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Hoff, Ayoe Gry; Andersen, Jesper Levring; Buisman, Erik; Frost, Hans Staby; Murillas, Arantza; Powell, Jeffery P.

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Economic Efficiency of Fisheries Management Measures in an Innovative Evaluation Framework Perspective

Ayoe Hoff, Jesper L. Andersen, Erik Buisman, Hans Frost, Arantza Murillas and Jeffrey P. Powell

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Preface

The CEVIS project (Comparative Evaluations of Innovative Solutions in European Fisheries Management) has been funded by the EU Six Framework programme. CEVIS is a multi-disciplinary project in which 14 European research institutes within biology, economics and social science have been cooperating.

Although results from the work are published in books and journal articles it is important that the underlying model development, data, and data applications are documented and accessible This report comprises detailed information of the work carried out in work package four of the CEVIS project. This package investigated the economic efficiency of four cases in an innovation evaluation framework (IEF). In chapter one of this report the objectives of CEVIS, the evaluation framework and the selected cases in work package four are introduced starting from the project description of CEVIS. Chapter two comprises a review of and a reflection on economic indicators. Chapter three to six deals with the four cases of management regimes in term of specification of the problem and hypothesis, the method applied to address the problem and the results.

The work in work package four has been headed by Ayoe Hoff, the Danish Institute of Food and Resource Economics (FOI). The cooperating partners are the Dutch Institute of Agricultural Economics (LEI) and the AZTI Foundation, the Basque Country, Spain. FOI has, in particular, been working together with the Danish Institute for Fisheries Research, now DTU Aqua, while LEI has cooperated with the Dutch Institute for Fisheries Research, IMARES. AZTI covers both economic and biological expertise.

All chapters in the report have been subjected to extensive discussions in the whole group. Hans Frost (FOI) has mainly been responsible for chapter two. Erik Buisman and Jeffrey P. Powell (LEI) have been mainly responsible for chapter three. Jesper L. Andersen and Ayoe Hoff (FOI) have been main responsible for chapter four, and Arantza Murillas (AZTI) has been the main responsible for chapter five. Finally, Ayoe Hoff has been the main person responsible for chapter six. Elsebeth Vidø (FOI) has carried out the final editing.

Director General Henrik Zobbe
Institute of Food and Resource Economics
Copenhagen, February 2009

Summary

The work in the CEVIS project was organised into eight work packages. In this report the effect of innovative fisheries management is tested on economic efficiency. The task, of which the results are presented in this report, is to compare and evaluate fisheries management regimes in terms of economic efficiency. Economic efficiency can be conceptually defined and evaluated in various ways, but the objective was to review, both theoretically and empirically, how economic efficiency of fisheries can be estimated and summarised as an indicator of performance and related to an innovative evaluation framework (IEF) as developed in one of the other work packages of the CEVIS project, aiming at assessing the likely economic efficiency outcome of various management options for a range of case study fisheries.

In CEVIS, in general, the term "indicators" is used broadly to include measurements and observations of the inputs, key processes and outcomes of management. The substance of the IEF will be a set of indicators as well as the procedures for measuring them. Chapter two of this report is not solely a literature review but also an analysis that reflects on the issue economic efficiency when used as an indicator. The aim is to identify the information that will be used to assess the economic performance of the selected cases. The use of indicators requires at least four steps: 1) criteria used for assessment of economic efficiency; 2) identification and specification of indicators; 3) reference points; and 4) interpretation and assessment of outcome and decisions (e.g. the traffic light system).

For the whole CEVIS project a number of cases have been selected. Four specific cases have been subjected to analyses in this report: 1) For the North Sea, management systems with respect to recovery programmes for flatfish have been investigated. The management systems are TAC/quota controls, and effort controls; 2) In the Baltic Sea case, various extensions of marine reserves have been investigated; 3) For the Western shelf, the case has centered on participatory governance with respect to improving stock assessments due to better information about discards and unreported landings provided by the industry and finally; 4) the transferable effort system in terms of sea days of the Faroe Islands has received attention.

The selected indicator for evaluation of economic efficiency is net present value (NPV). For the innovative management schemes evaluated in the four cases the main results are as follows:

For the North Sea flatfish recovery programme, a TAC/quota scenario, a minimum effort scenario and a maximum effort scenario have been assessed. For the TAC/quota scenario, the sole quota is assumed to be driving the fishing effort of the fleet. For the minimum effort scenario, the most restrictive quota of sole and plaice is used to determine the allowed effort, and for the maximum effort scenario the least binding quota of the two is used to determine the effort. It is assumed that fishermen behave differently under the TAC/quota and the effort management schemes, meaning that under TAC management the trip with the lowest profit per quota unit is dropped first. Under an effort management system it is the trip with sea days showing the lowest profit that are dropped first. The NPV over 40 years is € 484 millions for the TAC scenario, € 671 millions for the minimum effort scenario and € 328 millions for the maximum effort scenario. Thus, over the whole simulation period, the minimum effort scenario performs better than the TAC scenario followed by the maximum effort scenario.

For the Baltic Sea, the economic consequences of marine protected areas have been assessed. Three scenarios have been investigated by maximising the fleets' profits over 10 years. The optimisation is done under a range of restrictions including maximum and minimum number of days at sea per vessel and expected quotas. In the base status-quo scenario, the total net present profit for the Danish fleet is DKK 6,331 millions (€ 850 millions). In scenario 1 with extended closures around the Bornholm and the Gotland Deep and scenario 2 with further extension of the closed area around the Bornholm Deep, the values are DKK 3,640 millions (€ 489 millions) and DKK 3,689 millions (€ 495 millions) respectively. As such, the scenario evaluations indicate that extending the marine protected areas in the Baltic Sea will decrease the economic efficiency of the Danish fishing fleet.

