level of the net profits earned.
The state variation box, conceived on a yearly basis, is formulated by fishing systems. As a matter of fact, it might be assumed that variations in the level of profits would produce different behaviours depending on the different fishing system considered.
The model allows final users to exploit a relationship between average fishing days and profits, and the relationship between number of vessels and profits by specifying the relevant parameters. Should this relationship not be accepted by users, the model could be utilised by users to consider these variables as independent from the level of profits. Therefore, the variables will prove to be constant unless different management measures are adopted.

Management Box

The management box is the module that deals with the selection of the simulation scenario. Indeed, using this box it is possible to select the management measure to be simulated.

The management box enables us to choose from a pool of management measures usually adopted by the Public Administration. The pool includes restrictions of fishing effort, such as temporary withdrawal or capacity reduction plans, and technical measures, such as changes in the mesh size of trawls. The model allows us to select the management measure, the period of its implementation and the fishing system affected.
The effect of the management measures are simulated by exogenous changes in specific parameters. For instance, the technical measures are described in terms of variations of gear selectivity, whilst temporary withdrawal is defined as a reduction in fishing days during the relevant months. Furthermore, permanent withdrawal is represented as a reduction in the number of vessels, while the economic measures are described in terms of variations of taxes and subsidies.

IV.4 Model output

The model simulates the sector evolution over the number of years to be specified by users. The final output is represented by the historical series simulated through all the variables included in the logical-conceptual pattern of the model.

Table IV.1 Model output of BIRDMOD

By area and by fleet segment	By area and by species	By area, by species and by length class	By area, by fleet segment and by species
Net Profit Landings Landings per unit of GRT CPUE Total tonnage Total effort Average days at sea Revenues Average price	Biomass in number Biomass in weight Average SSB	Biomass in number Biomass in weight SSB	Landings Revenues Prices

An overall evaluation of the management measure simulated by the model is also foreseen by output. The evaluation is performed by considering the general economic outcome. This is calculated in terms of net profits, management expenses met by the Public Administration to impose the measure, social costs due to the measure adopted and, particularly, to the possible reductions of the sector workforce. The result is then compared to the trend of specific biological parameters, evaluated using appropriate Reference Points.

IV.5 Data requirements

Data are collected through three levels of aggregation by:
- Species for the biological parameters within the age/length structured biological model;
- Fleet segment for the economic data related to landings, costs and prices;

- Fishing gear for the data on landings and activity.

The source of data on landings, costs, prices and activity is the IREPA monitoring system. Some biological parameters are estimated by means of trawl surveys (MEDIT and/or GRUND); while some others are obtained or generated by experimental data or hypotheses formulated according to the conditions in the Mediterranean and reported in the literature.

IV.6 Institutional base

The strategic significance of this research programme rests in the methodological support formulated to design the BIRD-MOD bio-economic model, which is to consider all the main variables involved in the system, i.e. the biological and economic variables, for the benefit of the evaluation and management processes. Therefore, consistent with the objectives of the VI Triennial Plan and the PNR/PA 2000-2002, the present programme aims at supporting the environmental sustainability and the replenishment of fish stocks. Accordingly, it is also oriented towards a constant increase in the productive levels of the sector without jeopardising its economic value. Moreover, a more effective process for the adoption of management resolutions would be an advantage both at a national level and in the complex framework of the Common Fisheries Policy. By providing deeper knowledge of the resource dynamics, the expected outcomes of the programme may well support the adoption of measures addressed to preserve resources, economic activities and manpower of the sector, consistent with the guidelines and the principles of the FAO Code of Conduct for a Responsible Fishery.

Designed at fostering the timeliness and effectiveness of the normative and managerial activities of both the Central Administration and (as provided for by the VI Triennial Plan) the Regional Administrations, the creation of a support tool for short-term analysis and data processing is among the expected benefits of the programme. Besides, the results of the research programme will provide an effective tool for the evaluation and managing of medium and long term impacts of the sector's common and national policies. A further benefit will come from its multi-disciplinary strategy, which is directed at confronting the complex bio-economic issues with a systemic and integrated approach. Accordingly, this strategy would also strengthen the scientific system of the fishing sector.

V. MEFISTO

BEMMFISH and MEFISTO 3.0

Mediterranean Bio-Economic Simulation Model

Francesc Maynou (ICM-CSIC), Jordi Guillen (GEM – UB), Ramon Franquesa (GEM – UB) & Jordi Lleonart (FAO)

V.1 Objective

BEMMFISH (*Bio-economic modelling of Mediterranean fisheries*, Q5RS 2001-01533) was an EU project to develop fisheries analysis tools carried out between 2001-2004. The project was developed by several European research centres under the coordination of the ICM-CSIC. One of the results of the project is MEFISTO 3.0 (Mediterranean Fisheries Simulation Tool), which constitutes a bio-economic simulation model specifically tailored to Mediterranean fisheries.

The objective of the MEFISTO model is to simulate the particular behaviour of Mediterranean fisheries (specifically excluding large pelagics fisheries) in biological and economic terms. It is conceptualised as a bio-economic model for non-industrial / artisanal fisheries, allowing for multi-species dynamics with technical interactions and multi-fleet dynamics, where the control variable is effort (not the catch). In MEFISTO, additional control variables, such as modifying the selectivity patterns, introducing subsidies, etc., are possible. The model does not include biological interactions among species, fish migration or optimisation routines. Likewise, it does not include handling or processing costs, because in Mediterranean fisheries the fish products are sold fresh.

At a basic level, the simulation model allows the user to project into the future the biological and economic indicators of the current situation. Alternative management policies can be simulated by changing the initial conditions: *e.g.*, changing maximum fishing time, adding or removing taxes, increasing or diminishing the fleet size, etc. In all these cases the impact on the indicators of each boat, stock, price, etc. can be analysed.

On the other hand the model can simulate possible future events and evaluate their impact. So, simulations can examine what will happen if the biomass decreases (through natural environmental fluctuations) or if the price of fish falls or increases by a certain amount.

MEFISTO allows the user to simulate the impact of changes in effort and the use of several technical and economic measures, as user-input “events”. Among these are:

- effort control (in fishing days and hours, number of boats);
- gear characteristics; in particular selectivity;
- establishment or changes in minimum sizes for certain species;
- changes in subsidies and taxes.

Furthermore, the model allows changing some parameters in a certain time period in order to simulate possible future scenarios. For example, changes in:

- fuel price;
- dismissal price;
- subsidies;
- fishing hours and days;
- boat activation or deactivation;
- degree of gear selectivity;
- fish imports volume;
- fish price.

V.2 Scope

MEFISTO is an open model, not specifically designed for a particular georgraphical area. All dimensions of species, fleet segments, vessels, etc., are specified by the user. It may be used in any area with a basic economic structure that can be assimilated to the Mediterranean model and demographic (biological) data on at least one main species.

Likewise, any management area is defined by the user.

