SOCIOEC

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Introduction

The aim of the present document is to provide key steps to be followed when carrying out an Impact Assessment (IA) analysis to evaluate the socio-economic impacts of new policy options in the fishery sector. The methodology is based on case studies, with the aim of covering all the EU regions and all possible innovative management options, paying special attention to what is foreseen in the new Common Fisheries Policy (CFP).

The methodology illustrated in the present report addresses the core of the quantitative analysis, aimed at giving a quantification of the likely and most important expected impacts.

Indeed, the IA of the SOCIOEC project has been organised as a three-step analysis:

1. first, qualitative IA based on "soft" methodologies (i.e. focus group and interviews). This phase has been addressed as a preparatory phase for those following;
2. second and third steps, quantitative IA exclusively based on "hard" methodologies (i.e. simulations and cost-benefit analysis).

The first step has already been addressed in previous tasks and deliverables. The second is the object of the present deliverable while the third will be dealt with in the next step of the project (task 5.4, Ranking of new policy options, and Deliverable 5.6).

According to the most recent and complete IA guidelines (EU, 2009), the analysis of impacts of new policy options should address the likely economic and social impacts - both intended and unintended - for each selected new policy option.

Indeed, an IA should provide evidence to policy makers with which to take decisions. The more quantification one can provide, the more convincing the IA analysis will be. It is important that the IA is based on reliable data and the results are transparent and understandable to non-specialists (e.g. stakeholders). Indeed, stakeholder involvement is one of the main challenges of the SOCIOEC project, both in giving inputs to the analysis (inputs in the selection of new management measures) and in evaluating ex-post the results of the analysis (feedback). Stakeholder involvement is a fundamental aspect in IA analysis as it increases awareness of the wider implications of policies and counterbalances the methodological limits of monetizing impacts (OECD, 1997).

Wherever possible, according to data availability and models set-up, the assessment should go beyond the immediate effects (direct impacts) and take into account indirect effects such as side-effects and knock-on effects in other segments of the economy (fishery sectors such as processing, aquaculture, etc.). Along with impact assessment, the uncertainties or risks associated with each option should be quantified and clearly exposed.

The aim of the quantitative analysis is to provide clear and quantifiable information on the impacts of the policy options. This can then form a basis for comparing them:

1. against one another;
2. against the status quo (baseline scenario) and
3. for ranking them in relation to the general criteria of *effectiveness, efficiency and coherence*.

This comparison represents the focus of the next phase of WP5, task 5.4, Deliverable 5.6. Indeed, in this sense the quantitative analysis, for which the present document provides key steps, plays the role of a preliminary phase to the final one of choosing the best options to achieve the pre-defined objectives.

In this document, firstly a presentation of the general approach followed by the SOCIOEC project (chapter 1), and secondly a deeper discussion of the key aspects to be taken into account when running an IA analysis (chapter 2, Indicators, chapter 3, Tools for simulation, chapter 4, Scenario approach).

1. Definition of a common methodology: the synthesis table

The present paragraph illustrates the methodological approach that will be applied within the SOCIOEC project at case study level, in order to assess the socio-economic impacts of the proposed innovative management measures. The methodology tries to reply to the following research question: *which are the innovative management measures able to reach the main objectives of the (new) fishery policy?*

In replying to this research question, the project has taken into account the number of discussions regarding the new CFP that is held in different fora at a European and MS level.

Actually, within the SOCIOEC project, the definition of case studies starts by the identification of the new measures that are expected or likely or advisable to be applied in the different EU regions and fisheries. These are the measures that are proposed by the new CFP (i.e. discard ban) as well as those coming from long-term discussions between managers, scientists and other stakeholders (for example effort and quota in the Mediterranean region).

Indeed, as mentioned above, the first step in a proper IA analysis is the qualitative evaluation of all the possible expected impacts. This phase has been addressed as a preparatory work to the quantitative evaluation, which methodology is the core of the present report.

A more thorough qualitative analysis will make the quantitative phase easier. Indeed, the selection of the best policy options able to properly achieve the pre-fixed objectives is facilitated by an ex-ante screening of all the possible options and related effects. This type of analysis has been carried out in the previous phase of the project drawing on expertise available, desk reviews of existing researches, studies and evaluations, possibly enriched by using the results of consultations with stakeholders. The SOCIOEC project is benefiting of the mutual collaboration with other EU FP7 projects, like MYFISH, ECOFISHMAN, BENTHIS and COMFISH. The results of this analysis, at case study (CS) level, are available in Deliverable 5.3. Everything that is reported in the present report, at CS level, is a result of the preparatory qualitative analysis.

Hence, we could conclude that the methodological scheme followed by the SOCIOEC case studies will try to reply to the following research question and not actually the above one: *are the innovative management measures proposed able to reach the objectives set out at high level by the new CFP and specifically by regional and/or local fora?*

The answer of the SOCIOEC project is aimed to be as standardised as possible as one of the main aim of the project is, indeed, to create a standard procedure for IA that could represent a useful and practical analytical tool to be used in future evaluation of fishery management plans at EU level (e.g. IA analysis for LTMP as for STECF and ICES context).

Having said that, the methodological approach can be synthesized by the following table, that identifies the necessary elements to gather and agree on in order to structure the analysis before any simulation is run:

Synthesis table used as a standard format for the quantitative IA analysis at CS level

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Objectives in relation to the measure (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short -ST and long run-LT)	Tool / Model Used for simulations	Model output (in relation to ecological, economic, social indicators)	Scenarios to be evaluated in relation to the measure

The first two columns of the table are project specific as they are needed within the project to identify the case studies. The case study regions are defined according to RAC areas. There is a fifth one taking into account the features of non-EU fisheries. Sub-case studies have been defined taking into consideration specific fisheries, relevant at EU and regional level, for different reasons, e.g. shared stocks or regional importance of the fishery.

The innovative management measures (third column) are chosen from measures that have been discussed in policy fora or in scientific fora. In order to ensure as strongest link as possible with stakeholders as well with the general policy discussions, the innovative management measures selected are those identified in and outside project discussions but with the relevant and essential contribution of stakeholders, case by case. In this sense, the SOCIOEC project is based on inspiration from external sources.

The identification of objectives of the innovative management measures were derived from a combination of individual and group meetings with a range of fishery stakeholders, telephone interviews, email surveys and analysis of existing relevant material on specific case study fisheries. Details on the discussions of specific objectives at case study level can be found in D2.2 (Defining by case study a locally appropriate suite of second level objectives consistent with the overarching objectives), where the extent to which objectives can be specified for case study fisheries is explored.

Once objectives have been identified, the next step in the quantification of impacts is the definition of the most appropriate indicators able to measure them. The present report tries to identify the most appropriate indicators in relation to the large variety of cases identified within the project, from a technical (fisheries) and geographical (EU region) point of view. This will allow us to provide a general procedural scheme and tool able to be used and replied in other similar contexts.

In order to evaluate if a management option is able to reach a predefined objectives, the objectives have to be measured by a set of indicators and these (indicators) have to be evaluated against a set of specific reference points. Reference points can be associated with either a critical or an optimal state, where the former identifies a limit which must not be exceeded (LRPs, limit reference points) and the latter a target to be attained by the system (TRPs, target reference points). More details on indicators and reference points are explored in chapter 2. Both the identification of indicators as well as of the reference points is strongly influenced by the definition of the time frame of the assessment. Of course the time frame (if short, medium and long-term) will depend upon the policy option and the scenario that will be simulated.

For each management measure, the evaluation of the impact has to be assessed by defining a priori the scenario that the implementation of the policy option under consideration could likely generate, from a short and long term perspective. The scenario approach used for the IA analysis within the SOCIOEC project is better described into chapter 4. The synthesis table filled in with the specificities of all the case studies is provided at the end of the report.

As already mentioned, the present report illustrates the methodological approach used for the quantitative phase of WP5.The more quantification an IA can provide, the more convincing the IA analysis itself will be. Chapter 3 provides a description of the quantitative models used within SOCIOEC to quantify the impacts. The description covers all relevant aspects of running a specific model: data availability, measures that can be simulated, output that can be provided. Doing so, the report provides a synthetic overview that is easily understandable for experts as well as non-experts. The limitations and necessary trade-offs in quantitative analysis, scenarios and indicators which are related to the model used, are further detailed below.

1.3 Objectives and innovative management measures

An important contribution of SOCIOEC is an emphasis on other types of objectives that have not been given so much focus this far. The main category of objective previously specified in European fishery policy has been biological (good status of stocks) with social and economic objectives only being introduced shortly. The more reduced availability of quantitative data for the analysis of economic impacts on one side and the demand for qualitative data to meet the requirements of social impact assessment remain some of the challenges to be able to measure the progress towards social and economic objectives.

In a previous deliverable (D2.2 Defining by case study a locally appropriate suite of second level objectives consistent with the overarching objectives) the extent to which objectives can be specified for case study fisheries was explored. Setting reference levels for the objectives helps to assess the performance of management measures by comparing the value of certain indicators to the reference level. Furthermore, the specification of objectives, even if only in a purely qualitative way, contributes to the assessment of the impact of management measures, as qualitative information can be obtained and then compared to the objective in a basic (but often very informative) way, indicating trends, that is, whether the management measure is driving the fishery towards the objective or away from it.

The analysis of fisheries policy objectives in SOCIOEC also covers the relative importance of fundamental high level biological, economic and social objectives. This ranking procedure and the corresponding trade-offs can help with the scoring process in the impact assessment methodology. The study of the objectives included the identification of complementarities and conflicts among them, which can also be helpful in the process of assessing the complex impacts of management measures.

With respect to the methodology employed, the objectives analysed in SOCIOEC were derived from a combination of individual and group meetings with a range of fishery stakeholders, telephone interviews, email surveys and analysis of existing relevant material on specific case study fisheries objectives.

Long-term objectives can be achieved by following different paths. Different management systems and/or management measures can show similar effects in the long-term, but significant differences in the short-term. As a consequence, long-term objectives should be complemented by short-term objectives. This is particularly true for the economic and social dimensions, which can sustain the “negative” short-term effects of measures for stocks recovery within reasonably limits.

The innovative management measures selected for the SOCIOEC case studies are those identified with the relevant and essential contribution of stakeholders, case by case. In this sense, the SOCIOEC strongly complies to the prescription of the EU guidelines on IA, requiring the stakeholder involvement throughout the policy process (definition of objectives and policy options as well as in the IA process).

The process of identification of new policy options able to achieve the objectives (set out in collaboration with relevant stakeholder) should include, according to IA standards:

- the “no policy change” baseline scenario (needed to judge the impact of new policy options against the present scenario);
- improved implementation/ enforcement; in some cases (e.g. lack of right incentives, governance failures) perhaps only an improvement in the implementation/enforcement process is needed (this means higher management costs and probably different fishermen behaviour/responses);
- self- and co-regulation.

In identifying the most appropriate policy options, it is important to take into account that options should be complete and sufficiently well developed to allow differentiating them on the basis of their performance against the relevant criteria of *effectiveness, efficiency and coherence* with objectives.

The selection of management measures to be evaluated within the SOCIOEC project has taken into account the main failures of the past CFP as well as proposals by the new CFP (e.g. discard ban). Indeed, in some case studies, the management measure proposed represent a change log if compared with the past (e.g. effort quota in the Med). In other cases, the management measures evaluated are those proposed by new regulations (e.g. new mesh size).

A complete list of the management measures object of a quantitative evaluation can be found in the synthesis table shown at the end of the report.

2. Indicators and reference points

The aim of this chapter is to provide an overview of the main literature and the most recent developments of the selection of the most appropriate indicators, paying attention to the biological indicators but focusing more on the social and economic dimension.