For the Western shelf, the effect of management through participatory governance has been assessed. It is assumed that the participatory governance will improve the quality of the input data to the assessment in terms of reduced bias and uncertainty. This improvement will, principally, be reflected in the reduction of the unreported landings and inclusion of discard data. Five scenarios have been investigated: The base case, two TAC and two effort scenarios for which discards and unreported landing are observed with the implication of improved stock assessment and improved management. The result is that over a 40 year period the TAC scenario with full observation of discards and unreported landings performs best. Effort management where there is no underreporting performs almost as good as the TAC scenario with full observation.

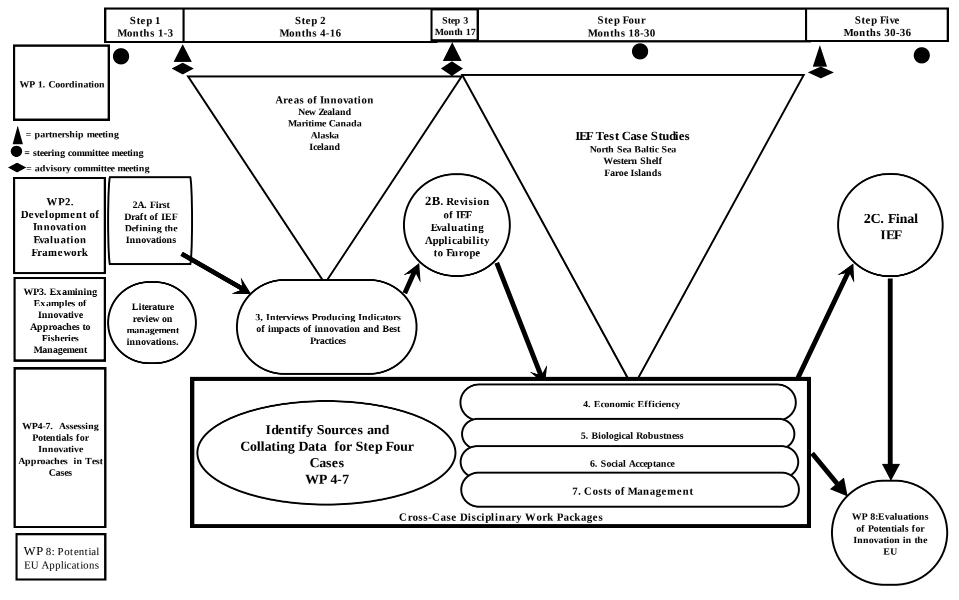
For the Faroese effort case, six scenarios have been evaluated. The species considered are cod, hake and saithe. The applied model is, in general, similar to the one applied to the North Sea case in the sense that the minimum and the maximum effort to catch each of the three species are computed and used in the projections of future catches and effort. For two of the min/max effort scenarios, a restriction on the change in effort at 10% has been used and for two other a 20% restriction on change has been used. The fifth scenario evaluates the situation where neither the minimum nor the maximum effort is used, but the effort that maximises net present value (NPV). Finally, a TAC scenario is evaluated in which the TAC is allowed to change within a limit of 15% from year to year. The result is that the two latter scenarios, the NPV and the TAC scenarios are showing the best economic performance. The worst scenarios are the ones applying maximum effort.

1. Introduction

1.1. The Structure of CEVIS

The work in CEVIS was organised into eight work packages and five steps as shown in figure 1.1. The effect of innovative fisheries management is tested on economic efficiency, which is the focus of this report. The work of work package four is linked to the biological models used in work package 5 as those form part of the necessary foundation for evaluating economic efficiency.

Figure 1.1. CEVIS work packages



Source: The CEVIS work programme, Annex 1, description of work

1.2. Objectives

Starting from the project description there are a very large number of possible fisheries management systems that differ with respect to the fishery outcomes they generate. The task, of which the results are presented in this report, is to compare and evaluate fisheries management regimes in terms of economic efficiency. Economic efficiency can be conceptually defined and evaluated in various ways. The main objective of this work package four is thus to review both theoretically and empirically how the economic efficiency of fisheries can be estimated and summarised using indicators of performance related to the IEF developed in work package 2 aiming at assessing the likely economic efficiency outcome of various management options for a range of case study fisheries.

1.3. Innovative Evaluation Framework

The CEVIS project description states that an evaluation of any aspect of management, be it a policy, a specific measure or an institution, consists of comparing its performance with its objectives. An important organizing concept for the multi-disciplinary work in CEVIS is the identification of performance indicators that can be used to evaluate the impact of the innovations to be examined on the performance of the regime. Because this is a multi-disciplinary project, in CEVIS in general the term “indicators” is used broadly to include measurements and observations of the inputs, key processes and outcomes of management.

The substance of the IEF, therefore, will be a set of indicators as well as the procedures for measuring them. The indicators of the inputs, key processes and measures of performance will include both quantitative, precisely measurable variables and qualitative (categorical) variables that are important to success to the relevant objectives. A critical tension the project seeks to hold is between A) the “adaptive management” indicators, processes and measures of performance that management regimes use to evaluate their own performance; and B) the “comparative” indicators, processes and measures of performance that allow for comparison between management systems. The work presented in this report is based on the development of indicators that are practical, measurable and acceptable comparative indicators.

1.4. Selected cases

For the whole CEVIS project a number of cases have been selected as shown in table 1.1. The cases shown in the table cover various more specific management systems, some of which have been chosen for investigation in work package four. Focus has been placed on the four areas marked with bold.