V.3 Model output

MEFISTO produces two types of output:

i) Standard graphs, for a quick analysis of the results, including the most relevant indicators aggregated at a suitable level: mean biomass, spawning stock biomass, recruits, average fishing mortality, catch by stock, catch by fleet, effort (activity in time), catchability, capital, number of vessels, profits, total revenues, and total costs. The data used for the standard graphs can also be exported in MS Excel format, for further customization.

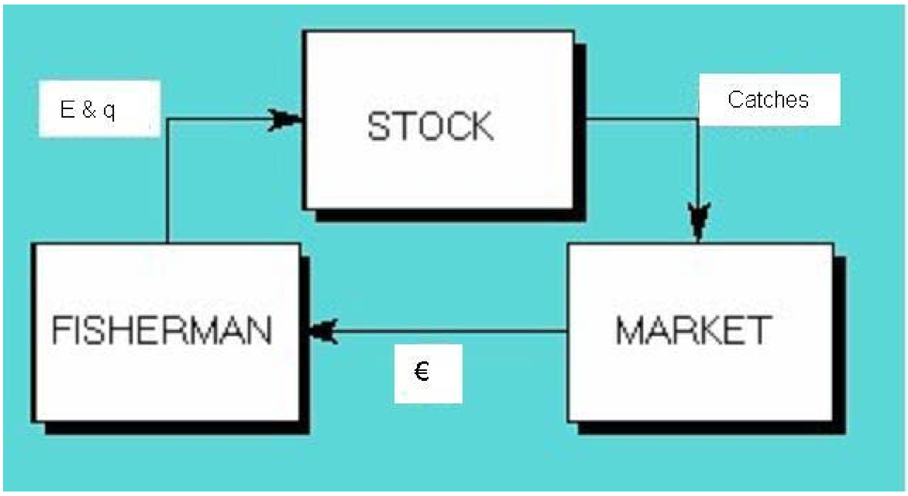
ii) Custom graphs, for more detailed analysis at the level of cohort, species, vessel or fleet.

   a. At the vessel level the analyst can examine: trade costs, daily costs, labour costs, average salary of the crew, annual costs, annual VC + FC, capital, financial costs, debt, opportunity costs, total costs, total revenues, profits, catch main species, catch secondary species, revenues main species, revenues secondary species, effort, number of fishing days, and catchability.
   b. At the fleet level the following indicators are available: total costs, profits, effort, catchability, capital, number of vessels, revenues by species, and catch by species.
   c. At the stock level: Stock biomass, SSB, number of recruits, catch, mean number, fishing mortality, and catch by gear.
   d. At the cohort level: natural mortality, initial number, mean number, mean biomass, catch, fishing mortality, catch by gear, and catchability.

V.4 Model structure

MEFISTO is a dynamic model built on three modules or boxes:

Figure V.1. MEFISTO bio-economic model boxes and flows.



- Stock module: simulates the resource dynamics in the sea, from reproduction to growth and death. The stock module can simultaneously contain several sub-modules (in the case of multispecies fisheries). The model considers two types of species:
    1. the main species are those species whose dynamics (behaviour, biomass, reproduction, growth, etc.) are known by the scientist (for example, through stock assessment) and therefore simulated explicitly, and
    2. the secondary species, those economically relevant species whose dynamics are not known, but their catch are empirically related to the catch of the main species.

The stock module receives information on fishing effort *E* and catchability *q* (including the capacity to fish that a certain boat or fleet has), to produce fishing mortality *F*. This module generates the amount of catches for the period. These catches are sent to the following module: the market.

- Market module: From the initial data, the market module converts the fish catches of each species generated by the stock model (main as well as secondary) into money, through price functions. These price functions can consider for each species (depending on information available) the influence of the fish size, the supply of fish in the market, and the fish imports on the market. Additionally, an exogenous modifier of price can be included in the form of an event or signal that distorts the endogenous formation of price.

- Fishermen module: simulates the fishermen's economic behaviour and decisions. Based on the money generated in the market module, fishermen can increase the capital invested in fishing. The fishermen module therefore obtains the effort (within a system where maximum effort is fixed by law) and the catchability, which the fishermen can affect by investing capital in the boat.

At each time step of the simulation (*e.g.* year simulated) a complete cycle of the 3 modules is run. The benefits (profits) of the preceding period are therefore reflected in the activity of the boat in the following period. The time steps can then be repeated as many times as are required to simulate the desired total time period.

The set of biological and economic variables/parameters that represent the base bio-economic condition of the fishery are defined for year 0 (t_0). These correspond to the data obtained by a preliminary bio-economic survey and are the data entered by the case study analyst. The year 0 parameters are fixed throughout the simulation horizon (*e.g.* growth parameters) or change dynamically according to the equations used in the model (endogenous variables). The value of control variables can be changed by the user during the course of the simulation horizon (events).

The data set of a scenario defines the initial conditions (t_0) for both the biological and economic sub-models. The model is run through a time horizon $t=1, \ldots , T$. The fraction of the population entering the economic sub-model (catch) is given by the fishing mortality (F) at each time period t. The catch of "target" species (and the input from secondary species, if any) determines the revenues (together with the fish price) and, in part, the costs. The costs are further modified by the fishing effort applied (as part of F) and possible economic controls, such as taxes, subsidies or decommission incentives. From the net result (*outcome*) of the difference between revenues and cost, the economic agent ("fisherman") takes a decision, based on behavioural rules, on how to modify F in the following time period. This modification of F can be further altered by the manager in the form of measure controls, such as effort controls etc.

The model comprises a common set of sub-models and computer routines drawing from a standardised data set (input Excel File) and allows the user to conduct simulation or optimisation runs for a given scenario.

V.5 Data requirements

In order to run the model in a realistic way, a particular set of data is required.

i) Economic data: *can be obtained from companies (vessels) and fishing associations, through specific surveys***.**

In the first place, market information is needed. This should be available through sale invoices. This information includes data on the sales in weight and value of the primary species and secondary species, at the level of each individualized boat and on the smallest timescale possible (fishing days).

Secondly, information on general aspects of the vessels that compose the fleet of the analyzed area is needed: number by segment, power and tonnage. These data should be available through the fleet census. In the case of small discrepancies, they can be easily solved.

Thirdly, individual information by fishing vessel is needed. This information is only accessible through individualized surveys where the following information is asked:

- Crew number
- Total Present Value of the investments (value of the ship in its present state with all equipment)
- Subsidies received the previous year (if any). For example subsidised biological closed seasons
- Annual fixed costs, such as: mooring, insurance, administrative expenses
- Variable costs by fishing day, excluding fuel (those that depend on the number of days a vessel fishes), such as: oil, ice, bait, light, food, etc. (if paid for by the owner)
- Daily fuel consumption
- Commercial costs (if it is a fixed percentage of the sales, if not, it should be within annual costs)
- Annual Maintenance costs: includes painting, electrical maintenance of the motor, nets, electronic equipment, etc. transformed into annual costs (so that if they occur every five years, then it has to be divided by five)
- Percentage of the variable costs that can be postponed if there are economic difficulties
- Monthly fishing days by boat
- Gear characteristics (metres of net, number of hooks, etc.)
- Daily hours of work (including the hours employed before and after on land)
- Percentage of the share for wages

ii) Biological data on main species through stock assessments (e.g. GFCM), including Fishing Mortality, and literature on growth, natural mortality parameters, or Stock-Recruitment relationships. When the stock assessments are not available, biological sampling of catches at port is needed in order to conduct a VPA.