As evidenced by a vast literature (FAO, 1999; OECD, 2003) and projects (e.g. CopeMed, AdriaMed, the Impact Assessment Studies related to the CFP, BEMTOOL, Remuneration of spawning stock biomass - FISHRENT), the importance attached to biological and socio-economic indicators have greatly increased over the last twenty years. Since the early '90s, indicator-based approaches to management have been widely used to provide rapid assessments of the successes and failures of fishery management systems with regard to the four major dimensions of sustainability, which is ecology, society, economy and institutions (Rice and Rochet, 2005). In 1999, FAO proposed a methodology to define indicators on the basis of a small number of key criteria or variables and appropriate indicators and related reference points (FAO, 1999). In 2003, the OECD Committee for Fisheries (COFI) published a study focused on fisheries-related indicators used within the OECD (OECD, 2003). One of the main OECD recommendations was that the selection of indicators should be based on clear policy relevance, compatibility across countries, analytical soundness and data availability. More recently, the World Bank developed a new set of Fishery Performance Indicators (FPIs) for evaluating and comparing the world's fisheries management systems based on their success in being ecologically sustainable, socially acceptable, community enriching, and generating sustainable resource rents or profits(The World Bank, 2012).

Furthermore, the indicator-based approach is an integral part of the Community framework for the collection, management and use of scientific data in order to implement the CFP (Regulation (EC) 199/2008, and subsequent Commission Decisions No 949/2008 and 93/2010). In 2007, the EU Commission developed a list of "Guidelines for an improved analysis of the balance between fishing capacity and fishing opportunities" (STECF, 2007). These indicators have been developed with the purpose to assist EU Member States for the compilation of their annual reports containing information concerning the efforts undertaken in order to achieve a *stable and enduring balance between fishing fleets and the available resources* as established by the Council Regulation 2371/2002. The so called "balance indicators" have been classified according to four dimensions (Economic, Biological, Social and Technical) and reflect the CFP objectives of ensuring an exploitation that provides sustainable economic environmental and social condition.

Taking into consideration the conclusions reached by previous studies and reports, the present document is aimed to produce an overall picture of the main biological and socio-economic indicators classified according to their key objectives, such as the achievement of the environmental, economic, and social sustainability.

Many factors may affect the selection of suitable indicators in order to guarantee transparency and comparability. Taking into account the specificity of fisheries and the management framework, indicators should be relevant, accurate, quantifiable, understandable, replicable, comparable, sensitive and readily available using current expertise and data (the World Bank, 2012). Rice and Rochet (2005) also argued that the number of indicators chosen should be minimal to prevent conflicting signals and to avoid redundancy. For this reason they propose to score indicators against selection criteria with the following nine properties:

1. Concreteness which implies that indicators should be directly observable and measurable rather than reflecting abstract properties which can only be estimated indirectly.
2. Theoretical basis, which implies that indicators should reflect features of ecosystems and human impacts that are relevant to the achievement of objectives. They should be based on well defined- and validated theoretical links.
3. Public awareness, which refers to the public understanding of the indicator, that should be consistent with its technical meaning.
4. Costs, which implies that indicators should be cost-effective because monitoring resources are limited.
5. Measurement, which denotes that indicators should be measurable in practice and in theory. They should have minimum or known bias, and signal should be distinguishable from noise.
6. Historical data, which denotes that indicators should be supported by an existing body or time-series of data to aid interpretation of trends and to allow a realistic setting of objectives.
7. Sensitivity, which refers to trends in the indicator that should be sensitive to changes in the ecosystem state, pressure or response that the indicator is intended to measure.
8. Responsiveness, which highlights that indicators should be responsive to effective management action and provide rapid and reliable feedback on the consequences of management actions.
9. Specificity, which means that indicators should respond to the properties they are intended to measure rather than to other factors and/or it should be possible to disentangle the effects of other factors from the observed response.

2.1 Reference levels (LRP or TRP)

The use of suitable indicators also requires setting appropriate reference points or threshold values in order to understand the performance characteristics of the indicators and to interpret their trends. As reported in Caddy & Mahon (1995), reference points can be associated with either a critical or an optimal state, where the former identifies a limit which must not be exceeded (LRPs, limit reference points) and the latter a target to be attained by the system (TRPs, target reference points). In general, LRPs level states that management does not wish to exceed due to possible undesirable consequences and TRPs level states that management wishes to obtain to maximize benefits from the fishery.

However, choosing the reference point represents a critical issue. From a biological point of view, most indicators make reference to maximum sustainable yield (MSY), which is the highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing environmental conditions and selectivity pattern (Garcia and Staples,2000).

Putting aside the difficulties of calculating MSY for any particular stock, which requires knowledge of several biological (*e.g.* growth, natural mortality, stock-recruitment relationship) and fishery (*e.g.* selectivity) related quantities, it becomes problematic to use it in fisheries where there are more than one species (OECD, 2010). Only in the case where there are no species interactions, it is possible to calculate MSY for each and every species. As long as species interaction come into play, e.g. in the case of predator-prey relationships or where there is competition with regards to food or space, it becomes practically and theoretically impossible to maximize MSY for each and every species.

For the above mentioned reason, alternative precautionary reference points can be based on spawners per recruit (SPR). These proxies are designed to work in a precautionary sense for a range of life histories, and do not require knowledge of the stock-recruitment relationship. Other alternative target reference points are based on the fishing mortality that maximizes yield-per-recruit (FMAX), the closely related F0.1 (F at which the slope of the curve of yield-per-recruit is 10% of its slope at the origin)and the fishing mortality leading to maximum biological production (F_{MBP}).

From a socio-economic viewpoint, the solution that maximizes the economic yield (MEY) is commonly used as a target in fisheries management. MEY is often difficult to measure and can be criticized for being too focused on monetary values. In theory, it should include all relevant costs and prices, including environmental and social costs and benefits (OECD, 2012).

2.2 Biological /ecological indicators

Biological or ecological indicators are usually categorized according to three main dimension or component (BEMTOOL 2012):

1. The ecological state indicators are those pertaining the ecosystem.
2. The pressure indicators are those conveying the information on the fishing pressure/impact.
3. The response or impact indicators are those enabling the monitoring of the effects of management actions.

With reference to the state indicators, the mean length of an individual species of a stock contributes to a simple description of the demographic structure of the population because it gives information on the relative abundance of large and small individuals in the population. Mean length must be calculated on the basis of the total size distribution, in order to estimate the variance and the relative abundance of small- and large-bodied species within each population (Shin *et al.,* 2005). The mean length of the stock, however, can be strongly influenced by recruitment. Also, the percentiles of the population length distribution contribute to the description of the demographic structure of the population and its status, because it is informative on the relative abundance of the different components. The critical length of the exploited stock is the size in the stock giving the higher contribute in terms of biomass. Biomass index measures the total biomass of a population/stock while the spawning stock biomass index measures the total spawning stock biomass of a species. Mean length of the spawning stock contributes to a simple description of the demographic structure of the population and on its status. It has the advantage to be not much influenced by recruitment. In some cases, metrics reflecting spatial distribution of a stock, or of some components of the stock, are also meaningful indicators of the population health (Lehuta et al. 2013). Several authors also promote the use of indicator trends rather than absolute values to smooth the signal and to avoid alerts due to high inter-annual variability (Trenkel et al. 2007).

Pressure indicators such as total mortality rate (Z) and exploitation rate (E) are widely used indicators because their meaning is clear and the expected effect of fishing on them is well understood, so that reference points can be set (Rochet and Trenkel, 2003).They are both related objectives of keeping fishing pressure at a sustained level and maintaining stock reproductive capacity. The Exploitation rate is classically defined as the ratio of fishing mortality rate out of the total mortality rate and represents the fraction of the total removed production due to the fishing activity. In case of data poor situation, having an estimate of natural mortality (M), the exploitation rate can be estimated as (Z-M)/Z. Harvest Rate is an index of F that can be obtained from the total catches of a stock and the biomass at sea. This index is assumed proportional to F and its evolution is assumed to express changes in fishing pressure. Several authors investigated the use of effort distribution over métiers and space as relevant indicators of fishing pressure in particular to quantify the change in the pressure in response to management constraints (Greenstreet et al. 2009; Lehuta et al. 2013).

According to the impact dimension, the Mean length of fish in the catches contributes to a simple description of the demographic structure of the harvested population. It can be influenced also by the recruitment. Also the Percentiles of the length distribution of catches contribute to the description of the demographic structure of the catches and influence of recruitment can be overcome, when considering the higher percentiles. In the context of mixed fisheries, catch profiles and measures of the diversity of species caught are relevant indicators of the impact exerted on the whole fish community.

Table 1 contains a list of candidate biological/ecological indicators that can be used in IA analyses.

Table 1: Biological /ecological indicators

Dimension/ Component	Objective	Indicator	Reference Point or Reference direction or Traffic light
Ecological State	Preserve population structure	Mean length of the stock	Stable or increasing trend
Ecological State	Preserve population structure	Critical length of the exploited stock	Critical length of the unexploited stock (F=0)
Ecological State	Preserve population structure	Percentiles of the population length distribution	Stable or increasing trend
Ecological State	Conserve abundance and diversity	Biomass level	Stable or increasing trend
Ecological State	Maintain safe level of reproductive potential	Spawning Biomass level	SPR
Ecological State	Maintain safe level of reproductive potential	Mean length of the spawning stock	Stable or increasing trend
Pressure	Maintain or reduce mortality	Total mortality	Z* Z_{MBP};Z_{MSY}
Pressure	Maintain or reduce mortality	Fishing mortality	F_{max}; $F_{0.1}$; F_{MSY}
Pressure	Maintain or increase stock productive potential	Yield	MSY
Pressure	Maintain or reduce mortality	Harvest Ratio	Stable or decreasing trend
Pressure	Maintain or reduce mortality	Exploitation rate	
Pressure	Avoid report on other metiers/species	Effort distribution	
Impact	Reduce discard rate	Mean length of the catches	Stable or increasing trend
Impact	Reduce discard rate	Percentiles of the length distribution of catches	Stable or increasing trend
Impact	Reduce discard rate	Catch profile (species)	Diminishing by-catch proportion

2.3 Socio-economic indicators

Socio-economic indicators are generally classified according to five dimensions or areas: Economic, Governance, Social, Technical and Production:

- Economic dimension refers to the criteria of profitability and includes the economic variables associated to revenues, prices, costs and economic performance;

- Governance or institutional dimension refers to the economic efficiency of management, the level of compliance, the extent of transparency and participation;
- Social criteria primary refer to employment;
- Technical indicators include variables related to fleets activity and capacity;
- Production indicators include variables related to the physical production.

The description of each indicator by reference levels (LRP or TRP) and time frame (short -ST and long run-LT) are presented in Table 2.

With reference to the Economic dimension, the most common indicator to measure the economic performance of a fleet segment is the Return on Investment (ROI), which indicates the percentage ratio of net profit plus the opportunity cost in relation to the investment. The economic sustainability is calculated by comparing the investment profitability rate with the theoretical risk free rate, usually the long term bonds rate (around 5%). Results greater than zero but lower than the limit reference point suggest that normal returns are being generated. Results below zero suggest negative returns and indicate economic over-capitalisation (STECF -12-10).

As data on intangible assets are not always available, the Return on Fixed Tangible Assets (ROFTA) is used as a proxy for the Return on Investment. As for the ROI, if ROFTA is higher than the risk-free interest available elsewhere then the fleet is in a healthy and is able to replace large capital items as this becomes necessary. If the ROFTA is below the limit reference point this means that such investments are not worthwhile in financial terms because greater gains may be obtained by investing funds elsewhere.

Other important long term profitability indicators are net present profit or EBIT (Earning Before Interests and Taxes) and the net present margin. EBIT is an often used financial profitability measure. Data to calculate this ratio is collected from the income statement. EBIT is also referred to as operating earnings, operating profit or operating income. It is the revenue minus variable cost i.e. the profit before taking into account interest payments and income taxes. This measure must be considered both by owners, creditors and investors as it shows income from operating activities. EBIT is especially valuable while comparing firms with different financing structures. Higher value of EBIT indicates better state of the firm. However EBIT is not a relative ratio and does not indicate how efficiently assets and resources are used. Net profit or EBIT is generally applied in order to estimate the resource rent. It would provide a direct comparison with returns available elsewhere in the economy.