For the North Sea, management systems recovery programmes for flatfish have been investigated. The management systems are TAC/quota controls and effort controls. In the Baltic Sea case various extensions of marine reserves have been investigated. A new very extensive model have been developed in cooperation with another EU funded Sixth Framework project named PROTECT aiming particularly at investigation of marine protected areas. This work has also been reported to PROTECT. For the Western shelf case the investigations have centered on participatory governance with respect to improving stock assessments due to better information about discards and unreported landing provided by the industry.

Table 1.1. The IEF test case studies and their main foci

	North Sea	Baltic Sea	Western Shelf	Faroe Islands
Participatory Governance	The North Sea RAC Dutch *Biesheuvel* system		The South Western RAC	
Rights-based regimes	British Producer Organizations with Fish Quota Allocations			Transferable effort quotas
Effort Control	The flatfish recovery plan comprising TAC and effort management	Rotating Marine Protected Areas to protect juvenile cod		Marine protected areas
Decision Rules		Harvest control rules tying specific cod biomass reference points to specific fishing mortality rates	Adaptive management of anchovy	

Source: The CEVIS work programme, Annex 1, description of work

Finally, the transferable effort system in terms of sea days of the Faroe Islands has received attention. The system applied on the Faroe Islands is rather unique in the sense that no fish quotas are used. The system with transferable sea days is supplemented with a number of closed areas the effect of which has not been subjected to investigation in our case.

2. Economic indicators, review and selection

2.1. Introduction and concepts

This chapter is not solely a literature review but also an analysis that reflects on the issue economic efficiency defined by the use of indicators. The aim is to identify the information that will be used to assess the economic performance of the selected cases. The use of indicators requires at least four steps:

1. Criteria used for assessment of economic efficiency
2. Identification and specification of indicators
3. Reference points

Interpretation and assessment of outcome and decisions (e.g. the traffic light system)
Often there is some confusion about the concepts economic efficiency and economic indicators. While the economic efficiency concept is, theoretically, well established, see for example Cohen and Cyert (1965), the use of indicators is a convenient analytical tool to structure information but not a theoretical concept in itself. Theory is linked to item 1 above because for example optimal factor allocation or comparison between two options are, in theory, obtained in specifically defined ways and the measurement of the outcome requires certain indicators and certain criteria for assessment. Before an assessment is performed categorization of the problem considered is helpful. It may be fruitful to compare fleet segments while it may not necessarily be fruitful to compare salmon fishery with salmon farming. The criteria used for assessment should be founded on economic theory about economic efficiency. However, criteria could also be “soft” in the sense that they are based on value judgments for example employment or investment rates. A long list of such criteria can be found in the literature and often the criteria are adapted to the case (categorization) that is under consideration.

The concept economic efficiency is clearly defined in the neo-classical micro economic theory, and is further explained in section 2.2. In theory a fishery is ‘economically efficient’ if the resource rent is maximized. Other economic indicators are not providing information about economic efficiency as such but only about the state or the development of the system from an economical point of view. These indicators could be either socio-economic (macro economic) or business economic indicators. It is not always easy to distinguish between the macro economics, micro economics, socio-economics and business (private) economics. Another problem is what concerns society and what concerns agents in terms of consumers and producers (companies). However, the concept economic efficiency originates from micro economics, and from this origin has implications for socio-economics and business economics.

This literature review is based on peer reviewed articles (white literature) and grey literature. Most of the information, however, is to be found in the grey literature.

2.2. Pareto optimality

From an economic perspective, a fishing fleet is said to be economically efficient, or more correctly, Pareto efficient, if it is impossible to reallocate goods and production factors between agents involved in the fishery in such a way that somebody is made better off without making somebody else worse off (Varian 1999). This is defined as the *Pareto condition*. The *Kaldor-Hicks* condition says that if gains by one agent, groups of agents, etc., are sufficiently high to compensate the losses of another agent, groups of agents etc., then the solution is an improvement in economic efficiency. The Kaldor-Hicks criterion does not require that compensation is actually paid, which means that a more efficient outcome can leave some people worse off. In practice, it is difficult, if not impossible, to implement changes that result in Pareto improvement, whereas, it is much easier to identify solutions which can result in outcomes that will satisfy the Kaldor-Hicks criterion for improvement in efficiency.

Often heard phrases when dealing with fisheries, are: 'One vessel is more economically efficient than another', or 'the vessel has become more economically efficient'. These are not wrong from a linguistic perspective, but such phrases conflict with the definition of economic efficiency stated above as they describe states of the system that, given the heavily exploited nature of European fisheries, will be economically *inefficient* in most cases, even though some agents may have increased their individual economic performance.

In principle, a fishery is Pareto efficient if the resource rent is maximized. The resource rent is the amount left over after all costs have been deducted from the landings value given there are no external effects outside the fishery such as ecosystem effects, and is a key variable with respect to assessing the conditions for economic efficiency of a fishery, see Andersen (1983), Gordon (1954) Hardin 1968 and Scott (1955). The costs include both direct exploitation costs and so-called opportunity costs, i.e., how much could have been earned if the capital and labour had been used in the best alternative to fishing. At vessel level, landings values and costs can be extracted from recorded statistics. For the whole industry, the exploitation costs will depend on both the total fishing effort and the level of exploited stocks, as one vessel's catches will decrease the stocks in the future and hence increase the fishing costs. This external effect is not accounted for in the costs and earnings statistics. As such, economic efficiency cannot be assessed by solely using available economic data, but must be estimated using bio-economic models that include information about the costs and earnings of fishing vessels as well as the size of the fish stocks. In such models, the spawning stock biomass should optimally be considered a capital input in the same way as vessel capital, and return (remuneration) on the fish stocks should be included in a similar manner. The return or rent of fish stocks can be viewed as compensation to society for the common property of the fish stock, and this should be added to the effort costs.