V.6 Institutional base

The model was developed by research centres (ICM-CSIC, GEM-UB) in the framework of EU project BEMMFISH, and previous Spanish projects. It is publicly available with no restrictions in its use.

It is a user friendly model with a stand-alone application for Windows 98 or higher, and no programming skills are needed to operate it.
Data can be entered through Excel and the output results also exported to Excel.
The model is updated when any part of the code is modified reflecting current research by the development team.
The model and available literature and case studies can be downloaded from:
www.gemub.com

ftp://cucafera.cmima.csic.es/pub/maynouf/mefisto3.zip

VI. EMMFID

An Economic Management Model for Fisheries In Denmark

Jens Kjaersgaard and Hans Frost (FOI)

VI.1 Objectives

An Economic Management Model for Fisheries In Denmark" (EMMFID) was developed as part of a project, that aimed to develop an all-inclusive bio-economic allocation model for the fisheries in Denmark. The project was financed by The Directorate for Food, Fisheries and Agri Business (under the Danish Ministry of Food, Agriculture and Fisheries).

The basic goal for the fishery, in context of the project, is that society aims to achieve a balanced economic use of resources while maintaining fish stocks at a sustainable level. This means that biological limitations on yield from the fish stocks are taken into consideration. In this perspective, the objective is to:

> Be able to describe and model fishing activities in such a way that economic consequences due to interaction of industry activities and regulation of fishing resources considering sustainability of stocks can be clarified.

EMMFID is a numerical model, set up as a constrained optimization programme, and covers the entire Danish fishery. Its main purpose is to serve as a tool in *'what-if'* analysis and '*what's best'* analysis, where "what's best" refers to changes in the endogenous variables of the model, whereas "what if" refers to changes in exogenous variables and parameters. It is designed to shed light on management questions such as: what will happen if certain objectives are pursued subject to technological and biological restrictions? Or: what is best if the economic return from the capture sector is maximised subject to environmental constraints?

The model is designed to make best possible use of the extensive databases that exist for the Danish fishery with respect to landings, catch per unit effort, and costs and earnings. On a global scale it adds to the uniqueness of the model, or the tool, that the Danish databases are comprehensive and continuously updated. EMMFID is designed to comply directly with the biological advice based on biological modelling and assessment for the North East Atlantic Sea, but does not include endogenous dynamics in fish stocks.

VI.2 Scope

EMMFID comprise the entire Danish fishery (non-commercial activity can be excluded). The level of detail is determined by five sets of dimensions:

1. Fleet segment (26 alternatives)
2. County (14 alternatives)
3. Management areas (34 alternatives)
4. Species (118 alternatives)
5. Month (12 alternatives).

The vessels are categorized according to length and primary use of gear. Vessels that participate in licensed fisheries with limited entry are separated. This results in 26 different fleet segments. Regional aspects are included by making a distinction between vessels from the 14 different counties. Management areas are defined according to the quota regulation as combinations of species and fishing areas. Therefore the model works with 34 areas instead of the usual partition in The North Sea, Skagerrak, Kattegat, Baltic Sea and the Sounds and Belts. A very detailed breakdown with 118 different species include both quota and non-quota species. Most are individual species but five are combinations of two or more, due to the quota determination. Finally the model deals with seasonal aspects by evaluating activities on a monthly basis.

The dimensions of the model can be modified, for example, to include new (foreign) fleet segments or concern more specific fisheries. However, changes are possible only to the degree that necessary data are available.

VI.3 Model structure

EMMFID is a mathematical programming model developed in GAMS (General Algebraic Modeling System). The model seeks an allocation of fishing effort, in terms of number of vessels and days at sea, that maximises the objective function subject to a set of constraints. In other words, the model calculates the optimal fishing behaviour given that certain conditions are valid. EMMFID operates with many constraints and much work has been put into constructing these in a way so that the model is able to represent a reliable framework for agents given the current production technology and management system.

The model is static; a model-run will cover the behaviour in a given year, and there are no ‘built-in’ stock dynamics. Change in fishing vessels/effort (‘investment dynamics’) is included, but the model does not optimize over time because of the fish stock/fleet complexity, but at points in time. Possible paths towards a new situation (solution) are not investigated within the model. Different states of the system (scenarios) are compared for analyses, i.e. comparative static analyses are performed. These scenarios can be formulated in terms of the objective function, the constraints and assumptions about exogenous variables and parameter values. Consider for instance the differentiation between a short and a long run scenario, e.g. maximisation of contribution margin or net profit. It is reasonable to assume that the number of vessels is constant in a short run, but not in a long run perspective.

Examples of different objectives could be: 1) Maximise contribution margin / profit, 2) Maximise employment, or 3) Maximise fleet size. The first objective is generally used, when setting up (bio-) economic models. Nevertheless, the other two non-monetary objectives are interesting because these are objectives of certain political interest not least with respect to distributional impact.

Constraints describe the set of feasible solutions for the system. For a realistic system framework, these would include restrictions on: 1) Catch (such as: Catch must be less than TACs), 2) Profit (such as: Minimum constraints on yearly profit/contribution margin per vessel), 3) Days at sea (such as: Maximum/minimum number of days at sea per vessel), or 4) Fleet behaviour (such as: Fishing ground and species to be exploited). Excluding such restrictions in the maximisation problem would imply a solution that is impossible to realise in the ‘real’ world.

An overview of the EMMFID model is given in Table VIII.1 below. A variant of EMMFID used for the annual FOI publication ’Economic situation of the Danish fishery’ is also described. This is a forecasting model used to calculate the expected economic situation, given the TACs and other relevant conditions.