The net present margin is expressed as the ratio between net profit and revenue and, as ROI, it is usually compared against rate of 5%.

Another important indicator to estimate the remuneration of capital and labour is the Total Gross Value Added, which expresses the Added Value that a fishery contributes to the National Economy and is expressed as income minus operating costs. Salary for the crew is not included in the operating costs. Setting target values for this indicator is very complicated. As limit reference point, a value above zero means the fishery has a value for society.

In some studies, gross value added is calculated in relation to revenues in order to calculate the percentage of revenues which is directed to salary, profit, opportunity cost and depreciation. Gross value added per employee is also an often applied indicator of social sustainability. Trends of these indicators in the AdriaMed project were analysed using the so-called traffic light system. This is set according to their percentile values in the following series: > 66th percentile, 66th-33rd,and < 33rd percentile.

The Ratio between the current revenue and the break-even revenue (CR/BER) gives an indication of the economic sustainability of the fishing fleet in the short term. This break even revenue point is defined as the revenue point at which the gross cash flow equals the fixed costs. Hence, if the ratio is greater than 1, then enough cash flow is generated to cover fixed costs, indicating that the segment is economically viable in the short term. Conversely, if the ratio is less than 1, insufficient cash flow is generated to cover fixed costs, indicating that the segment is economically unviable in the short term. However, as capital costs are not taken into account, when this indicator is below 1, it cannot be identified whether overcapitalisation in the fishery is present or not.

Some studies, such as AdriaMed and CopeMed, included among the economic indicators numerous ratios based on revenues or costs as revenues per vessel or per days or Costs of fishing (or variable costs) per day or per vessel.

Productivity ratios are generally expressed in terms of weight of landings per number of vessels or per capacity and refer to the stability of fishing opportunities and supply. If production and price of one species may affect total supply also these types of information result relevant in order to assess impacts on the downstream sector.

Regarding the social dimension, employment is the most used indicator of the social condition of a fishery. In addition to the employment, gross values added per full time equivalent (FTE) and gross values added per vessel are the most common social indicators. The average wage per FTE or per number of employees gives a reference based on the salary that the crew receives. This indicator is compared with the minimum or the average salary. General speaking a reduction in wage (or in the proportion to the minimum wage) could imply a reduction in the purchasing power and so a worse situation, even if the indicator was higher than the minimum wage.

Governance or institutional dimension refers to the economic efficiency of management, the level of compliance and the extent of transparency and participation. Management costs or enforcement costs, mainly related to EU management budgets to catching sector, are the most used indicators of governance. Subsidies provide information about the dependency of the industry on public support.

Finally, technical indicators include all capacity and effort variables, among which the size of the fleet in terms of number of vessels is also a proxy for employment. One of the most used technical Indicator is the ratio of the average time spent at sea divided by the maximum feasible fishing time in the relevant activity. It takes a value of unity when all vessels are fishing as much as practicable, even though the fishing season may be short. Values less than one indicate that parts of the fleet are fishing less than they could. A value below 0.7 is usually taken as a sign of low vessel utilization (STECF, 2013). However, some vessels may not fish at all in the entire year and are "inactive". If there are many inactive vessels in a fishing fleet, this is an indication that the fleet is not in balance with the resources.

Table 2 contains a list of socio-economic indicators that can be used in IA analyses.

Table 2: Socio-economic indicators

Dimension	Objective	Indicator	Description	Reference Point or Reference direction or Traffic light	Time frame
Economic	Increasing profitability	Return on Investments (ROI)	(profits + opportunity cost)/ investment	Long term risk- free government bond rate	medium/long
Economic	Long-term economic health / profitability	Return on fixed tangible assets (ROFTA)	(profits + opportunity cost)/ fixed tangible assets	Long term risk- free government bond rate	long
Economic	Economic viability	Operating Cash flow (OCF)	Income-all operational costs (crew, fuel, repair, variable, fixed costs) excluding capital costs	>=0; Analysis of trends	short/long
Economic	Long-term economic health / profitability	Net Profit /EBIT	Income – all costs, including capital costs	>=0; Analysis of trends	medium/long
Economic	MEY	Total Gross value added (GVA)	Income- all operative expenses except capital costs and crew cost	>0 or maximum GVA	medium/long
Economic	MEY	Net Profit Margin (NEP)	Net Profit/ Revenues (%)	>= 5% or maximum	medium/long
Economic	Economic efficiency	Gross Added Value/Revenue	percentage of revenues which is directed to salary, profit, opportunity cost and depreciation.	Traffic Light System - Analysis of trends	medium/long
Economic	Economic efficiency	Gross Operative Margin/Revenue	percentage of revenues which is directed to profit, opportunity cost and depreciation.	Traffic Light System - Analysis of trends	medium/long
Economic	Economic efficiency	ROS (Return on Sale)	percentage of revenues which is directed to profit and opportunity cost.	Traffic Light System - Analysis of trends	medium/long
Economic	Economic efficiency	Revenue/Invested Capital (%)	percent ratio of revenues in relation with the investment.	Traffic Light System - Analysis of trends	medium/long
Economic	Increasing profitability	Net Profit per vessel (000 €)	average net profit of each vessel.	>= current levels, Analysis of trends	medium/long

Economic		Break-even revenue or break-even point –(BEP)	the revenue point at which the gross cash flow equals the fixed costs	Analysis of trends	short/long
Economic	Maintenance of profits/ short-term viability	Ratio of revenues to break even revenue or break-even point	Current Revenues/BEP	>=1	short
Production	Productivity	Total production	Total landings	current levels, Analysis of trends	short/long
Production	Productivity and supply	Production of target species	Landings by target species	current levels, Analysis of trends	short/long
Production	Stability of fishing opportunities and supply	Vessel Physical Productivity	Landings per vessel (ton)	Traffic Light System - Analysis of trends	short/long
Production		Capacity physical productivity	Landings per GRT (ton)	Traffic Light System - Analysis of trends	short/long
Production		Landings per day (ton)	average production in terms of weight of landings for each day at sea.	Traffic Light System - Analysis of trends	short/long
Production		Catches per unit of effort CPUE (kg)	average production of each effort (GRT*days/No vessels) unit in terms of weight of landings.	Traffic Light System - Analysis of trends	short/long
Economic	Economic viability	Revenue per vessel (000 €)	average production of each vessel in terms of market value.	Traffic Light System - Analysis of trends	short
Economic	Economic viability	Revenue per GRT (000 €)	average production in terms of market value for each capacity unit (GRT) of the vessels.	Traffic Light System - Analysis of trends	short
Economic	Economic viability	Revenue per day (000 €)	average production in terms of market value for each day at sea.	Traffic Light System - Analysis of trends	short

Economic	Economic viability	Revenue per unit of effort RPUE (€)	average production of each effort (GRT*days/N.vessels) unit in terms of market value.	Traffic Light System - Analysis of trends	short
Economic		Average market price of landings	average price by species(€/kg)	Analysis of trends	short/long
Economic		Average market price of target species	average price by species(€/kg)	Analysis of trends	short/long
Economic		Fuel cost per vessel (000 €)	average fuel cost of each vessel.	Traffic Light System - Analysis of trends	short/long
Economic		Fuel cost per day (000 €)	average fuel cost for each day at sea of a vessel.	Traffic Light System - Analysis of trends	short/long
Economic		Maintenance cost per vessel	average maintenance cost of each vessel.	Traffic Light System - Analysis of trends	short/long
Governance	Efficiency of management	Compliance rate	ratio between the number of infringements and the number of inspections	Analysis of trends	short/long
Governance	Efficiency of management	Management costs	Estimation of annual EU management budgets related to the catching sector by MS	Analysis of trends	short/long
Governance	Efficiency of management	Management costs	Proportion of EU Fisheries Sector Commitments to EU GDP	Analysis of trends	short/long
Social	Job attractiveness	Average crew remuneration	Crew costs / number of employees	>= minimum wages	short
Social	Sustainability	Employment	number of employees	>= current level	short
Social	Sustainability	Fleet	number of vessel	>= current level	short

Social	Sustainability	Gross value added per FTEs	GVA/FTEs	Comparison with the wage obtained from the alternative employment in the industry	short/long
Social	Sustainability	Gross value added per vessel	GVA/no. of vessels	>0	short/long
Social	Equity	Revenue per crew (€)	average production in terms of market value for each man employed.	Traffic Light System - Analysis of trends	short/long
Social		Crew/GRT	ratio between man employed and GRT employed.	Traffic Light System - Analysis of trends	short/long
Technical	MEY	Fleet size, Effort	No, Kw, GT, Fishing Days	Analysis of trends , E (MEY)	short/long
Technical	Technical efficiency	Ratio between the maximum effort that could be exerted by the fleet and the effort deployed	Average days at sea/maximum days at sea or average effort per vessel and the maximum effort per vessel (in kW-days or GT-days	>70%	short/long
Technical	Technical efficiency	Capacity Physical Productivity (CFP)	Weight of landings/ GT	Analysis of trends	long
Technical	Technical efficiency	Power Physical Productivity (PFP)	Weight of landings/ HP	Analysis of trends	long
Technical	Technical efficiency	Per vessel Hour Physical Productivity (HFP	Weight of landings/ total fishing time	Analysis of trends	long
Technical	Technical efficiency	Man Physical Productivity (MFP)	Weight of landings/ No employees	Analysis of trends	long
Technical	Technical efficiency	Vessel Physical Productivity (VFP)	Weight of landings/ No vessels	Analysis of trends	long

3. Tool / Model Used for simulations

A bio-economic model can be defined as a comprehensive set of functional relationships between biological and economic variables, designed to represent a system in mathematical terms. Although they are necessarily simplified representations of reality, bio-economic models in fisheries allow the main relationships between biological processes and those of an economic nature to be detected. Bio-economic models allow the complex system of interactions, dynamics, and natural and anthropogenic relationships that characterise fisheries to be quantitatively represented and measured through mathematical equations. Despite the intrinsic limitations of a model-based approach, this tool has proved to be very useful in management. From the first studies by Gordon & Schaefer in the 1950s (Gordon, 1953; Gordon, 1954; Schaefer, 1957), bio-economic models have become increasingly refined, so that they are now regularly used at an international level to assess the possible effects of alternative management actions.

A significant amount of effort has been devoted to produce bio-economic models able to synthesize the main features of European fisheries and to forecast their evolution. An overview of existing models can be found, among others, in Conrad (1995), FAO (1998), Bjørndal et al. (2004) and Tjeerd-Boom et al. (2008). One of the most recent and comprehensive review of existing bio-economic models developed in Europe has been provided in "Survey of existing bioeconomic models" by Prellezo at al. (2009). Even though this survey is relatively recent, many other models were subsequently developed. The number of bio-economic models for fisheries management has seen an exponential increase in the last few years. Indeed, among the ten models selected for use in SOCIOEC and briefly described below, only Fcube was mentioned in Prellezo at al. (2009).

Existing bio-economic models have structures that can vary widely. For instance, bio-economic modelling approaches for the Mediterranean fisheries differ significantly from those adopted for the Northern European fisheries. This is mainly due to the prevalence of multi-species and multi--gear fisheries in the Mediterranean Sea, and a consequent management system mostly based on input control and technical measures. On the contrary, North-European fisheries are generally managed by output control system, like TAC or other quota regimes, as they do are multi-species fisheries but in a lesser extent than in the Mediterranean waters.

The structure of a bio-economic model depends on several factors. The modelling process is generally driven by the needs and constraints related to the case study where the model is expected to be applied. Among the main drivers upon which the modelling process is based, there are model objectives, the quality of the available data, and the characteristics of the fisheries sector.

As regards the objectives of a bio-economic model, a distinction is usually made between simulation and optimisation models. The model type determines the relevance of each economic component and the approach used for its implementation. Another important factor is the type of management action to be simulated. Input-oriented or output-oriented models can be used, depending on the management system to be simulated in the area under analysis. Also spatial models can be used when spatial management actions such as Marine Protected Areas (MPAs) have to be tested.