The value of the resource rent will, as such, depend on the level of effort used, as well as the state of the fish stocks. The latter is implicitly a function of the former and, as such, some effort level will exist for which the resource rent is maximised for a given fishery. When only one stock is exploited, the maximum resource rent of the fishing fleet will coincide with the maximum economic yield of the stock (Gordon 1954), i.e. with the optimal sustainable exploitation level seen from the fishermen's point of view. Most fisheries, however, do not exhibit this ideal one-stock situation, as several stocks and fleets usually compose a fishery. That makes it difficult or impossible to arrive at the optimal solution in which the resource rent is maximized at the same time as the maximum economic yield is reached for all stocks. In this case, the resource rent is still the total catch value minus all costs, but the maximisation of this is likely to coincide with over-exploitation of some species and under-exploitation of others.

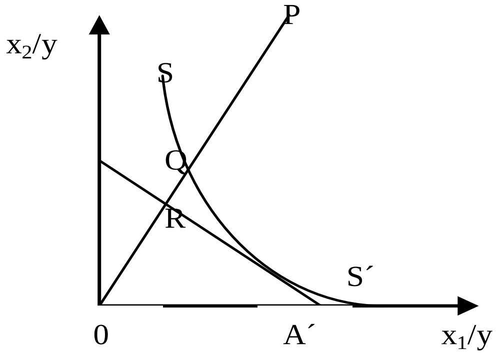
However, achieving economic efficiency in fisheries, as defined above, is in many cases not possible as most fisheries are subject to embodied externalities. Externalities are any external effects caused by individual fishermen, but not included in their accounting system or behaviour (Seijo et al. 1998). In fisheries, externalities are most often negative, i.e., the actions of one fisherman cause the rest of the fishery to be worse off. Three types of negative externalities can be identified for most fisheries, stock, crowding, and technological externalities. The stock externality refers to the fact that a fish stock is reduced every time a fisherman harvests it, thus increasing harvest costs for subsequent fishermen. Crowding externalities occurs when vessel aggregation on fishing grounds increases the marginal harvest costs. Technological externalities occur when fishing gear technologies change the population dynamics of fish stocks, e.g., through targeting certain age-groups, or through bycatch. From above, it should be clear that in most practical situations a fisherman increases his own welfare at the expense of the welfare of other fishermen because of one or more of the above mentioned externalities. Thus, his welfare actually increases the economic inefficiency of the entire fishery unless he is able to compensate other fishermen, which is generally not the case in fisheries subject to overfishing and/or open access. Thus, it seems more correct to monitor economic development of fishing fleets using economic performance measures, including measures of resource rent.

2.3. Data Envelopment Analyses (DEA)

Efficiency measurement begins with Farrell (1957) who defined total economic efficiency concept based on the combination of the following two components: a technical efficiency (the capacity to obtain maximal output given a set of inputs), and an allocative efficiency (the capacity to use inputs in optimal proportions given their prices). Felthoven (2002) and Pascoe and Herrero (2004) use DEA framework to estimate efficiency in fisheries; and a whole issue of Marine Resource Economics edited by Vestergaard (2005) has been devoted to capacity efficiency issues using DEA.

Farrel showed a simple example with two firms which use two inputs (x1 and x2) to produce a single output (y), within Constant Return to Scale (CRS). In the following, figure 2.1. S´S is a unit isoquant and firms operating on S´S are fully efficient. A firm operating in P is inefficient as it employs higher inputs to generate the same output, as the firms on the isoquant. The technical efficiency of the firm is measured by the ratio 0Q/0P; while the allocative efficiency is measured by the ratio 0R/0Q. The product of both measures represents the economic efficiency which is measured by the ratio 0R/0P.

Figure 2.1. Efficiency measures: technical and allocative efficiency



Following Farrell´s idea, a DEA-model, which is a mathematical programming model, estimates the efficient isoquant from sample data by means of a non-parametric piece by piece linear convex isoquant. The application of DEA model to fisheries is used to estimate efficiency measure; however, one of the main restrictions of characterizing efficiency through DEA framework is that it provides an efficiency measure in relative terms given that estimates efficiencies related to the most efficient isoquant. The DEA framework provides an efficiency measure by comparing each individual production unit - a vessel - against all other units. In this sense, the efficiency of each vessel is obtained by comparing its output and input use ratio with the "best use or practice". The so-called best use is related to the one that assures the highest output/input ratio. This relative efficiency measure could not satisfy the so-called Pareto economic efficiency.

2.4. Fisheries economics and economic efficiency

Because of the externalities in fisheries it is necessary to distinguish between the individual fisherman's efficiency and the efficiency of the industry (society). The individual fisherman may become more efficient from his own viewpoint if he can increase his profit. There is reason to believe that each fisherman is efficient in the sense that his use of production factors (fishing effort) is determined by the intersection between his marginal costs (exclusive externalities) and the price he will get for the fish. But exactly because of externalities the whole industry is inefficient. This problem is well known from the fisheries economics literature and dealt with in figure 2.2.