Table VIII. 1 EMMFID, model overview

	'Economic situation of the Danish fishery' *(Annual report)*	*EMMFID model*
Type of model	*Forecasting model*	*Programming model*
Dimensions		
Vessel segments	26	26
Species	118	118
Areas	34	34
Time period	Year	Month
Home port (county)	No	14 (county)
Objectives	Projection of economic indicators	Max gross margin (short run). Max net profit (long run). Other goals
Variables		
Sea days	Omitted	Variable (endogenous)
Vessels	Constant	Variable (endogenous)
Prices and costs	Variable (exogenous)	Variable (exogenous)
Quota up take	Variable (exogenous)	Variable (exogenous)
Catch per day	Omitted	Variable (exogenous)
Stock abundance	Omitted	Variable (exogenous)
Restrictions		
Management areas (quotas)	56 (reduction 15, human cons. 41)	56 (reduction 15, human cons. 41)
Are quotas taken?	Yes (subject to quota up take)	Not necessarily
Number of sea days	Constant	Max. pr. month (min. pr. month)
Number of vessels	Constant	Max and min.
Economic	-	Positive gross margin (short run) and net profit (long run)
Catch composition Vessel/segment Whole sector	 Varies Varies	 Constant Varies
IQ and ITQ	-	Omitted
Data		
FD, vessel register	Yes (annual update)	Yes (annual update)
FØI cost and earnings	Yes (further broken down)	Yes (further broken down)
FD, landings statistics	Yes (trip level)	Yes (trip level)
EU-FD, quota	Yes	Yes
DFU-FD log book database	No	Yes
ICES stock assessment	No	Yes
FD special permits	No	Not operational

VI.4 Model output

The division of fishing activities with respect to the previously mentioned dimensions implies that output can be produced with a remarkably high level of detail. The following standard table can be used to evaluate output from the EMMFID programming model:

Table VIII. 2. EMMFID, model output

	Number of vessels	Revenue	Contribution margin	Gross profit	Return on capital
Fleet segment 1					
------------------- 2					
Fleet segment 26					

The table gives an overview, but does not reveal the comprehensive information available. EMMFID determines optimal allocation of fishing effort under given conditions. The endogenous variables are number of vessels and days at sea. In terms of the endogenous variables and the parameters of the model, corresponding optimal output measures can be determined, i.e. revenue, costs, profit, distribution of catch, catch composition, quota up take, etc.

VI.5 Data requirements

The primary data source is DFAD (Danish Fisheries Analytical Database), under elaboration in collaboration between:

- The Danish Fisheries Directorate (FD),
- The Danish Institute for Fisheries Research (DIFRES),
- The Danish Research Institute of Food Economics (FOI).

FD and DIFRES supply information on vessels characteristics, activity, catch and catch value. FOI delivers data on costs and earnings.

Data on catch, catch value and effort are available on trip level and aggregated according to the dimensions previously mentioned in section VI.2. A fishing trip often involves catches of species which are related to different management areas. Therefore activity is allocated within areas proportionally to the distribution of catch value. The account statistics include the following cost items[11]:

a) Fuel and lubricants	d) Rent and tax on real property
b) Ice, provisions, stores	f) Insurance
c) Maintenance	g) Other services
d) Sales costs	h) Crew payment

From these items four cost components are calculated (to be used in the model), see table VIII.3.

Table VIII. 3. EMMFID, cost components

1.	Average variable operating cost per day at sea	a) + b)
2.	Average fixed cost	c) + e) + f) + g)
3.	Average variable landings cost per DKK per day	d)
4.	Average variable crew cost per day	h)

[11] Average within fleet segment.

The data used in the model relate to the data regulation programme (EC No. 1639 / 2001). Fleet segmentation and vessel characteristics, as well as the data on production, fit the extended programme. Cost data fit the minimum programme since there is no direct regional differentiation. However, the model relates the variable operating costs to the number of fishing days and calculates contribution to the margin (per day, per vessel) relative to management area, home county, fleet segment and month.

VI.6 Institutional base of the model, accessibility, readiness to use

It has been considered important to construct a type of model that is able to: 1) Handle multi-species fisheries, 2) Provide a realistic estimate of the economic outcome, and 3) Reflect the fishing technology that catches several species at a time.

Including the entire Danish fishery enhances the analysing prospects. Optimal allocation of effort, distribution of catch and catch composition can be evaluated in a comprehensive context. There is a great analysing potential relative to sub-models where fishing activities ‘outside’ the model requires special treatment or assumptions.

A set of equations works as building blocks of the model and various set-ups (scenarios) are available just by simple adjustments. Equations can be switched on and off and parameter values are easily adjusted. Despite the flexibility of the model and the analysing prospects, it is not “user friendly” as such. GAMS programming skills are needed to operate the model.

The model has been operating at FOI for the last couple of years, and it can contribute with valuable information to management authorities. For example, it has been applied to evaluate issues related to fleet capacity, vessel scrapping and stock recovery. The model is continuously updated and new data are incorporated as they become available.

A detailed description of EMMFID can be found in:

Frost, H. and J. Kjærsgaard (2003). Numerical allocation problems and introduction to the Economic Management Model for Fisheries in Denmark. FOI Report 159.

VII. SRRMCF

The Swedish Resource Rent Model for Commercial Fishery

Anton Paulrud and Tore Gustavsson (Swedish Board of Fisheries)

VII.1 Objectives

"The Swedish Resource Rent Model for Commercial Fishery" (SRRMCF) was developed as a tool by the Swedish Board of Fisheries when elaborating a Strategic Plan for the Swedish Commercial Fishery in Sweden. The model is also considered to be a useful tool for a diverse range of management issues according to the future EFF (European Fishing Fund) on the commercial fishing in Sweden.

The basic objectives for the fishery are that society aims to achieve an economic use of resources while maintaining fish stocks at a sustainable level. This means that biological limitations on yield from the fish stocks in the form of quotas are taken into consideration. In this perspective, the objective is to be able to describe and model fishing activities in such a way that economic and social consequences due to interaction of fishery industry activities and regulation of fishing resources considering sustainability of stocks can be clarified.

The SRRMCF is a numerical model, set up as a constrained optimization programme, and can cover the entire Swedish fishery. Its main purpose is to serve as a tool in solving the structural questions of fishery. It is designed to shed light on management questions such as: what will happen if certain objectives are fixed subject to technological and biological restrictions? Or: what is best if the economic return from the capture sector is maximised subject to environmental constraints?

The model is designed to make best possible use of the available databases that exist for the Swedish fishery with respect to landings, catch per unit effort, and costs and earnings. In many ways is this model in its structure very close to the Danish EMMFID model. The difference is that the more advanced EMMFID model uses more comprehensive geographical data on areas and management areas. This is not possible, at least not yet, as full data on geographical level does not exist on the more geographical diverse Swedish fishery. This is partly compensated in this model by using existing knowledge on fishing types and geographical divided fish species. The way it is done is that each type of fishing has a catch composition of one or more "target species" and a connected catch of one or more "by-catch species". So, the volume of target species is connected to an amount of by-catch by a ratio-based span, and opposite around. The knowledge about the different fishing types is based on assumptions from landing statistics based on previous years on catch composition.

The model is continuously updated. SRRMCF is designed to comply directly with the biological advice on quotas based on biological modelling and assessment. This also means that the model does not include endogenous dynamics in fish stocks.

VII.2 Scope

SRRMCF comprise the entire Swedish sea fishery (non-commercial activity is excluded). The level of detail is determined by four sets of dimensions: Fleet segment (presently 14 alternatives), Fishing types (presently 43 alternatives), Species (presently 42 alternatives), Month (12 alternatives).

The vessels are categorized according to length and primary use of gear. This results in 14 different fleet segments. Regional aspects are included by making a distinction between fishing types and species. The different species include both quota and non-quota species. Most are individual species but some are combinations of two or more, and some are the same species but divided by geographical reasons or by outlet. Finally the model deals with seasonal aspects by using monthly based restrictions on certain fisheries.