The structure and availability of economic and biological data represent another very important factor in the classification of bio-economic models. These models, being generally developed to analyse a specific fisheries area or sector, have a structure that tends to be adapted to the type of data available in that area and for that type of fishery.

Finally, the structure of a bio-economic model reflects the main characteristics of the fisheries sector being assessed. Fishing activities are characterised by being strongly heterogeneous and different management procedures, as well as different modelling approaches, are adopted according to their features. For instance, fisheries can be single-species or multi-species, pelagic or demersal, can use a single fishing gear or a multitude of fishing gears.

Within the SOCIOEC project, an Impact Assessment is expected to be carried out for a large number of innovative management measures to be simulated in different geographical areas and for different fisheries. Each case study is defined by a specific geographical area, stocks and fleet segments involved in the fisheries under investigation, and a set of management measures to be evaluated. Even though some bio-economic models are particularly flexible to accommodate different features and needs of many case studies and to simulate a variety of management measures, there is no specific reason to use a single model for all case studies. Therefore, given the specificities of each case study, the quantitative analysis within the impact assessment process is expected to be carried out through the most suitable bio-economic model (or any alternative tool for quantitative analysis) for that case study.

In this chapter, the models and tools selected for the SOCIOEC case studies are presented and discussed. For each of them, there is a short description of the main features of the model, references and history, which management measures can be simulated by the model, the model data requirements and the outputs produced by the model. To verify the suitability of the model, the issues listed above are compared with the management measures to be simulated, data availability and indicators selected for the case studies where the model is expected to be applied. Furthermore, the reasons for the selection of that specific model are reported as well as a description of possible model adaptations needed for its use in SOCIOEC.

3.1 DISPLACE

The model has been selected for use in the case study of Danish western Baltic Fishery.

DISPLACE (Bastardie*et al.* 2014 in Can. J. Fish. Aquat. Sci.) stands for a Dynamic, Individual-based model for Spatial fishing PLAnning and effort displaCEment and combines individual fishing vessel activities and underlying stock dynamics to evaluate the effect of various management options and stock status on a short to medium term perspective.

The DISPLACE project (www.displace-project.org) develops and provides a platform primarily for research purposes to transform the fishermen's detailed knowledge into models, evaluation tools and methods that can provide the fisheries with research and advice. The model intends to serve as a basis for decision support tools for (fishery) managers. Among other goals, economic benefit of stock replenishment and sustainable harvesting should be demonstrated. This contributes to evaluate the combined ecological and economic impacts of fishery management before its implementation (i.e. impact assessment).

DISPLACE is a spatial and individual vessel based bio-economic simulation framework which combines a spatial fishing behaviour model at high resolution and spatial population models. DISPLACE is on a per-vessel basis covering several fisheries and stocks and is a benchmark tool capable of integrating fishermen's decision-making processes when they face changes in fishery management, economic factors influencing the fishery, economic viability, and underlying stock conditions, including spatial and seasonal patterns in resource availability.

DISPLACE is foresee as an important approach in near future development in ICES and EU advice and future marine spatial planning context being a strong representative for spatial explicit bio-economic models that covers both many stocks and fisheries.

DISPLACE operates with high resolution in time and space (a spatio-temporal explicit model). It allows contributing to maritime spatial planning for e.g. evaluating the effects on stocks and fisheries (impact assessment on stocks and fisheries of marine management). The economic evaluation includes evaluation of spatial restrictions in fishery with particular emphasis to test if there is any economic benefits from the restrictions and if these benefits offset costs of the effort displaced on surrounding or new areas (bio-economic consequences of fishing effort displacement).

The Baltic Sea evaluation will question to which extent the international plans (DNK, GER and SWE) for offshore windmill parks (and potentially NATURA 2000 sites) in the Baltic area are affecting the fishing opportunities per activity and fishing communities in the vicinity of the planned windmill sites. The present evaluation intends to cover the implications of the re-zoning in terms of individual profitability, and also in terms of the sustainability of the exploitation of the main commercial stocks in the area (i.e. sprat, herring, cod and flatfish).

Hence, a baseline (*statu quo* scenario) is compared to a spatial restriction scenario where re-allocations of fishing effort occur according to closures, changed catch, costs and earnings according to vessel-specific fishing grounds in interaction with changed stock dynamics. To evaluate the robustness of the outcomes, a second scenario dimension could further investigate various productivity levels of the underlying harvested stocks.

DISPLACE requires high resolution catch (weight and value) and effort from trip-based logbook information and Satellite VMS-information (i.e. logbook coupled to VMS data). Biological dynamics are informed from the analyses of high resolution resource availability data from e.g. disaggregated research survey or combined fishery information on disaggregated resource availability (at least on ICES rectangle basis). This further makes use of (ICES) stock assessment and fishbase data, STECF landings data per ICES rectangle, and the GIS mapping of various maritime spatial uses.

Within the western Baltic Sea case study, the exploitation targeting FMSY for cod, sprat and herring, the fleet capacity being assumed constant over the projection period, DISPLACE generates fishing effort, revenue from catches, operating costs and profit (GVA) from the various activities of the fishing vessels, by vessel and trip (which can be summed up to e.g. metier and quarter/year). On the biological side, time series of partial fishing mortality by stock and usual stock indicators (R, F, SSB) are produced.

DISPLACE is well-suited to evaluate the effect of spatial plans on the short to medium term perspective. Being two-ways directional modelling, i.e. the human decision-making influences the overall spatial fishing patterns and stock/species removals which in turn impact the stock/species status and trajectories, makes dynamic and robust predictions as biological objectives are at the mean time addressed. By simulating the individual effort allocation and operating costs the model is also well-suited to predict the effort reallocation behaviour depending on individual economic factors and evaluate the costs of any spatial constraints on the fisheries at various scales (individual, fishery, entire fleet).

The core model is written in C++ and does not require any change for performing the present application. The parameterization (incl. coupling of logbooks and sales slips to VMS data) and model output analyses are using a set of routines written in the R freeware. This particular DISPLACE western Baltic Sea application requires the parameterisation to be harmonized over Danish, German and Swedish fishery data.

3.2 FCube

The model has been selected for use in the case study of the North Sea regional demersal fisheries.

Fcube (Fleet-Fisheries Forecast): Fleet and metier based forecast, tailored to providing mixed-fisheries considerations to the annual ICES single-stock TAC advice. The development of Fcube has been rooted the actual regional fisheries management and advice in the North Sea since 2006. It has been built as an overall flexible framework that has evolved following management questions and needs. It is now used by ICES as part of annual advice and for ad-hoc mixed-fisheries requests. The overall framework is also being used by STECF for e.g. addressing management issues of the cod LTMP. Fcube is written in R and FLR, free, open source and plate-form independent. Can be then linked and integrated in any FLR modelling (Hamon et al., 2007; Iriondo et al., 2012; Jardim et al., 2013).

Fleet and metier based multi-stock management, as opposed to single species management. It can also be translated into effort quota, as effort is one input, and is suitable for catch quotas and discards ban scenarios. It can be used to help designing flexible Harvest Control Rules to avoid conflicting single-stock management objectives. The primary focus and use is on biological short/medium-term advice through scenarios simulation. An update of economic impact assessment is being plugged in.

For SOCIOEC, two analyses are conducted: simulating impact of various transition schemes to catch quotas (collaboration with CEFAS and University of East Anglia as part of PhD work by Harriett Condie) and investigating flexible Harvest Control Rules for mixed fisheries management.

The model uses single stock assessment and advice, but can be also adapted to stocks without analytical assessment. Fleet and metier catch and effort data as available from e.g. ICES InterCatch, STECF databases or directly from national institutes. DCF Economic data. Much work has been done over the recent years in integrating the model together with annual data updates in the DCF frame, and improving the reliability and consistency of data time series (ICES data call merging data needs for both single-stock and mixed-fisheries advice since 2012).

Outputs mainly stored as FLStocks and FLFleets objects including all results by fleet, metier and stock, plus additional R arrays and dataframes. All results can be easily summarised and plotted afterwards, or integrated in other frameworks. Additional outputs of model computations are programmed if needed.

Model selected because it is fully up-to-date with and already integrated into the advice framework for the North Sea demersal mixed fisheries, and because it covers the broad international fisheries in the North Sea.

Beyond its current use in ICES advice, the model and its data flow are being continuously developed to address further issues, such as medium-term projections, economic impact assessment and inclusions of new areas and species.

3.3 FISHRENT

The Fishrent model has been selected for use in the case studies of the North Sea mixed demersal fishery, North Sea flatfish fishery, Basque trawlers in ICES Areas VI, VII and VIIIabde and Basque purse seiners in the Bay of Biscay.

Fishrent (Salz et al., 2010) is a multi-species multi-fleet bioeconomic model that has been developed from best practice knowledge gained from similar models used in Europe over the past decade (E.g. Frost et al., 2009). Fishrent is both a simulation model and optimisation model that can enable consideration of a diverse array of policy aims. Developed initially in Excel, the main outputs describe the likely trajectories and status of the modelled fisheries and fleets under the policy aims considered.

Fishrent has been selected for several case studies in SocioEc as it has a long history of development (Hoff and Frost, 2008; Salz et al., 2010) and has shown to be particularly useful for the economic analysis of fleets in previous projects (Coexist, Vectors, Myfish). Fishrent is widely recognised by fisheries economists in Europe. Furthermore, in providing strong links to the biology, Fishrent provides a strong bioeconomic modelling framework for the analysis of such case studies. The management options already in effect in these fisheries (i.e. TACs, effort controls etc) are central to Fishrent making it a particularly relevant framework to build additional or new policy alternatives for investigation. In all case studies proposed, it is necessary to develop specific features in the model by making minor changes with the aim of getting a real characterisation of the new management measures.

The model has been implemented in several frameworks: originally MS Excel (Frost et al. 2013), but also in GAMS (General Algebraic Modeling System) with input and output interfaces in R. The GAMS version of the model includes all the features of the Excel model and the spatial description of species and effort (see http://www3.lei.wur.nl/fishrent/Downloads/FishRent%20%20in%20equations-%20a%20detailed%20description.pdf for a description of the equations). Fishrent is deterministic but dynamic in the sense that year-on-year changes observed are fed back into the model to update fishing opportunity. Fishrent can consider input (i.e. effort controls) and output (i.e. TACs) based management approaches.

The structure of Fishrent is well-defined (Frost et al., 2013) but as with policies can be developed over time to consider options that have become relevant. This is particularly important considering the CFP Reform agenda. Fishrent has been used to simulate management scenarios in both North European and Mediterranean fisheries (Salz et al. 2010), but for SOCIOEC with the upcoming CFP Reform the potential effects of a new range of policy options can be considered using the model.

The North Sea is one of the most important economic areas for fishing in the EU. The case study of North Sea demersal fisheries in that area involves the fleets from several Member States all of whom have different interests in the fisheries, as indicated by quotas allocated. There is and has been since the inception of the CFP, and for 50 years plus previously, considerable management of these fisheries and with the CFP Reform this management will change significantly in forthcoming years. For example, discard regulation banning discards for demersal fisheries will come into force in 2016. Given the multi-species nature of these fisheries, this could have a significant impact on the success of these fisheries and the viability of relevant fleets over time. Fishrent is well placed to investigate the likely impact on fleets and fisheries given these new policies.