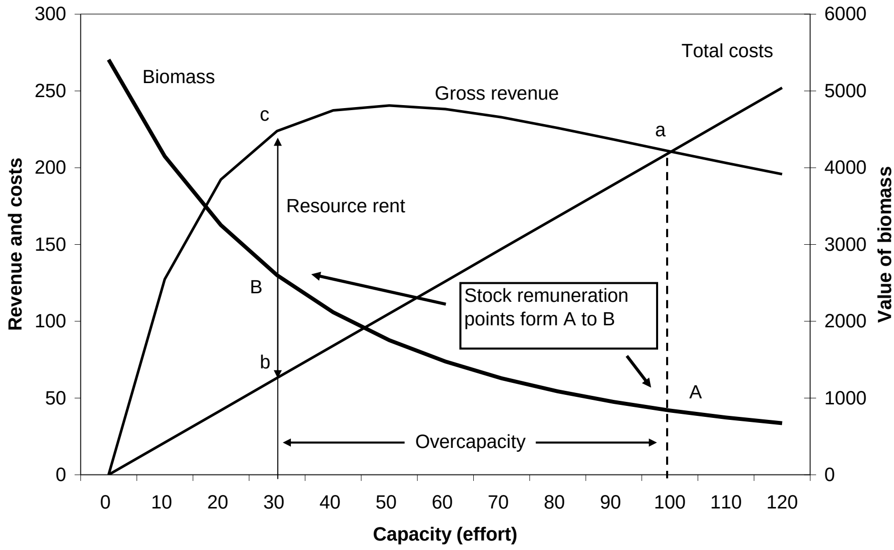
Figure 2.2 shows the so called Gordon-Schaefer model (Gordon 1954) with some added information that is explained below. The Gordon-Schaefer model is constituted by the gross revenue curve and the total cost curve for the entire fishing industry. In its simplest form the entire industry is composed by one species harvested by one fleet composed of homogeneous vessels. The gross revenue curve is the (biological) Schaefer yield curve of a fish stock multiplied with the price of the fish normalized to 1. The total cost curve is composed by all the homogeneous vessels' costs. If the vessels are non homogeneous some vessels would earn higher profits than others (infra marginal producer rent).

It is shown in the literature that because of the externalities discussed above "equilibrium" of the fishery is determined by the intersection between the gross revenue and the total costs (at point a in figure 2.2). This is often called the open access equilibrium because this is how the fishery will adjust if no restrictions are imposed. At this point each single vessel is "efficient" from the fisherman's point of view because its own marginal cost is equal to the price of the fish. This cannot be seen from figure 2.2, but it is important to notice that even though the earnings of the total industry in point a equals 0, the individual vessels can actually earn a high profit, the level of which is determined by its opportunity costs i.e. what the capital (and labour) could earn elsewhere. However, the entire fishery is economically inefficient.

If the fishery is restricted for example by restricting the number of vessels or the amount of catch (quota) the entire fishery can earn more money in the long-run. If capacity is restricted to 30 compared to 100 (the open access equilibrium) in figure 2.2, the distance between gross revenue and total cost for the whole fishery (the distance between points b and c in the figure) is maximized. The distance between gross revenue and costs is defined as the resource rent although it includes consumer and producer rent.

In principle the fishery is Pareto efficient if the resource rent is maximized assuming no externalities outside the fishery for example through ecosystem effects. Therefore the resource rent is a key variable with respect to economic efficiency for the whole fishery.

Figure 2.2. Socio-economic efficiency including the concepts of resource rent, overcapacity, and remuneration of the biomass



Economic efficiency determined by the resource rent cannot be extracted from statistics but has to be calculated by use of bio-economic models that include information about the fish stocks and the fishing vessels. On vessel level the profit can be extracted from the recorded statistics, but the vessels' contribution to the resource rent of the whole industry also has to be calculated by taking the net profit of the vessels after deduction of all costs and then subtract the opportunity profit. The fish stock is embodied in this measure. Therefore, the calculation of the maximum resource rent requires explicit information about the fish stock and its capacity to produce yield.

Thus, economic efficiency for a whole fishery cannot be determined without knowledge about the yield of the fish stock. This requires biological information based on fish stock assessment that produces information about the development of the stocks. The information about the spawning stock biomass is published by, among others, the International Council for the Exploration of the Sea (ICES). This information makes it possible to calculate the development of stock biomasses and the yield as a function of fishing mortality. Assuming that fishing mortality is a linear function of fishing effort the stock biomass development as a function of effort is shown in figure 2.2 as decreasing from the left to the right.

If the spawning stock biomass is considered a capital input in the same way as vessel capital, the biomass capital could be remunerated in a parallel way. The fish stock remuneration could be viewed as a payment to society for the common property of the fish stock and this remuneration could be added as a cost to the effort costs. If the remuneration is a constant percentage of the stock value, the remuneration will differ with stock size. For example in point A in figure 2.2 it is low relative to the remuneration in point B.

If, on the other hand, the percentage is determined according to the yield of the stock (landings) in proportion to the stock, the percentage should be high in point A and lower in point B. The yield in proportion to the (low) biomass in point A in is 25% while the yield in point B is 8%. If the opportunity cost of capital is for example 8% the stock should be increased to the corresponding level. The calculated remuneration of the stock could be subtracted from the total profit recorded for the fishery in question, and this efficiency measures would provide some information about state of the fishery.

In many cases only point estimates of the fish stocks are available. In these cases it is still possible to calculate the remuneration to the stock, although not with the same degree of precision as if the stock development is known.