The dimensions of the model can be modified, for example, to include new (foreign) fleet segments or concern more specific fisheries. However, changes are possible only to the degree that necessary data are available.

VII.3 Model structure

SRRMCF is a mathematical programming model developed in LINGO (LINGO System Inc.). The model seeks an allocation of catch and fishing effort, in terms of amount of caught fish, number of vessels and days at sea, that maximises the objective function subject to a set of constraints. In other words, the model calculates the optimal fishing behaviour given that certain conditions are valid. SRRMCF operates with many constraints and much work has been put into constructing these in a way so that the model is able to represent a reliable and robust framework for agents given the current production technology and management system.

The model is static; a model-run will describe the optimal situation for a given point in time, and there are no ‘built-in’ stock dynamics. Change in fishing vessels/effort (‘investment dynamics’) is included, but the model does not optimize over time because of the fish stock/fleet complexity, but at one point in time. Possible paths towards a new situation (solution) are not investigated within the model. Different states of the system (scenarios) can be compared for analyses, i.e. comparative static analyses are performed. These scenarios can be formulated in terms of the objective function, the constraints and assumptions about exogenous variables and parameter values. Consider for instance the differentiation between a short and a long run scenario, e.g. maximisation of contribution margin or net profit. It is reasonable to assume that the number of vessels is constant in a short run, but not in a long run perspective. The model also calculates the situation of “today” without optimization.

Examples of different objectives could be: 1) Maximise contribution margin / profit, 2) Maximise employment, or 3) Maximise fleet size. The first objective is generally used, when setting up (bio-) economic models. Nevertheless, the other two non-monetary objectives are interesting because these are objectives of certain political interest not least with respect to distributional impact.

Constraints describe the set of feasible solutions for the system. For a realistic system framework, these would include restrictions on: 1) Catch (such as: Catch must be less than TACs), 2) Profit (such as: Minimum constraints on yearly profit/contribution margin per vessel), 3) Days at sea (such as: Maximum/minimum number of days at sea per vessel), 4) Catch behaviour (such as: Species to be exploited, seasons etc.), 5) Market restriction (such as: Industrial need for fish), 6) Mammals (such: effects of seal populations). Excluding such restrictions in the maximisation problem would imply a solution that is impossible to realise in the ‘real’ world. An overview of the SRRMCF model is given in Table VII.1 below.

Table VII. 1 SRRMCF, model overview

Type of model	*Linear Programming model*			
Dimensions			**Restrictions**	
Vessel segments	14		Quotas	Yes (set for all species)
			Seasonal fishing	Yes, certain species
Species	42		Number of sea days	Max. pr. year (month)
Fishing type	44		Number of vessels	Unrestricted or Max/Min.
Time period	Year (monthly restrictions)		Economic	Yes, by market restrictions
Objectives	Max. or Min. of a given objective function		Fishing stops	Yes, for certain species
			Catch composition	Max. and Min. ratio
Variables			Mammals	Yes, seal effects
Sea days	Variable (endogenous)		**Data**	
Vessels	Variable (endogenous)		SBF, cost and earnings	Yes (further broken down)
Employment	Variable (endogenous)		SBF, landings statistics by log book	Yes (annual and per trip)
Catch	Variable (endogenous)		SE, quota	Yes
Prices and costs	Variables (exogenous)		ICES stock assessment	No
Employment per vessel	Variable (exogenous)			
Fishing type (catch composition)	Variables (exogenous)			

VII.4 Model output

The division of fishing activities with respect to the previously mentioned dimensions implies that output can be produced with a remarkably high level of detail. The result that comes from the SRRMCF is comprehensive information that determines an optimal allocation of catch under given conditions. The endogenous variables are catch, number of vessels and days at sea. In terms of the endogenous variables and the parameters of the model, corresponding optimal output measures can be determined, i.e. revenue, costs, profit, distribution of catch, catch composition, quota up take, etc. Naturally the model calculates marginal estimates for all included variables.

VII.5 Data requirements

The primary data source is the yearly cost and earning study performed by the Swedish Board of Fisheries. The data from this study is the same as the requirement of the EU data collection Regulation made. Fleet segmentation, cost data and vessel characteristics, as well as the data on production, fit the minimum programme since there is no direct regional differentiation. However, the model relates the variable operating costs to the number of fishing days. The second source of data is landing statistics from log-books collected by the Swedish Board of Statistics.

VII.6 Institutional base of the model, accessibility, readiness to use

It has been considered important to construct a type of model that is able to: 1) Handle multi-species fisheries, 2) Provide a realistic estimate of the economic outcome, and 3) Reflect the fishing technology that catches several species at a time.

Including the entire Swedish fishery enhances the analysing prospects. Optimal allocation of effort, distribution of catch and catch composition can be evaluated in a comprehensive context. There is a great analysing potential relative to sub-models where fishing activities ‘outside’ the model requires special treatment or assumptions. The model is as mentioned before not as advanced as the Danish EMMFID model but despite this disadvantage of not getting the same amount of information from the model, it has it advantage in not needing the same amount of data input.

A set of equations works as building blocks of the model and various set-ups (scenarios) are available just by simple adjustments. Equations can be switched on and off and parameter values are easily adjusted. Despite the flexibility of the model and the analysing prospects, it is not "user friendly" as such. Lingo programming skills are needed to operate the model but making the model accessible from Excel based spreadsheets are under way.

The model is relatively new (2005), but it has contributed with valuable information to the Swedish Board of Fisheries in the Swedish Strategic plan for the fishery in Sweden. The model is continuously updated and new data are incorporated as they become available. A detailed description of SRRMCF can be found in:

Reference:

Paulrud, A., 2005. Resursräntemodell för det svenska yrkesfisket - ett verktyg för analys av det svenska yrkesfisket. (In Swedish) Rapport. Fiskeriverket (Swedish Board of Fisheries).

VIII. COBAS

A dynamic bio-economic model of the fisheries of the South-West

Simon Mardle and Sean Pascoe (CEMARE)
Trevor Hutton and Gurpreet Padda (CEFAS)

VIII.1 Objective

"Invest in Fish South-West will define a strategy for the sustainable management of fisheries in the region during 2006. This strategy will look to further improve fish stocks in the long-term while balancing the needs of the community, regional economy and the wider marine environment."

IiFSW is a new type of project – it is driven by a steering group that is comprised of stakeholder representatives who together will determine the final strategy. The stakeholders represented each have a direct interest in the management and use of the fish stocks in the South-West, and they represent: statutory and conservation agencies, commercial fishing, fish processors, retailers, restaurateurs, regional development, recreational sea anglers, and environmental NGOs and conservation organisations.

The COBAS dynamic bio-economic model has been developed under the Invest in Fish South-West (IiFSW) project. The model is to be used to assess a range of management options for stock recovery for the South-West over a 15 year time horizon. The model includes a number of key features:

- it contains the main biological and economic processes in the fisheries;
- it contains the technical interactions in the fisheries;
- it is able to simulate the effects of a wide range of management options proposed by the stakeholder groups;
- it is able to provide information on the key indicator variables of interest to the stakeholder groups; and
- it is able to take into consideration the considerable uncertainty underlying the biological and economic processes.