The North Sea flatfish fishery, one of the first fisheries in the world where Individual transferable Quotas (ITQs) have been implemented by some Member States, is a very valuable fishery that is dominated by Dutch beam-trawlers (2013 TACs; Sole 75%, Plaice 35%) with other countries such asDenmark and UK also catching plaice (2013 TACs; 19% and 27% respectively) and Belgium and Germany also catching sole (2013 TACs; 8% and 7% respectively). Management has changed considerably since the first introduction of quota in 1975. The quota was effectively individually allocated in 1976 but the real enforcement of the landings limit began in the late 80's. Co-management was introduced in 1993 to improve the management of the individual quotas and increase their tradability amongst fishers. In 2009 a long-term management plan was implemented which led to the two main species (sole and plaice) to be within safe biological limits in 2012 (ICES, 2013). The degree of tradability of fishing rights between and within countries are likely to impact the economic performances of the fishery and Fishrent is being modified to consider trade internationally between fleets. In addition, discard regulation banning discards for demersal fisheries will come into force in 2016. Given the multi-species nature of these fisheries, this could have a significant impact on the success of these fisheries and the viability of relevant fleets over time. Fishrent is well placed to investigate the likely impact on fleets and fisheries given these new policies.

The management of the Basque inshore fishery in the Bay of Biscay shows an interesting evolution characterized by a decrease in fleet and catches and an increasingly complex management system, which attempts to take into account stakeholder's initiatives on local management measures. The management system seems to tend to the increasing use of individual limitation on catches and even the incorporation of rights-based management tools (i.e. in the bluefin tuna fishery). This fishery is multi-fleet and multispecies, and Fishrent is a good tool to evaluate the selected management options.

The Basque offshore fishery shows an evolution characterized by a decrease in fleet and catches (in Subarea VII, and catches of hake in Subarea VIIIabd) and a transition during the last two decades towards a management system based on Individual Transferable Quotas. Despite the consultative role of the fleet, as members of the Southern RAC, Basque offshore stakeholders grouped under the umbrella of their Producers Organizations (POs) which have a limited by effective influence in fisheries management. The POs can manage the individual quotas of their associates and also can take decisions on management measures. Fishrent is a model that fits perfectly to evaluate management measures of this mixed fleet.

Fishrent enables the simulation of both input and output based management measures, from TAC and other quota regimes to those based on fishing effort. Constraints in the model allow the investigation of the relationship between catch, discards and landings. In addition, the spatial component of the GAMS model version allows a redistribution of fishing effort to match the catch composition to the available quota and take into account the avoidance behaviour of fishers of certain areas/species. This is particularly relevant to the CFP Reform as the allocation of quota to what is actually caught becomes more transparent and fishers will have to adapt their fishing pattern to avoid species for which the quota is already filled.

The three key and related management options for the North Sea mixed demersal fisheries that will be assessed through a variety of scenarios include: discard ban, effort management, and capacity assessment. As for the North Sea flatfish fishery, the key management options include: ITQs with different trading systems and a discard ban. It's likely that through the analysis of these issues, several conflicts will be highlighted between the economic viability of the fleets, the relative stability and the status of stocks. Fishrent clearly provides for the information required in this instance.

The model will be primarily used to simulate the effects of the policies indicated. However, Fishrent will also be used to provide an optimal view of the fishery over time given selected constraints imposed. This will be used for comparison to the simulations undertaken and will provide a high level view of maximum economic yield.

In the case studies of Basque trawlers in ICES Areas VI, VII and VIIIabde, the innovative management measures that will be tested are ITQs, zero discards, self-management, TAC increase and decommissioning schemes (scrapping subsidies). In the case study of Basque purse seiners in the Bay of Biscay the management measures that will be simulated are individual quotas (IQs) of Bluefin tuna which could be transferred only two years every five years, individual daily limits, labels – certification and pelagic RAC.

A key element to Fishrent is that fleet and economic data has been structured on data collected as part of the Data Collection Framework. This enables consistent analysis to be conducted ensuring that best available national data is used. However, where possible the data relating to specific fleets can be updated to provide more in depth analysis. The biological module is founded on ICES published data for the key stocks where parameters are estimated offline to populate the necessary biological functions in the model to track the status of the stocks. Fishrent uses a Cobb-Douglas production function to estimate catch year-on-year.

Additionally, in the GAMS version of the model, catch and effort data by ICES rectangle and species spatial distribution are used for the spatial version of the model. They are collected from the national institutes and available surveys. Data requirements are explained on:

http://www3.lei.wur.nl/fishrent/Downloads/Fishrent%20manual.pdf.

The biological and economic data is requested for the model use in case of Basque fleets. The biological data is based on ICES and ICCAT published data. Landings and prices are collected and integrated in a database of fisheries by AZTI-Tecnalia. The economic data comes from statistical information collected by the Basque Government through fishing sector annual surveys.

The output of Fishrent is designed to provide a full economic assessment of the fleets considered over a period of 25 years. Also, biological variables are calculated for each year, including stock biomass, recruitment and fishing mortality. The full list of endogenous variables in the model is reported in Annex I, Tab. 2. Note that all results are available by Fleet (i.e. Country, Main gear and Length of vessels), Species (i.e. Stocks) and Year.

The main model output for the Basque fleets, will be mainly based on the following variables: profit, gross value added, stock biomass, number of vessels and average price. These results will be disaggregated by fleet and/or by species.

Note that all results are available by Fleet (i.e. Country, Main gear and Length of vessels), Species (i.e. Stocks) and Year.

Fishrent contains six modules: biological, economic, market, behaviour, policy and interface. In order to evaluate the scenarios envisaged for this case study (e.g. discards, effort management, ITQs etc), changes will be required to all of the modules. As part of this project, for the North Sea mixed demersal fishery case study, Fishrent has been extended to consider up to 20 fleets and 20 species rather than the original 10 of each in the original version. As for the North Sea flatfish fishery case study, a trade module is being added and the option will be given to land discards at a special price. The cost structure will also have to be reviewed to account for the additional costs due to landing unwanted catch.

Modules that require specific attention to ensure best fit with scenarios include: the behaviour module, which provides for investment/disinvestment in fleets; the biological module, which drives selectivity of stocks; and the economic module, which indicates the performance of fleets and average vessels. A key issue that won't be overlooked is the calibration and validation of the model to shocks in changes to stock availability and fleets. That is, what does happen if half of a fleet are suddenly found to be unprofitable as a result of landing restrictions?

3.4 HDA models

The model has been selected for use in the case study of demersal trawler fishery in GSA 17 (IT).

HDA models comprise four models developed since 2007 to generate future projections based on a set of biological and socio-economic indicators for Mediterranean fisheries. These models follow a prevalently economic approach to modelling, where the economic equations are mainly based on the economic module of the BIRDMOD model (Accadia and Spagnolo 2006) and the BEMTOOL model (Accadia et al, 2013).

HDA0.1 (SGMED-10-03) and HDA0.2 (STECF-13-15) are stand-alone economic models not integrated with any specific biological component. These consist of an economic module and a management module, and can be associated with any biological model in a non-integrated approach. This allows HDA0.1 and HDA0.2 to estimate economic consequences of any harvesting strategy preliminary defined by using biological models or stock assessment procedures.

HDA1.1 and HDA1.2 are integrated bio-economic models, which can be considered as variants of the BIRDMOD model, where the biological module is developed according to a simplified approach and generally based on logistic models. The simplification of the biological module was designed to allow the models to be also used with a scarcity of biological data. Thus, in addition to management and economic modules, these two models also include biological and fishermen behavioural modules. Both models were developed for and used in the Impact Assessment Studies related to the CFP.

HDA1.1 and HDA1.2, which have been selected for use in the SOCIOEC project, are multi-species and multi-fleet simulation models designed to estimate the likely effects of management measures primarily based on effort restrictions in the short, medium and long term. Simulations are conducted step-by-step at regular time intervals through the period defined for prediction.

HDA1.1 and HDA1.2 can simulate management measures based on fishing effort restrictions: reductions in fleet capacity and/or fishing activity. Furthermore, the simulation of a likely fishermen behaviour in case of implementation of a system of individual effort quotas is allowed by the behavioural module included in these models. Therefore the models are appropriate to simulate the innovative management measure proposed for the case study of demersal fisheries in the Northern Adriatic (GSA 17).

Input data for HDA1.1 and HDA1.2 consist of a number of parameters used to simulate the relationships among the variables included in the logical-conceptual pattern of the models. Parameters are estimated through time series analysis. Parameters in the economic module of both models are estimated through historical data on the socio-economic variables collected within the EU-DCF. As the Italian monitoring system developed for the DCF makes available data at administrative region and GSA level, all DCF variables are available also for GSA 17. Parameters in the biological module of HDA1.1 needs data on biomass indexes and fishing mortality by species for a sufficient number of years. These variables have been collected for a number of species through MEDITS and GRUND programmes at GSA level. However, species monitored by these programmes are not always coincident with the main species landed by the fleet segments under investigation. For this reason, a simplified biological module based on a logistic model has been developed in HDA1.2. Parameters in the biological module of HDA1.2 needs only historical data on landings and fishing effort, which are generally made available by the Italian monitoring system.

The models output consists of the historical series simulated for the biological and socio-economic variables included in the logical-conceptual pattern of the models. As reported in Annex I, Tab. 3, endogenous variables can be differentiated by category. Technical variables on fleet size are aggregated at fleet segment level. With the exception of revenues, also economic and social variables are aggregated by fleet segment. Revenues and the market variables are aggregated by fleet segment and species. This allows a link between the economic and biological variables to be created. Indeed, biological variables (biomass) is aggregated by species. Furthermore, a number of variables are derived from the previous ones. These are some key economic indicators, like the return on investment and the net profit margin, as well as some productivity indicators. All variables are estimated by the model for each year in the simulation period providing a quantitative assessment of the management system in the short, medium and long term (it is expected that the system achieves an equilibrium before the end of the simulation period).

Three key indicators have been selected for measuring the achievement of the specific objectives associated to the case study: fishing mortality, EBIT and RoFTA. Furthermore, the level of fishing mortality achieved during the simulation period is expected to be compared to Fmsy. Therefore, at least these indicators should be estimated by the model.

The values of EBIT and RoFTA can be estimated through HDA1.1 or HDA1.2 for each year in the simulation period. On the contrary, fishing mortality and Fmsy can be estimated only through HDA1.1. However, the use of HDA1.1 is possible if data on biomass indexes and fishing mortality by species are available for a sufficient number of years. When biological data are not available, HDA1.2 can be used. In this case, the model will estimate landings and MSY instead of F and Fmsy.

As reported above, within the SOCIOEC project, HDA models (HDA1.1 and HDA1.2) have been selected for simulating the implementation of a system of individual effort quotas in the case study of demersal trawl fisheries in the North Adriatic (GSA 17). This innovative management system consists of fishing effort restrictions in terms of a maximum number of fishing days per year per vessel and the possibility for the operators to sell partially or totally their effort quotas to other operators.

Management systems based on fishing effort restrictions are generally applied in the Mediterranean fisheries and the likely effects of input control measures can be simulated by a large number of bio-economic models, especially those developed for the Mediterranean. Variations in fleet capacity and/or fishing activity can be simulated, for instance, through HDA, BEMTOOL, BIRDMOD, FISHRENT, MEFISTO, etc.. However, among these models, only HDA models (in particular, HDA1.1 and HDA1.2) have been specifically developed to simulate the likely behaviour of fishermen associated to the transferability of individual effort quotas. As a consequence, HDA models have been selected for simulating the implementation of the management system in the case study of North Adriatic trawl fisheries.

Even though HDA1.1 and HDA1.2 comprise a behavioural module for simulating the transferability of effort quotas in the Italian fisheries, this module has never been tested and discussed with local stakeholders. Consultations with local operators on the most likely behaviour of fishermen in case of implementation of this management system could suggest improvements and adaptations in the models structure. Therefore, it is expected that stakeholders meetings will provide useful information to modify and validate the models structure.

3.5 BEMTOOL

The model has been selected for use in the case study of demersal trawl fisheries in GSA 22 (GR).

The BEMTOOL model (Accadia et al., 2013) was developed within a research project funded by the DG MARE of the European Commission within a framework contract, named MAREA (www.mareaproject.net), aimed to provide scientific advice for the implementation of the CFP in the Mediterranean Sea.