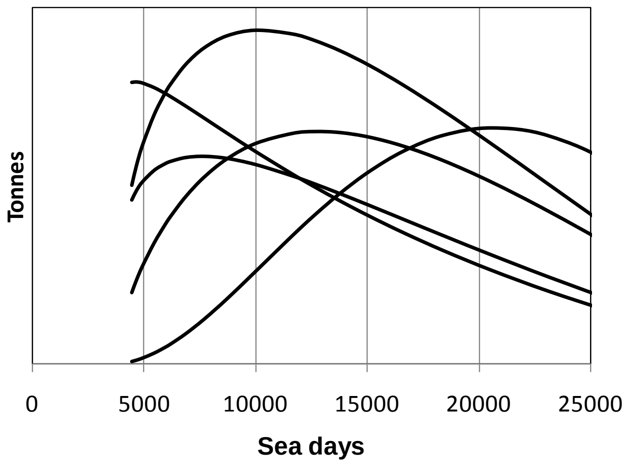
Most fisheries are, however, not representatives of the ideal one-stock one-fleet situation described above. Usually several stocks and fleets compose a fishery. That makes it impossible to arrive at an optimal solution in which the resource rent is maximized and reference points such as Maximum Economic Yield (MEY at point c in figure 2.2) or the biological reference point Maximum Sustainable Yield (MSY, at the peak point of the gross revenue curve in figure 2.2) are reached.

The more common situation where a fishing fleet is exploiting several stocks at the same time is shown in figure 2.3 and 2.4. Figure 2.3 shows the yield curve (landings curve) of different stocks as a function of sea days. The yield curves are calculated by use of a Gompertz[1] function (Conrad and Clark, 1994) and the associated number of

[1] Benjamin Gompertz (March 5, 1779 - July 14, 1865, London, England) was a self educated mathematician.

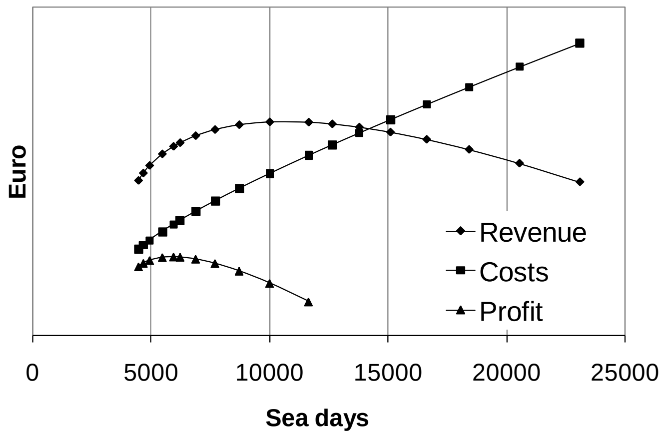
sea days as a function of the landings of the different species is calculated by use of the EIAA model (SEC 2004). It is assumed that the fleet is not able to exploit the species sequentially (one by one), but exploits the stocks in a fixed relationship.

Figure 2.3. Landing of different species as a function of effort (sea days)



It is noted from figure 2.3 that the peak points (MSY) of the yield (landings) curves cannot be obtained for all the species at the same time. If the yield (landing) curves are multiplied with the fish prices and aggregated and the costs of producing sea days are taken into account one arrives at the picture shown in figure 2.4.

Figure 2.4. Gross revenue, total variable costs and profit for a fleet segment exploiting several species



Aiming at maximizing the resource rent the figure shows that the optimal number of sea days for this segment is around 6000 days. Figure 2.4 can be compared with figure 2.2. They show the same features but the underlying assumption are different in particular with respect to the level the various species are exploited. Some are exploited above and some below their biological reference points MSY.

Finally, with reference to conventional economic theory individual fishermen maximize their profit when the marginal costs are equal to the price of the fish. This means that it is possible for (some of) the individual fishermen to earn high profits even in cases where the resource rent is dissipated. These profits are recorded in cost and earnings statistics but it is not possible without knowledge about the opportunity costs to determine the extent to which this profit includes resource rent.

The most appropriate criteria to assess economic efficiency are discussed below but before that a review of indicators and where they are used is carried out.

2.5. Indicator systems

Indicators systems are often addressed in relation to sustainable, precautionary and responsible fisheries (FAO 1995a, 1995b, 1995c, 1996, 2001a, 2001b, 2003, 2005).

Therefore, the indicator systems are developed to cover several dimensions. The indicator systems described in this section are not fisheries specific, but developed to address a range of issues within four dimensions:

1. Ecological
2. Social
3. Economic
4. Institutions/governance systems.

Economic indicators are thus part of a broader system, which is described by different indicator systems that in a sense are variations of a theme.

The approach of FAO and OECD generally includes more than only economic indicators as these bodies focus on sustainability of fisheries primarily from a biological and economic point of view, but with increasing focus on social an institutional aspects. FAO, in particular, has put emphasize on biological indicators in the Code of Conduct for a responsible fishery (FAO 1995a) that originates from the UN conference in 1992 (the Rio declaration. Agenda 21, United Nations Conference on Environment and Development, 1992).

A framework developed by FAO to address issues about sustainable fisheries is the Sustainable Development Reference System (SDRS). With respect to fisheries the relationship between conventional fisheries management schemes and the SDRS system is presented in table 2.1. For a fishery system comprising markets, fish resources, fishing fleet and fishermen an objective about sustainable fisheries may be set up. A management plan would need to include several steps to pursue the objective. In the SDRS indicators are defined to host information about monitoring the development towards this objective. Reference points are needed for assessment, and interpretation is required to arrive at decisions and implementation. Hence information is structured in a clear way to make interpretation and decision making easier.

Table 2.1. The relationship between conventional management plans and SDRS

Fishery	Fisheries management plans	SDRS
	Objectives	
Markets, Resources	Monitoring	Indicators
	Assessment	Reference points
Fleets, People	Decision	Interpretation
	Implementation	

FAO (1999)

For management purposes indicator systems produce information for different sorts of analytical assessment frameworks.