CEMARE and CEFAS are together developing a bio-economic model of the fisheries in the South-West. Surveys and investigations on the marine environment, marine mammals, sea anglers, fishermen and policy have all been undertaken by experts in their respective fields.

VIII.2. Scope

The model includes the areas of the English Channel and Western Approaches (i.e. ICES divisions VII d – j)[12]. The model includes all key stocks and all key fleets. In addition, the model is designed to consider the impact of management options on recreational fishers, the environment and the regional economy as well as on the fleets. After extensive consultation the steering group has decided upon the set of management options to be evaluated. These will be refined towards the end of the project (2006).

The area modelled contains a number of multi-species multi-gear fisheries dominated by high value fish and shellfish species such as sole, lobster and scallops. Many of the key species caught economically are non-quota such as scallops, cuttlefish and lemon sole. The fleet operating in the area consists primarily of UK and French boats, although a number of Irish and Spanish vessels also operate in the area. There are a large number of small (i.e. less than 10m) vessels that are generally owner-operated, multi-purpose vessels. The structural dimensions of the model are:

Table VIII. 1: Key model dimensions

UK Fleets = (by main gear type used)*	16 (+external non-SW)		
Total Stocks =	43	Total species =	39
Age-structured =	27	Quota species =	14
Surplus production =	16	Nonquota species =	25
Regions =	3 (Cornwall, Devon, SW Other)		
Other countries =	3 (France, Spain and Ireland)		

* includes different size class:

A number of distinct fishing activities (termed métiers) in the English Channel have been defined for the South-West fleets based on fishing gear employed and area fished. The key fishing activities are also largely multi-species, with the combination of species caught varying by gear type.

The model developed is a dynamic simulation model. The biological relationships developed and included within the model are based for the most part on up to date ICES assessments. For species that are not assessed by ICES, where data has allowed, this has been undertaken by a similar process, otherwise best available data has been used.

In addition to the commercial fishing sector, the recreational sector and the regional economy have also been explicitly included in the model. Further, environmental impacts associated with the fishing activity are included, and the environmental benefits from the different management strategies assessed.

The model aims at capturing the interactions and measuring the impacts of management changes on the fleet profitability, the regional economy, the environment and other stakeholders (such as recreational fishers). Both short term and longer term impacts are evaluated. Ultimately, the model will also be able to estimate the fiscal benefits in terms of increased tax revenue arising from the improved profitability of the fishing industry and regional economy.

[12] Note that there is no ICES division VII i.

VIII.3 Model structure

The main model is based on the previous Channel models (Pascoe and Mardle, 2001; Mardle and Pascoe, 2003). The new model which includes an explicit Celtic Sea (Western Approaches) component has been developed along similar lines to the original Channel fisheries model. However, stock relationships and all economic data have been updated. This new model concentrates on the analysis of the UK fleets. The French, Spanish and Irish fleets are included but at a less detailed level to the UK.

Fishing vessels were divided into seven main fleets based roughly on the gear definitions in the EU data regulation 1639/2001 (beam trawl, otter trawl, fixed net, longline, dredge, midwater and potters).

Table VIII. 2: UK fleets modelled - * indicates existing vessels

Fleet	< 10 m	10 – 24 m	> 24 m
Trawl	*	*	*
Beam		*	*
Midwater	*	*	*
Dredge	*	*	
Nets	*	*	
Pots	*	*	
Longline	*	*	

In total 26 UK metiers have been established. These are based on gear used and describe a mix of species that are ‘targeted’[13] in an area. In the statistical analysis undertaken to define the metiers (hierarchical agglomerative cluster analysis using the Ward method), around 95% of the activity is allocated directly. An outline of this structure is given below, with an indication of area fished and main species:

Table VIII. 3: Defined metiers

Trawl	*Beam*	*Midwater*	*Dredge*	*Nets*	*Pots*	*Longline*
7e, mixed	7d, sole	7e, bass	7e, scallop	7ef, wrecks	7d, lobster	7, mixed
7d, sole	7e(off), sole	7, mixed	7de, mixed	7ef, bass	7e, crab	-
7e, ceph	7e(in), sole	-	-	7d, trammel	7d, whelk	-
7f, skates	7ef, monk	-	-	7efg, hake	7, mixed	-
7j, monk	7e, cuttle	-	-	7d, gillnet	-	-
-	7h, megrim	-	-	7d, driftnet	-	-
-	-	-	-	7e, driftnet	-	-

The model is designed to be a simulation model and as such is less restricted than an optimisation model in terms of size and detail. The original Channel model was developed as both a simulation model Ulrich, Le Gallic and Dunn (1999, 2002) and an optimisation model Pascoe and Mardle (2001). The model was subsequently updated to include environmental damage and safety considerations (Mardle and Pascoe, 2003; Mardle et al., 2004). The model has also been considered by the ICES Bass Working group for use in assessing long run management options for the bass fishery (ICES, 2004). Due to the use of metiers, some spatial distribution of fishing fleets is possible. Particularly with respect to the regional structure of the industry, the spatial structure is linked to the input-output model.

[13] ‘Targeted’ species were in fact the main species as ordered by value.

A total of 39 species and 43 different stocks are represented in the model (see above). As with the previous model, catches of each species are estimated based on the level of fishing activity and the relative catchability in the metier. Effort is applied to a métier rather than individual species. Different combinations of catches in the different métiers are represented through a set of species specific catchability coefficients associated with each métier.

Species and metier specific catchability coefficients were estimated for each stock from the estimates of fishing mortality, total catches, metier specific catches and effort per metier These estimates are then used to estimate changes in effort when F changes or vice-versa. It is assumed that the allocation of effort reflects the changes in abundance and relative profitability of the activities over the year. The model is developed on an annual time frame. In this new model, the distribution of effort is allowed to vary according to scenarios modelled.

Revenue is estimated based on the level of landings and the price. Estimates of price flexibilities in the fishery suggest that prices are relatively insensitive to quantity landed (see Pascoe, 2000). These were assumed to be constant in the original model, however in this model price-quantity relationships can be allowed to adjust.

Running costs are determined as a function of revenue and the level of effort, while fixed and capital costs are determined by the fleet size and structure. Recent cost data has been collected and is incorporated into the model.

The model will estimate the impacts of fisheries management changes on a year-to-year basis over a period of time. At this stage, it is expected that the time frame of the model will be 15-20 years.

Recreational sector

The recreational sector interacts with the commercial fishery through their relative impact on the stock. In order to capture these interactions, some form of recreational catch-effort relationship is imposed in the model, through the inclusion of an additional metier for the recreational sector. Key species targeted by recreational fishermen include bass, wreck-fish and sharks. The travel costs of recreational fishing would also feed through to the regional model to provide an indication of the economic benefits associated with recreational fishing.