BEMTOOL is a multi-species multi-gear bio-economic simulation model, which resumes and integrates the different bio-economic models and biological modelling tools developed in the past for the Mediterranean fisheries. BEMTOOL, interconnecting, integrating and upgrading these tools, has also developed new functionalities and utilities to improve the simulation approach and to better capture the complex fisheries dynamics. In this sense, BEMTOOL can be considered as a modelling platform where the user can structure the most suitable trajectories for the case study under investigation by selecting among a number of alternative technical solutions for each model module and component.

The BEMTOOL structure is based upon six operational modules: biological, pressure, economic, behavioural, policy and Multi Criteria Decision Analysis (MCDA). Each module consists of a number of components. The organization in modules and components allows the model to be enhanced in the future with additional modules. Furthermore, each component can be simulated through a number of alternative functional relationships and technical solutions. This makes the model very flexible to accommodate the different features and data availability of the Mediterranean fisheries.

BEMTOOL allows to simulate and predict the effects of management measures and/or harvesting strategies in the short, medium and long-term. Furthermore, optimal levels of fishing effort and/or catches, which maximize the long-term sustainable production (either in physical or economic terms), can be estimated by the BEMTOOL model. Therefore, given the traditional categorisation of bio-economic models in simulation (answering the question “what if”) and optimization (answering the question “what’s best”) models, both questions can be answered by this modelling tool.

The BEMTOOL platform is developed in the R programming environment. Given the complexity of the model, a Graphical User Interface (GUI) has been developed in Delphi and integrated with the R code to simplify the use of the model. The GUI allows the user to produce simulations following a number of standardised steps.

A total of 11 management scenarios can be simulated by the BEMTOOL model. The basic scenario is represented by the Status Quo, where the management system remains unchanged during the simulation period. Other scenarios consist of changes in fishing gear selectivity, changes in fishing effort (in terms of number of vessels and/or days at sea), changes in fishing mortality, and introduction or variation of Total Allowed Catches (TAC). Furthermore, scenarios on Status Quo, changes in gear selectivity and changes in fishing effort can be simulated either assuming or not assuming an active fishermen behaviour affecting the levels of fishing effort. Finally, the single scenarios can be combined to simulate more complex management systems. The main management measure that will be explored in the case of the demersal trawl fishery in GSA 22, will be spatio-temporal shifts in effort to achieve discard reductions through avoidance of unwanted catches (e.g. juveniles, under-sized, non-target etc).

The management scenarios are aimed to both simulate and optimize fisheries performance. For instance, scenarios on change in fishing mortality can be used to simulate the achievement of the Fmsy for a stock in a number of years defined by the model user. Furthermore, a specific functionality has been made available in the BEMTOOL platform to estimate the maximum economic yield (MEY).

Data on biological, economic and transversal variables are required to run the model. Furthermore, a number of parameters should be estimated and provided as input to the model. However, the BEMTOOL platform has been conceived to accommodate Mediterranean fisheries with different data availability. The flexibility of the model is extended also to the data requirement, which depends on the specific modelling solutions selected by the model user. As a consequence, less data-demanding modelling solutions can be selected to work with poor data fisheries.

The model produces a standard set of outputs for each simulated management scenario. Model outputs are represented by all the variables included in the logical-conceptual scheme of the model, which values are reported for each year (and each month for some biological variables) of the simulation period. There is no limitation on the duration of the simulation period, which is defined by the model user, neither to the number of fleet segments, though both affect the computation time. The most relevant outputs of the model, which are also showed by the model graphical user interface through a set of standard graphs, can be divided in the following three groups:

- State of the stocks: fishing mortality (current and at MSY), stock biomass (current and at MSY), spawning stock biomass and mean length of the stock;
- Impact/Pressure: fishing mortality by fleet segment, yield by stock;
- State of the fleet: total landings, total revenues, average salary, number of employees, Break Even Revenues, net profits, gross value added, profit, salary and capital costs.

The output of the simulations can be used in BEMTOOL to compare different management scenarios and identify the optimal one. As the model was requested to develop and support multi-objectives approaches for fisheries management, a specific tool has been developed and incorporated in the BEMTOOL platform. This tool allows the user to perform a multi-criteria analysis that can be used to compare different management scenarios, taking into account the sometimes contrasting objectives of the CFP with regards to biological, economic and social dimensions.

Three key indicators have been selected for measuring the achievement of the specific objectives associated to the case study: fishing mortality, SSB as a measure of stock size and maintenance of profits and/or employment.

As mentioned above BEMTOOL provides a suitable modelling environment for short- and long-term projections of the different exploitation scenarios we want to address. Its outputs with regard to ecological, economic and social indicators meet the requested case study demands. Due to ongoing stakeholders consultations slight modifications of the model's parameterisation may occur.

3.6 IAM

The model has been selected for use in the case study of the Bay of Biscay sole fisheries (FR).

IAM is a multi-species, multi-fleet (or multi-vessel) and multi-metier bio-economic model. The model enables to represent resources dynamics, fleets dynamics and governance. The model was developed within a national research project aimed at defining methodologies for impact assessment of management plans for fisheries within a partnership approach with administration, stakeholders and scientists. The model is designed to assess biological and SOCIOEConomic impacts of scenarios related to fisheries management, evolution of the economic context and evolution of the environmental context (Merzéréaud et al., 2011). According to the European guideline for impact assessment, it provides ex-ante assessment of potential environmental, social and economic impacts of scenarios. The IAM model is the heart of the bio-economic partnership approach developed within the project. The approach also includes an important methodological step of development of efficient methods to describe and characterize the fisheries dynamics through the calculation of a set of indicators from existing databases. The model (and the approach) has already been used in the STECF expertise framework to run simulations of options for the Bay of Biscay sole management plan (STECF, 2011) as well in research projects to explore bio-economic impacts of management options, such as the adoption of selective devices in the Nephrops fishery in the Bay of Biscay (Raveau et al., 2012), the socio-economic analyses of the trade-off between different pathways to MSY (Macher et al., in prep) or the sensitivity of the MSY, MEY reference points to the multi-fleet context (Guillen et al., 2013).

The model can simulate conservation measures and access regulation measures. It enables to simulate the impacts of selectivity scenarios (Raveau et al., 2012), of variation of capacities in number of vessels by fleet, of variation of fishing effort, of fixed TAC values or management systems based on the control of fishing mortality with adjustment of the fishing time or of the number of vessels (STECF, 2011). Different Harvest Control Rules are implemented and different options are possible in terms of effort reallocation assumptions or distribution of the reduction in capacities or fishing time among fleets or vessels to reach a given TAC (uniform reduction or proportional reduction according to contribution to fishing mortality). The model can be used to run simulations of scenarios or for optimization and estimation of reference points such as estimation of MSY or MEY (Guillen et al., 2013) or scenarios of rent maximization with constraints of maintaining the maximum possible number of vessels in the fishery. The model also enables to explore scenarios of viability and distribution of impacts between vessels or fleets. The model is also used to test innovative management measures as in SOCIOEC where the model is used to test the impact of various governance systems for quotas: a market of quota, a centralized management by the state based on strict track records or co-management by Producer Organizations (Macher et al., 2013).

The model was designed to use as much as possible available data as inputs. The biological module of the model is age structured. Biological inputs are stock assessments 'outputs (Fishing mortality, Natural Mortality, Number of individuals, …). Biological inputs are typically based on outputs from XSA (eXtended Survivors Analysis) widely used by the ICES for stock assessment. The model was also adapted to be able to run simulations with outputs from SS3 (Stock Synthesis - used now for the Northern hake for example, which is an important species of the Bay of Biscay) and it is designed to be able to be adapted according to the needs. The transversal and economic inputs by fleet, metier or vessels are either indicators possible to calculate from the IFREMER Fisheries Information System (FIS) or indicators collected within the DCF (EC No. 665/2008 of the 14 July 2008). Main inputs are number of days at sea, production by species and metier (quantities and values), fuel costs, other variable costs, repair and maintenance costs, other non-variable costs (fixed costs). Data from transversal DCF data on price per grade or species by default or parameters of price-elasticity relationships if possible to estimate are used as parameters of the market module. R codes were developed for French fleets or vessels to create automatically inputs files by fleet or vessels from the FIS databases. This was indeed identified as a key challenge to be able to provide operational impact assessment in expertise working groups and to be able to replicates the methods easier on different fisheries or to update data for advice. All the input parameters are supposed to be available in the framework of the DCF. The level of aggregation of the DCF is, however, most of the time not pertinent and simulations could require disaggregated data.

The model's output consists of the historical series simulated for the biological and socio-economic variables included in the logical-conceptual pattern of the models. As the biological module is based on an age-structured model, the related variables are based on the standard equations of population dynamics and are aggregated by species and age class. The model provides biological outputs for each scenario, such as evolution of spawning stock biomass, landings, discards or fishing mortality by stock. The variables in the economic module are aggregated at fleet segment level (outputs by vessel were provided for SOCIOEC but then aggregated by fleet for the presentation of results). An intermediate level represented by metier can be used for those variables where data is available at this level of aggregation. This level of aggregation can be provided as output for catches, discards, landings, revenues, variable costs and fuel costs. The main derived indicators consist in the average values per vessel of variables measuring the fleet economic performance or in aggregated indicators by fleet or for the whole fishery. The model also provides indicators on total employment by fleet or for the whole fishery according to scenarios. The model thus provides a set of indicators useful for multi-criteria analyses. It also provides indicators for cost-benefit analysis of scenarios such as net present value of gross value added, gross cash flow of crew cost wages also calculated as crew and owner surplus variations compared to status quo. As the model integrates uncertainties, outputs are provided with statistic of distribution. Scenarios studied in SOCIOEC led to add new output indicators to describe the demand and supply of quotas by vessel or fleet and the dynamic of the fishery linked with quota market.

The model was developed, among other case studies, on the Bay of Biscay sole case study to be able to test scenarios of management for demersal fisheries. Experiences and applications of the model to the case study already existed. The approach was also developed and validated with stakeholders of the fishery. Furthermore, capacity to implement new scenarios in the model (such as a governance scenario based on quota market), ability of the model to run at individual based scale (vessel), routines of parameterization developed (see previous sections), and opportunities to optimize and simulate with appropriate speed of calculation due to C++ programing were appropriate to problematic explored in SOCIEOC in this case study.

The implementation of scenarios of quota market in the model for SOCIOEC has required adaptations to be able to work at the scale of the individual vessel and to model quota leasing in and out. The model was also adapted to provide new output indicators to describe results in terms of demand and supply of quotas by fleet.

3.7 ISIS-FISH

The model has been selected for use in the case study of Eastern channel flatfish mixed fisheries (FR).

ISIS-Fish is a modelling tool suitable for investigating the consequences of alternative policies on the dynamics of resources and fisheries (Mahevas and Pelletier 2004; Pelletier et al, 2009). This spatially explicit model allows quantitative policy screening for fisheries with mixed-species harvests (Pelletier and Mahevas 2005). It may be used to investigate the effects of combined management scenarios including a variety of policies: total allowable catch (TAC), effort control, licenses, gear restrictions, MPA, etc. Fisher's response to management may be accounted for by means of decision rules conditioned on population and exploitation parameters or explicit dynamic model with endogenous (e.g. fish prices fixed and variable costs) or exogenous variables. This fishery model is based on three submodels: (i) a fishing activity dynamics model, (ii) a population dynamics model and (iii) a management dynamics model. Each submodel is spatially and seasonally explicit, with a monthly time step. Within the modelled region, zones (i.e. sets of contiguous grid cells) are defined independently for each population, each fishing activity, and each management measure. The three submodels interact only if they overlap in space and time. In ISIS-Fish, fishing mortality is calculated from the distribution of fishing time over fish population areas, time, metiers, gear and fleets.

ISIS-Fish has been applied to the flatfish fisheries in the English Channel (Marchal et al 2011, Gasche et al 2013) with an extension to other demersal fish currently developed, the Bay of Biscay hake fishery (Drouineau et al 2006) and pelagic fishery (Lehuta et al 2010, Lehuta et al 2013a, Lehuta et al 2013b), the European deep sea fishery (Marchal and Vermard 2013), the New Zealand Hoki fishery (Marchal et al 2009) and the Baltic cod fishery (Kraus et al 2008).