One approach widely used for example by the OECD, FAO, and the European Environmental Agency (EEA) on the four dimensions is the *Drivers, Pressures, State, Impact and Responses (DPSIR)* framework. The DPSIR framework was developed by the OECD in the 1980s to structure information and is useful because it identifies cause and effect relationships, allowing for the separation of issues through the different DPSIR categories defined:

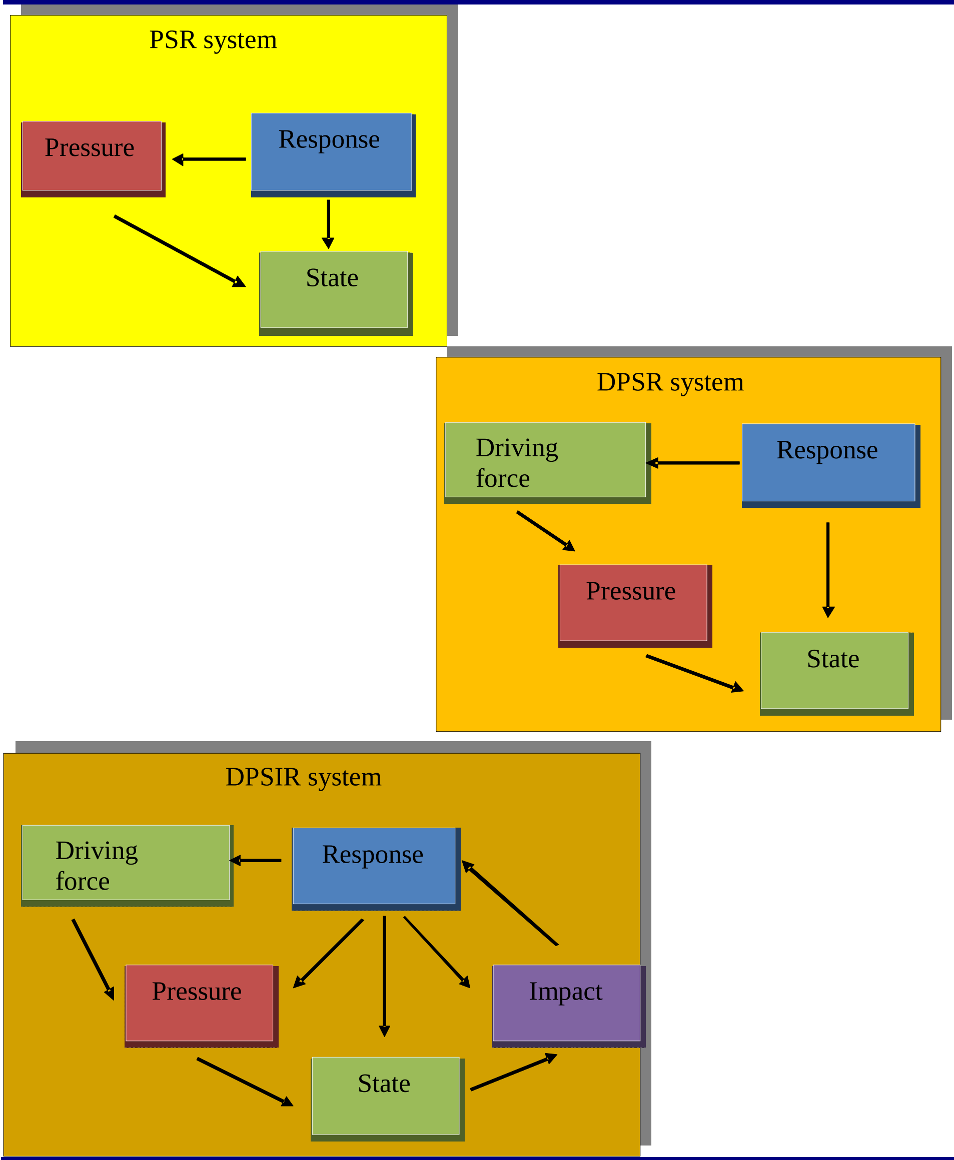
1. Driving forces are the underlying causes that lead to environmental pressures
2. Pressures affect the state of the environment
3. State refers to the state of the environment in terms of quality of natural resources
4. Impact refers to the effect that a pressure has on the state of a natural resource and on user groups
5. Response relates to the social response via policies, laws, programmes and research

The PSR (Pressure, State, Response) framework was developed in the 1970s[2], and subsequently adopted by the OECD's State of the Environment (SOE) group. The European Commission's indicator development follows this framework. Some organizations prefer variants of the PSR model; for example, the UN Commission for Sustainable Development (UNCSD) bases its indicator set on the Driving force-State-Response model (DSR or DPRS), which allows for a better inclusion of non-environmental variables, (Jesinghaus 1999), see Figure 2.5.

[2] by the Canadian statistician Anthony Friend

In broad terms, the PSR framework aims to identify the pressure on the environment from human and economic activities, which lead to changes in the state or environmental conditions that prevail as a result of that pressure, and may provoke responses by society to change the pressures and the state of the environment.

Figure 2.5. Indicator systems



Source: FAO (1999)

According to the pressure-state-response (PSR) framework that has been developed and used extensively within OECD, see for example OECD (2000), the indicators can be classified as shown in table 2.2. For the three dimensions the table shows what the cause of the pressure is. The next column shows how the state of the system could be measured and, finally, what actions could be taken to alleviate the pressure.