Regional economy

The inclusion of more detailed economic interactions between fisheries and the broader community has been relatively limited to date. In most cases, the regional impacts have been estimated separately from the bio-economic model. In the case of Mardle and Pascoe (2003), the regional employment multiplier was estimated separately and included in the bio-economic model.

Environmental impacts

There are two key areas with respect to environmental impacts that are proposed for the bio-economic model. That is, the impact of fishing on cetaceans and the impact of fishing on the ‘habitat’ (that may include non-commercial species).

VIII.4 Model output

The output information from the model can be tailored to the needs of the stakeholder for whom it is prepared. Typically an indication of stock status, fleet profitability, regional and environmental impacts are presented. The level of detail can be adjusted as required. The key endogenous variables of the commercial fishing fleets are number of vessels and days fished.

VIII.5 Data requirements

Data is obtained from a number of different sources: through survey for economic, regional and environmental data; through logbooks for structure and activity of the commercial fishing fleets; and through ICES and CEFAS for stock-relationships. It should be noted that stock relationships used in this model use the best available knowledge at the time of development. The costs and earnings surveys contained significant detail. The cost and earnings data collected for the model is based on an extended format proposed in the EC data collection regulation programme. An example breakdown of costs is given below:

Table VIII. 4. Model output form COBAS

a) Commission	g) Ice	m) Vessel insurance
b) Harbour Dues	h) Crew Travel	n) Vessel repairs
c) Subscriptions & Levies	i) Food & Stores	o) Gear
d) Shore labour	j) Bait	p) Hire & Maintenance
e) Fuel & Oil	k) Other Expenses	q) Other vessel owner expenses
f) Boxes	l) Crew Share	

The metier analysis undertaken is based on trip level data using trips of vessels landing in England and Wales marked as occurring in rectangles of Area VII.

VIII.6 Institutional basis

The model is being developed with guidance and input for use by a steering committee of stakeholder representatives. As such it has direct relevance to the regional management needs of the fisheries in the area. It could form the basis of a model for use by the proposed RAC of the area. This would clearly require further development with regards international fleets (i.e. France, Spain and Ireland). However, with significant past joint-model development for Channel fisheries, the structure and aims of the model are expected to result in a useful development for management.

At present, the model is developed in the GAMS framework – that is principally based on a language in terms of model definition and tables of numbers for results. There is some opportunity to link results directly to MS Excel to provide for graphical output of results. The project under which this model has been developed aims to provide a more user-friendly interface to the model, for general use (given usual concerns of maintaining integrity of the model).

The model is being developed as part of a project that is due to finish in mid-2007. As such, it is still under development. However, the structure as described in this overview is likely to remain.

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IX. ECONMULT

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IX.1 Introduction

This is a study on economic implications of the 3 year harvest control rule (HCR) for Northeast Arctic cod, decided in November 2002 by the Joint Norwegian-Russian Fisheries Commission. Results of this rule are compared to those of five other rules, including the previous one based on 1 year quota decision. Results are measured by nine indicators, four economic and five biological. The multi-fleet model ECONMULT, in combination with biological multi-species models, is used for this analysis of a Barents Sea fishery.

IX.2 Background

TAC advice for Northeast Arctic cod from ICES has fluctuated significantly more than TACs agreed by the Commission (see Table 1). The Commission has probably taken notice of economic, social and other industry interests when TAC decisions have been made. One of the agreed aims of the new 3 year HCR is”- *achievement of year-to-year stability in TACs”*.

Table IX.1. ICES TAC advice, Agreed TAC and Registered catch. Average figures 1995-2004

	ICES TAC advice	Agreed TAC	Registered catch
Average,‘000 tons	458	539	579
Stand. dev. (%)	264 (58)	160 (30)	136 (23)

Sources: (1) ACFM working group 2004, (2) Havets ressurser og miljø 2005, Fisken og havet, Særnummer 1-2005
Note: Including ”Unreported catch, not distributed across area and country”, Source (2)

IX.3 Methods and models for economic evaluation of HCRs

Economic and social implications of management decisions should as far as possible be in line with stock assessment and management procedures currently in use. This study is based on the multi-fleet model ECONMULT (Eide and Flaaten, 1998) that includes cost of harvesting, selectivity, productivity and revenues of 18 Norwegian vessel groups. This model is coupled to a recent prognostic biological model PROST (Bogstad et al., 2004; Åsnes, 2005) and the multispecies model AGGMULT (Tjelmeland and Bogstad, 1998), both developed at the Institute of Marine Research, Bergen.

IX.4 The ECONMULT model

ECONMULT is a simulation model with one or several groups of homogenous fishing vessels. Each group may harvest one or more of the fish stocks, and each stock may include one or more cohorts. A vector of cohort biomasses is an important interface between the biological and the economic part of the model. A fishery is defined as a combination of one vessel group and its main targeted fish stock. However, every cohort may in principle be caught in every fishery, either as being part of the main targeted stock or as by-catch.

There exists two types of variables in ECONMULT: Structure variables and Model variables. The Structure variables define the resolution of the specific fleet model, while the Model variables represent ordinary variables in the fleet model that have been defined.

There are three types of Structure variables in ECONMULT:

1. Variables that define the structure of the fleet model: Number of vessel groups, Number of targeted species, Number of separate biomass units (cohorts).
2. Bolean switches for turning on or off different features of the model.
3. The time unit.

Normally the Model variables are matrices. The size of each matrix is determined by the setting of the type 1 Structure variables. Model variables can be separated into:

1. Decision variables.
2. Endogenous variables.

What are decision variables and what are endogenous variables is partly determined by what type of management that regulates the fisheries. In an open access fishery no decision variables will be active, while a directly regulated system could have different decision variables being active at different times. Variables that always remain endogenous are the biomass and the number of fish in each cohort of the stocks defined in the model.

IX.5 The 3 year harvest control rule

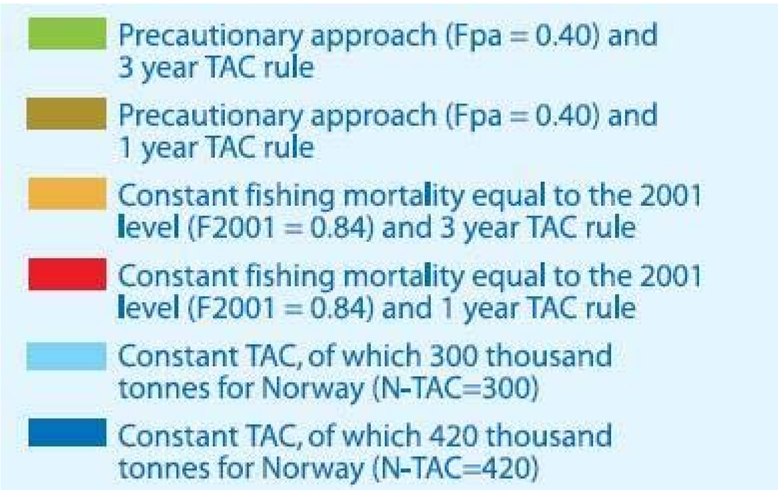
The 31st Joint Norwegian –Russian Fisheries Commission in November 2002 agreed on a new harvest control rule (HCR) to determine total allowable catch (TAC) of cod and haddock in the Barents Sea, to take effect from 2004.
For cod the HCR is:
- Calculate the average TAC for the coming three years based on a precautionary approach fishing mortality (F_{pa}). This is the TAC for next year.
- The following year the calculation of TAC for another three years is based on the revised stock assessment data, though, the TAC should not be changed by more than +/- 10% from one year to another.
- If the spawning stock is expected to fall below the precautionary approach level (B_{pa}) the parties will contemplate agreeing on a lower TAC than what follows from the main rule.