For the Channel fisheries case, the model will be used to simulate the impact of harvest control rules defined individually for each species, to help shape long-term management plans; the impact of discard restriction will also be analysed. The HCRs will be based on a variety of indicators, classical ones such as fishing mortality or biomass but also new ones like spatial indicators, length-based indicators, scientific survey –based indicators, etc. which account for the spatial and demographic status of fish populations and could also be used to design HCRs for species not analytically assessed. Consequences of management measures on fisherman behaviour will be accounted for using a gravity model, which drives the report of effort on areas, gear and metiers based on expected and realised profits and fishing habits.

The biological models build on the parameters of the assessment models when available and on scientific survey data and literature otherwise (non-assessed species and information on spatial distribution).

The fishing activity model is built based on statistical analysis of logbook data from 2008 to 2010. Fleets, metiers, areas and gear are first identified. The fishing activity parameters necessary to compute fishing mortality based on fishing time, are then assessed through statistical procedures. They standardise fishing time between fleets, metier, gear and species. Economic data collected at a yearly scale are used to implement the main costs experienced by the fleets.

Potentially a large number of indicators can be computed as outputs of the model. We will focus on a list of indicators of population's status (biomass and biomass trends, population age structure, discards) and indicators of fleet activity and performance (effort distribution, landings, revenues, profits, costs).

The Channel fisheries are mixed fisheries characterised by a large number of species caught simultaneously, (some under quotas, other not), a variety of gear and fleets and an important structuration of fishing activity and biological processes in space and time. The management rules proposed, particularly the restriction on discards and the simultaneous implementation of management plans for species caught together could modify the dynamic in place. To project the behaviour of this complex system under new management rules, we needed a model which could account for spatial co-occurrence of species, seasonal distribution of the activity and relative performance of fleets and gear.

Because of the flexibility of the model, no modification is needed for the simulations planned.

3.8 ITQ model - IMPSEL

The model has been selected for use in the case study of North East Atlantic pelagic fishery.

One of the problems of the EU Common Fisheries Policy is the overcapacity of European fleets (COM 2011), which is generally perceived as a major obstacle to achieve economically efficient fisheries. One theoretically acknowledged method to reduce overcapacity is to implement ITQ-systems. The ITQ system has during the past 10 years been introduced in several European fisheries such as the Danish, Swedish and British pelagic fisheries. However, recent interviews show that fishermen in Denmark advocate to expanding the current management system to an international ITQ system. The main questions are whether there are significant welfare gains to be done from introducing such an internationally ITQ system where quotas can be traded between member states / countries, and how the future quotas will be allocated.

The ITQ model, which is used to illustrate the possible gains from introducing international ITQ´s in the pelagic fisheries for mackerel and herring in the North East Atlantic, is based on a model developed in the IMPSEL project from 2005-2007 (Eliasen et al. 2008). The original model was developed in Excel and described the likely gains from a national ITQ system for the Danish demersal fishery, based on individual vessels of the Danish demersal fishery. The original model is therefore somehow different from the current model, because the latter includes more countries and is based on fishing fleets rather than individual vessels. The overall framework of the model is the same as the IMPSEL optimization model, but the current model has been restructured in order serve the current purpose of estimating the gains from an international ITQ system. The model search among the available catch compositions and find the solution that optimizes the gross cash flow among all fleets, given that quota constraint should be maintained.

The model estimates the economic gains from introducing international ITQ´s in the pelagic fisheries for mackerel and herring in the North East Atlantic. Different management measures have been proposed to the pelagic fishermen in Denmark in order to know which ones they would prefer. Out of 10 management measures, the majority of the interviewed fishermen ranked international ITQ´s as the most appealing one. Therefore, the model estimates how the spatial distribution of effort and catches will be altered in a long run perspective, if such management measure will be introduced, considering for the 6 most important fishing fleets targeting mackerel and herring in the North East Atlantic. The social and economic gains/losses of such redistribution will be a main result of such analysis.

A key element to the ITQ model is that fleet and economic data has been structured on data collected as part of the Data Collection Framework (DCF). This enables consistent analysis to be conducted ensuring that best available national data is used. The model requires cost and earnings data as well as days at sea data on a fleet level, while catches and catch values is required on a fleet- and fishing area level. For the EU fleets, these data were obtained from the DCF, collected under the Annual Economic Report on the fishing industry (STECF, 2012). The Norwegian was obtained from the Norwegian directorate of fisheries (Fiskeridirektoratet 2011). For Iceland, effort and landings data was obtained from the Icelandic Marine Resource Institute, while the economic data was obtained from Statistics Iceland.

The ITQ-model simulates how much the SOCIOEConomic performance (gross cash flow, gross value added) of the fleets change when introducing international ITQ´s in the pelagic fisheries. Furthermore, the model simulates the spatial distribution of effort and catches of mackerel and herring, if international ITQs are introduced. Different scenario analyses, reflecting the economic gains of allowing a certain degree (20%, 40%, 60%, 80% and 100%) of trade between countries, are analysed.

The original ITQ model was made in order to simulate the gains from national ITQs. Even though the current setup and dimensions are different from the original model, the overall modelling framework was desirable for the case of illustrating the gains from introducing international ITQs. The model allows the fleets to alter their spatial distribution of effort and catches, while keeping the catch composition the same. Constraints allow the simulation of ITQ´s to keep within the quota boundaries for each fishing area.

Some adaptions for the original model have been necessary in order to simulate an ITQ system that includes several countries and areas. The model has furthermore been adapted to work on a fleet level instead on a vessel level in order to be able to use the DCF data.

3.9 Econometric model

The model has been selected for use in the case study of Mackerel Fishery in BoB.

The inverse demand function and the average cost function are estimated in order to obtain detailed knowledge of the factors that affect the ex-vessel prices, the form of production and the cost structure, among other points. To identify the inverse demand function a number of variables are tested, including the size of the fish, the fishing techniques, the fishing season, the port where catches are landed and the fishing grounds. Of these variables, the fishing season, the fishing technique and the size of the fish captured are found to be significant and are therefore included in the specification of the function. The fishing grounds and the port where catches are landed are also significant for some categories, but are closely linked to the fishing technique and therefore improve the goodness of fit only slightly.

By contrast with the demand function, for the cost function a single equation is estimated, since not enough observations are available for distinctions between techniques to be drawn. However, the main differences in cost between techniques usually arise in the quantity of fuel consumed, and this mainly depends in turn on the size and power of each vessel. For that reason the fuel price index calculated takes the length and power of each vessel into account. In general, cost items are expressed in line with the variables of quantity, prices and the price of the different production inputs.

A detailed description of the model can be found in García-Enríquez, J. 2012.

The model sets out to analyse the economic situation of the Basque fleet engaged in the fishing season for mackerel. The non-competitive behaviour of the mackerel market and the low prices obtained at auction in ports have led in recent years to a race to catch more and more fish on the part of the various regional fleets. This has resulted in systematic failure to comply with the TACs allocated to Spain, thus flooding the daily market for the species and preventing any increase in prices at ports. The existence of a joint TAC leads the various fleets to engage in a race to catch mackerel, since the fishery is closed when the quota is exhausted. This independence of action on the part of the different fleets also seems to have favoured the disconnection of local markets. Due to it, a new management tools have been considered for this fishery in the last years: a Spanish administration introduces daily quotas by fisherman in 2009 (Orden ARM/2091/2008). In addition, Spanish administration also introduced new daily quotas by vessels in 2011 (Orden ARM/3315/2010). These quotas are introduced to avoid saturation of the daily market.

Finally, in addition to the daily quotas, the introduction by Spanish fishery administration of stricter checks on compliance in all Spanish ports in 2011 (currently continuous) will also be checked.

The data used in this study are taken from the AZTI-Tecnalia fishery database and the Sales Notes provided by the Basque Government, which publishes information on each fish auction. Specifically, information gathered in 2007 is used. The reason why data from other years have not also been used lies partly in a lack of detailed information and partly in the fact that 2007 was the last year in which fishing was not subject to any regulations intended to affect the economic component of fisheries.

Information on the annual costs of the vessels involved in the fishing season for mackerel is obtained from numerous sources -mainly the Basque government and the fishing industry- and is available from AZTI-Tecnalia.

The model seeks to provide detailed knowledge of the key factors that condition the ex-vessel price of the stock analysed, and of the structure of the form of production and costs of the fleet. The first step is to identify and estimate the inverse demand function of the market for initial sales of mackerel in the Basque Country. That function is then used to simulate the effect on prices of regulation measures introduced by the Spanish authorities in recent years. After this, we identify and estimate the cost function for this fishery, and use the results to learn, among other things, the gap between mackerel prices (expressed via inverse demand) and the operating costs associated with the fishing season.

This model has been developed specifically for the Basque Country mackerel fishery by the University of the Basque Country and AZTI-Tecnalia.

The model has been developed for specifically simulating the effect of daily limits on mackerel fishery. The model was completely adapted to the analysed fishery.

4. Scenarios to be evaluated in relation to the measure

Within the Impact Assessment process, the quantitative analysis is carried out through a scenario approach. The bio-economic models and the other quantitative tools described in the previous section are applied to case studies to produce a quantitative assessment for each scenario defined in the case study. Each case study in the SOCIOEC project is identified by a clear definition of the interested fisheries and the management scenarios to be evaluated over time.

Fisheries are defined in terms of geographical areas, stocks and fleet segments involved, and the management system currently in force in that area for those fisheries. Even though an optimal description of a fishery should include all the exploited stocks and all the fleet segments active in the area, a simplification is generally necessary to delimitate the case study for bio-economic analysis and to have a clear picture of data requirements. When main stocks and fleets are considered, the average characteristics of the remaining fleets and species can be assumed as constant over time in the simulation period.

The list of management scenarios to be evaluated represents a distinctive element of a case study. Scenarios can be distinguished in Status Quo Scenario (SQS) and alternative scenarios, where the former is the current management system while the latter consist of a set of scenarios associated to potential changes in one or more components of the current management system. Bio-economic models or other quantitative tools are used to simulate the effects of the management systems described in each scenario in the short, medium and long term.

The SQS is the simulation of what will happen if no change in the management system will be implemented. As each scenario simulation embraces a period long enough to measure long term effects, the SQS or baseline scenario is expected to include both the management measures currently in force and those officially planned for implementation by local management authorities in the next years. If the implementation of a new management measure has been planned and is going to be applied at a certain date (for instance, when a ministerial decree establishing the implementation of a specific measure at a certain date in the future has already been issued), this measure is expected to be included in the SQS. In SOCIOEC, all measures foreseen in the proposed EU regulations related to the reform of the CFP are assumed as new and are not included in the SQS (exception made for those measures already in force for specific case studies).

Once the SQS of a case study is defined, alternative scenarios can be defined in terms of differences with the SQS. Any change in the SQS represents an alternative scenario. Generally, the implementation of the management measures, proposed within the reform of the CFP, represent changes to the Status Quo and define alternative scenarios. One of the main innovations from the proposal for the new CFP is the landings obligation for “all catches of species which are subject to catch limits and, in the Mediterranean, also catches of species which are subject to minimum sizes”. This measure, known also as discards ban, represents an alternative scenario in several case studies of the SOCIOEC project, like North Sea mixed demersal fisheries, North Sea flatfish fishery, Eastern channel flatfish mixed fisheries and demersal trawl fisheries in GSA 22 (GR). Another management measure widely discussed during the process of reform of the CFP and included as alternative scenarios in some SOCIOEC case studies, like Basque trawlers in ICES Areas VI, VII and VIIIabde and demersal trawler fishery in GSA 17 (IT), is represented by the establishment of a system of transferable fishing concessions (where fishing concessions can be implemented either in terms of catch or effort quotas). The implementation ex-novo of an ITQ system or variations to quotas systems already in force are included as alternative scenarios in many case studies. Other alternative scenarios are represented by spatial and/or temporal restrictions with a possible re-allocation of fishing effort.