IX.6 Six harvest control rules tested

The three year HCR adopted by the Norwegian-Russian Commission has been tested by an ICES working group and found to comply with the precautionary approach criteria adopted by ICES (ICES, 2004). In addition, to analyse bio-economic implications of the adopted three year rule we compare the results to that of five other HCRs. The six rules are:

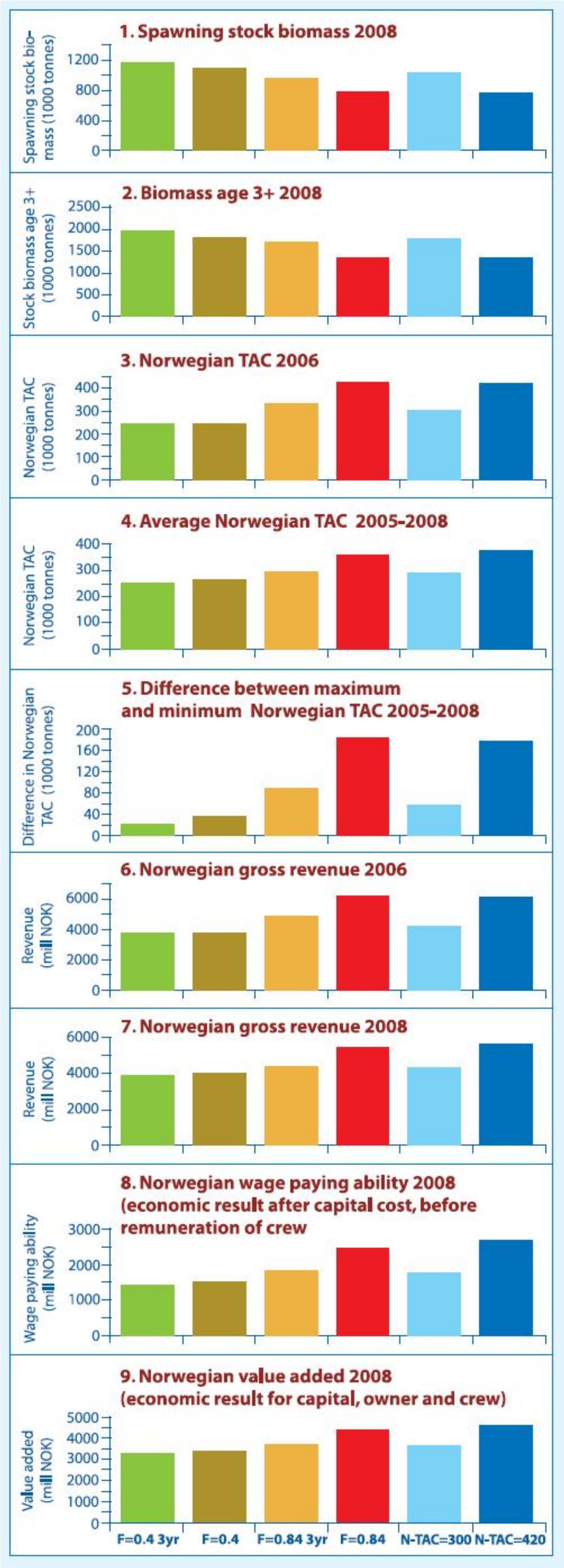
Green	Precautionary approach (F_{pa} = 0.40) and 3 year TAC rule
Yellow	Precautionary approach (F_{pa} = 0.40) and 1 year TAC rule
Light red	Constant fishing mortality equal to the 2001 level (F_{2001} = 0.84) and 3 year TAC rule
Red	Constant fishing mortality equal to the 2001 level (F_{2001} = 0.84) and 1 year TAC rule
Light blue	Constant TAC, of which 300 thousand tonnes for Norway (TAC_{Norw}=300)
Blue	Constant TAC, of which 400 thousand tonnes for Norway (TAC_{Norw}=400)

Figure VI.1 Results



Figures 1-9
Nine biological and economic indicators for evaluating harvest rules

1.SSB:	Spawning stock biomass, 1000 tonnes
2.SB(3+):	Biomass all fish age 3 year and above, 1000 tonnes
3.TAC_{Nor}:	TAC allocation for Norway, 1000 tonnes
4.AvTAC 05-08:	Average TAC allocation for Norway 2005-8, 1000 tonnes
5.MaxDiffTAC:	The difference between maximum and minimum TAC allocation for Norway 2005-8, 1000 tonnes
6.Revenue 06:	Gross revenue from cod fishing 2006
7.Revenue 08:	Gross revenue from cod fishing 2008
8.WPA 08:	Industry total wage paying ability 2008 (possible economic result for labour, after capital cost)
9. CM 2008:	Industry total contribution margin 2008 (economic result for owner, capital and crew).


1. Spawning stock biomass 2008
Spawning stock bio-mass (1000 tonnes)
2. Biomass age 3+ 2008
Stock biomass age 3+ (1000 tonnes)
3. Norwegian TAC 2006
Norwegian TAC (1000 tonnes)
4. Average Norwegian TAC 2005-2008
Norwegian TAC (1000 tonnes)
5. Difference between maximum and minimum Norwegian TAC 2005-2008
Difference in Norwegian TAC (1000 tonnes)
6. Norwegian gross revenue 2006
Revenue (mill NOK)
7. Norwegian gross revenue 2008
Revenue (mill NOK)
8. Norwegian wage paying ability 2008 (economic result after capital cost, before remuneration of crew
Wage paying ability (mill NOK)
9. Norwegian value added 2008 (economic result for capital, owner and crew)
Value added (mill NOK)
F=0.4 3yr
F=0.4
F=0.84 3yr
F=0.84
N-TAC=300
N-TAC=420

IX.7 Conclusion

For the period until 2008 the precautionary approach (F_{pa} = 0.40) and 3 year TAC rule agreed in 2002 implies an increase in both spawning stock (SSB) and total fishable stock, SB(3+), at the expense of all four economic indicators, when compared to five other HCRs. Real benefits of the 2002 rule can best be evaluated in long term simulations (to be reported elsewhere).

For future work:
- Economic analysis based on Russian data could be undertaken, to compare with results for Norway.
- Long term economic analysis should be used to evaluate the Commission's aim of taking into account *"- conditions for high long-term yield from the stocks."*

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