Changes in the current management system can consist also in new governance systems, like the co-management in the Basque trawlers in ICES Areas VI, VII and VIIIabde case studies or the centralized management system in the Bay of Biscay sole fisheries case study. Variations in the governance system which promote the participation of stakeholders to the decision-making process are expected to increase the level of compliance with regulations and the efficiency of management measures.

As reported above, alternative scenarios in the SOCIOEC case studies can be defined in terms of differences with the SQS. However, a level of detail sufficient to avoid confusion among different alternative scenarios is needed. For instance, the introduction of a new management tool, like an ITQ system or a discards ban, in the current management system can describe a number of alternative scenarios. Indeed, any management tool can be implemented and applied in different ways. For instance, a discards ban can be applied to different groups of species or to discards exceeding more than a certain percentage of total catches. Clearly, each group of species or percentage value defines a management measure and a different alternative scenario. Therefore, each alternative scenario is expected to be defined in terms of a management measure, i.e. a description of structure, timing and entity used for the implementation of a management tool.

Each scenario is projected in the future by using mainly bio-economic models. As reported in the previous section, different bio-economic models are used in SOCIOEC. As each model is a simplification of reality, model outcomes are unavoidably affected by a certain degree of uncertainty. Where models do not foresee a specific approach to deal with the problem of uncertainty, each scenario can be simulated several times by varying each time the most uncertain model assumptions. These can be related to both endogenous and exogenous variables. Endogenous variables are generally simulated by the model through dynamic equations. As some of these equations show a high level of uncertainty, like stock-recruitment relationships or price dynamics equations, many bio-economic models allow the user to select among different modelling options for these specific model components. Regarding the exogenous variables, these are associated to external factors not easily predictable, like changes in oil prices or interest rate. Exogenous variables are not (or cannot be) simulated by the model and are generally assumed as constant over time. Simulating each scenario by varying the most critical model assumptions or risk factors would allow to increase the robustness of model outcomes.

The SOCIOEC scenario approach can be represented by a matrix like that reported in Table 1, where rows are scenarios and columns are changes in risk factors. The list of scenarios includes the SQS and the alternative scenarios to be simulated, while risk factors consists of variations in the most critical model assumptions related to both endogenous and exogenous variables. Risk factor 0 is related to the model basic assumptions.

Table 1 – Matrix of scenarios for each case study

Scenarios	Risk factor 0	Risk factor 1	Risk factor 2	……	Risk factor n
Status Quo	sub-scenario 0.0	sub-scenario 0.1	sub-scenario 0.3	……	sub-scenario 0.n
Alternative 1	sub-scenario 1.0	sub-scenario 1.1	sub-scenario 1.2	……	sub-scenario 1.n
Alternative 2	sub-scenario 2.0	sub-scenario 2.1	sub-scenario 2.2	……	sub-scenario 2.n
……	……	……	……	……	……
Alternative m	sub-scenario m.0	sub-scenario m.1	sub-scenario m.2	……	sub-scenario m.n

5. The synthesis table: an overview of the approach

The methodological approach illustrated in the previous chapters resulted in the synthesis table shown below.

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
Baltic	All Danish western Baltic Fishery (potentially German fishery) for vessels above 12 m	Closures according to EU Directives: Windmill farms (energy-directive), fishery closures (CFP), Nat2000 (MSFD)	Ecological	Sustainability	SSB	>Bpa or >BMSY	LRP	Short / Medium
				MSY	F	>FMSY	TRP	Short / Medium
			Economic/Energy	Economic viability	GVA	None	No	Short / Medium
				Energy efficiency	VPUF	None	No	Short / Medium
	German fisheries around the island of Fehmarn (mostly below 15m)	Closures due to environmental causes, management based on effort alone (no quota restriction) for small vessels	Economic	Economic viability	Value of landings when available, break even revenue	None	No	Short / Medium
			Social	Ensure lively communites	Number of vessels that would leave the fishery	None	No	Short / Medium
North Sea	Regional demersal fisheries	catch quota/landings quota/discards ban; mixed fisheries HCR	Ecological	Sustainability	SSB	>Bpa or >BMSY	LRP	Short (1-5 years)
				MSY	F	>FMSY (and multispecie s Fmsy)	TRP	Short (1-5 years)
			Economic /governance	Economic viability	revenue	None	No	Short (1-5 years)
					value per unit of effort	None	No	Short (1-5 years)
				management	difference between Fcube min and Fcube max	none	no	Short (1-5 years)
	Flatfish fishery	Co-management in relation to ITQ	Economic	Maximisation of the profit out of the stocks	Profit	>0	LRP	LT
			Social	Distribution of catch per fleet/country	catch/country	historical shares		LT

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
			Ecological	Stock exploited at MSY	fishing mortality	Fmsy	TRP	LT
	North Sea mixed demersal fisheries	Discard ban, effort management, capacity assessment	Economic	MEY according to HCR and other limits	Fleet size, Effort, Landings, Revenue, Costs, Profit , GVA (also F)	Quota (landings/catch), Effort, SSB, BER	TRP	ST and LT
Mediterranean & Black Sea	Demersal trawler fishery in GSA 17 (IT)	Effort Quota	Ecological	MSY for main target species	F	Fmsy	TRP	
			Economic	Economic viability	EBIT	>=0		
				Sector attractiveness	RoFTA	>=long-term government bonds rate	LRP	
			Social	Social stability (wage level)	Average crew remuneration	>=average wage	LRP	
	Demersal trawl fisheries in GSA 22 (GR)	Discard reduction, spatiotemporal shifts in Effort; Effort Quota	Ecological	Viable stock size	SSB	>30% of virgin SSB	LRP	
				MSY	F	Fmsy	LRP	
				protection of juveniles	Metric of population selectivity	Mean age at selection - Mean age at maturity > 0	TRP	
			Economic	Maintenance of	Ratio of revenues to	>1	LRP	LT

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
				profits	break even revenue			
				MEY	Gross Value Added	Maximum GVA	TRP	ST
			Social	Sustainability	Employment	>= current level	TRP	ST
Western waters	Bay of Biscay sole fisheries (FR)	Management plan towards MSY, TAC/HCR scenarios with co-managment, IQ or ITQ and various scenarios of intial allocation of quotas	Ecological	Sustainability	SSB	>Bpa or >BMSY	LRP	
				MSY	F	>FMSY	TRP	
			Economic	Employment	Nb of employees	>= current level	LRP	
				Stability of fishing opportunities and supply	Annual landings	>= current level, Analysis of trends	LRP	
				Increasing yields	Landings per effort unit	Analysis of trends		
				Stability of incomes	Annual incomes	>= current level, Analysis of trends	LRP	
				Increasing revenue per unit of effort	Revenue per effort unit	>= current level, Analysis of trends		
				Increasing margin per unit of effort	return to be shared per unit of effort	>= current level, Analysis of trends		

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
				Increasing profit per unit of effort	profit per unit of effort	>= current level, Analysis of trends		
				Economic viability	Annual profits (Operating Cash flow)	>0 or other constraints + Analysis of trends	LRP	
				Economic viability	Annual Gross Value Added	Analysis of trends		
				MEY	GVA, Profits	maximum	TRP	
				quota market	price of quota	convergence		
				willigness to lease quota	margin by kg of sole	-		
				Benefits of the scenarios	Cost-benefit analysis NPV	>0	LRP	
			Social	Equity	Distribution of costs and benefits between crew and owners and between fleets segments			
				Job attractiveness	Average crew remuneration	>= current level	LRP	

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
				Fleets geographical distribution	Nb of vessels by fleet and region			
			Technical	Capacity	nb of vessels, power, tonnage, effort	Analysis of trends, E(MSY), E(MEY)		
	Basque trawlers in ICES Areas VI, VII and VIIIabde	ITQ	ECONOMIC	Maximize profit	Profit 15 /25 years	> 0	LRP	ST/LT
			SOCIAL (Number of vessels and employment)	Maximize gross value added	Gross value added 15/25 years	> 0	LRP	LT
		CFP. DISCARDS = 0	BIOLOGICAL	Improve the stock biomass	Stock biomass 15/25 years	> than biomass reference point given by ICES	TRP	LT
		SELF MANAGEMENT (quota allocation) within the PO umbrella	ECONOMIC	Increase profit	Profit 15 /25 years	> 0	LRP	LT
		TAC increase	ECONOMIC	Increase profit	Profit 15/25 years	> 0	LRP	ST/LT
		DECOMMISSIONING SCHEMES (SCRAPPING SUBSIDIES)	ECONOMIC	Increase profit in the long run	Profit 15/25 years	> 0	LRP	LT
			SOCIAL (Number of vessels and employment)	Optimise the number of vessels	Number of vessels	.= < than the current number of vessels - 5 vessels	LRP	

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
						(according to focus group, there are five vessels left over)		
	Basque purse seiners in the Bay of Biscay	IQ (Bluefin tuna)	ECONOMIC	Increase profit	Profit 15 /25 years	> 0	LRP	ST
		INDIVIDUAL DAILY LIMITS (anchovy)	ECONOMIC	Increase profit	Profit 15 /25 years	> 0	LRP	ST/LT
			BIOLOGICAL	Improve the stock biomass	Stock biomass 15/25 years	> than biomass reference point given by ICES	TRP	
		LABELS/CERTIFICATION (Anchovy and Albacore)	Economic	Increase price or reach new markets	Price/Agotan el TAC	> current average price	LRP	LT
			Biological	Sustainable biomass (MSC)	Biomass sustainability	> than biomass reference point given by ICES	TRP	LT
		PELAGIC RAC and SWWRAC (Anchovy long term management plan)????	Economic	Increase profit	Profit 15/25 years	> 0	LRP	LT
			Biological	Sustainable biomass	Stock biomass 15/25 years	> than biomass reference point given by ICES	TRP	LT

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)
	Eastern channel flatfish mixed fisheries (FR)	TAC+HCR; ITQs; Discard restrictions (+incentives)	Ecological	Ecological ref. points for populations or MSY, reduction of discards	Biomass and biomass trends, population age structure, discards	biological ref. points		10 years runs
			Economic	Positive profits	landings, revenues, profits, costs	base case		
Pelagic	North East Atlantic (supraarea 27, area 2a, 4a, 4b, 4c, 6a, 7b, 7j).The Danish, British, Irish, Norwegian and Icelandic pelagic fisheries for mackerel and herring	An ITQ system across countries	Biological	Distribution of effort and landings on fishing areas	Effort and landings	2008-2010	No	LT
			Economic	Economic gains by introducing ITQ´s across countries	GCF	2008-2010	No	LT
					profit	2008-2010	No	LT
			Social	Distribution of the GVA on countries	GVA	2008-2010	No	LT
	Mackerel Fishery in BoB	Daily limits	Economic	Increase the average price	Profit 15 /25 years	> 0	LRP	ST/LT
		Landings control (of daily limits)	Economic (Daliy limit)	Increase profit	Profit 15/25 years	> 0	LRP	ST/LT

Case study region	Sub-case study fishery	Innovative management measure to be evaluated	Dimension of objectives	Objectives (ecological, economic, social).	Indicators in relation to the objectives (ecological, economic, social)	Reference levels	Limit (LRP) or target reference point (TRP)	Time frame (short - ST and long run-LT)	T U s
			Biological (TAC control)	Sustainable biomas	Stock biomass 15/25 years	> than biomass reference point given by ICES	TRP	LT	
Non-EU fisheries	Two options: (i) Icelandic inshore handline fishery, and perhaps (ii) Icelandic nephrops fishery	Effort restriction (days at sea); overall TAC and open acces, and quota restrictions (ITQs)	Social, biological and economic objectives.	Social, biological and economic objectives.	Stock sizes, profitability, participation, landings, etc.		TRP	ST/LT	S e (

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