Table 2.2. PRS system applied to three dimensions

Dimensions	Pressure	State	Response
Ecosystem (resource and environment)	- Total catch - fish consumption	Stocks status	TAC and quotas
Social	- Fishing effort - Number of vessels - Growth rate of number of fishers	Number of fishers	
Economic	- Subsidies - Excess fishing capacity - Profitability	- Profitability - Sector employment	Economic incentives & Disincentives (e.g. subsidies, taxes, buy-back)

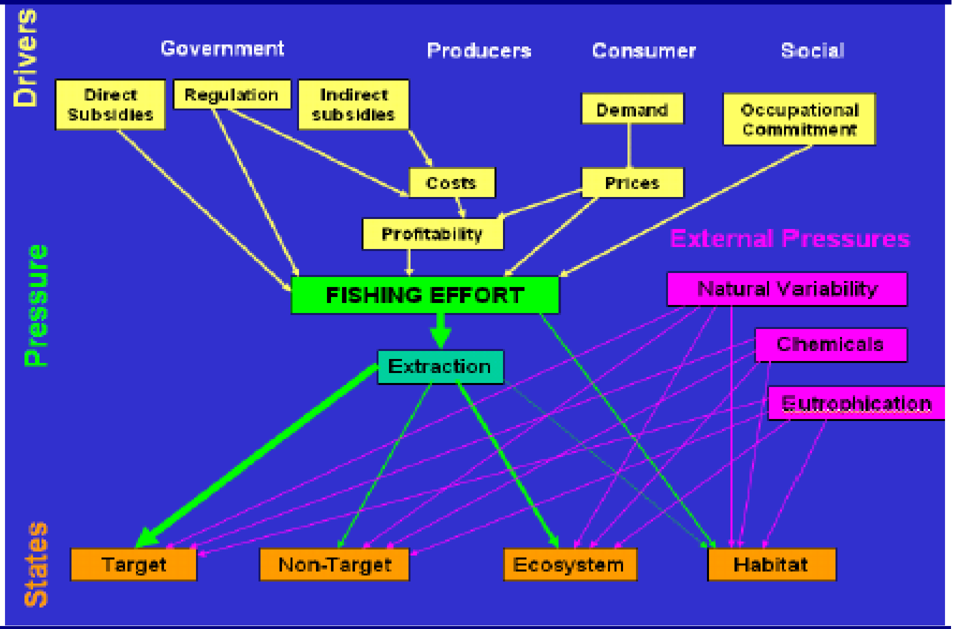
Le Gallic (2002)

The information systems DPSIR etc. require information about: 1. Criteria; 2. Indicators; and 3. Reference points. The following section addresses this area with examples from the economic dimension.

An example the DPSIR framework applied the Basque trawlers operating in the North East Atlantic is shown in figure 2.6; it is easily extrapolated to other fisheries. This example comes from ELME project.[3] The figure provides a summary of the cause and effect relationships using States, Pressures and Driving Forces indicators.

[3] European Lifestyles and Marine Ecosystems, by EU (EC/DG Research: Contract GOCE-CT-2003-505576)

Figure 2.6. DPSIR model applied to trawlers in North East Atlantic.



2.6. Economic indicators

2.6.1. Definition and use of indicators

An indicator has been defined as: “a variable, pointer, or index related to a criterion. Its fluctuation reveals variations in key elements of sustainability in the ecosystem, the fishery resource or the sector and social and economic well-being. The position and trend of an indicator in relation to reference points indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and actions” (Accadia and Spagnolo 2006).

OECD defines indicators as: Indicators are data or combination of data collected and processed for a clearly defined analytical or policy purpose (Le Gallic 2002). The OECD applies economic indicators in the annual reports Review of Fisheries in OECD countries

Table 2.3. Examples of economic criteria and indicators

Criteria	Example of Indicator	Structure	Reference Point
Harvest	landings by-catch	by species; age groups by area by fishery sub-sector	MSY historical level policy target level
Harvest capacity	GT (decked vessels) no. of boats (undecked vessels) total effort	by fleet type by fishery segment age composition of vessels fishing mortality/species	capacity or effort of MSY policy target level
Harvest value (in constant prices)	total deflated value (landed price)	by species groups by sub-sector & fishery	selected historical level
Subsidies	tax rebates grants	by sub-sector by fleets/fishery	historical level zero level target level
Contribution to GDP	fisheries GDP national GDP	by species groups	historical level
Exports	export/harvest value	by species groups by fishery segment	historical level
Investments	market or replacement value depreciation fleet age composition	by fleet type by fishery	historical level
Employment	total employment	sub-sector fleet/fishery	historical level realistic policy target
Net returns	(profit + rent) net return/investment value of entitlements	by sub-sector by fishery	historical level MEY
Effort (mainly at fishery level)	no of vessels; Fishing time amount of gear used employment	by fishery segment in physical or monetary terms	

FAO (1999)

Examples of economic indicators etc. can be found in FAO (1999), as shown in table 2.3. The criteria (or the name of the indicator) show the specific criterion that is enlightened by the indicator. The indicator and the structure columns show the type of information that could be produced to enlighten the criteria. Finally, the reference point column shows reference points that could and should be defined to be able to interpret and assess the system. These reference points can show both a state and a development. The concepts maximum sustainable yield (MSY) and the maximum economic yield (MEY) are suitable as reference points as they are set up independent of time. These are points to pursue. For indicators showing developments for example in employment, the annual development of the indicator could be compared to a stationary reference point, produced by using an average number over a number of years (historical level).

As regard the EU fisheries specifically, the data collection regulation (DCR) from 2001 (Council reg. 1543/2000 and Commission reg. 1639/2001)[4] includes a number of economic indicators as shown in table 2.4 and 2.5 but no reference points. These indicators are similar to the indicators used in the annual economic report about the economic performance of selected European fleet segments (AER) and the associated EIAA-model. The regulation 1543/2000 is currently under revision, and prior to this an extensive work has taken place. Some of the proposals about economic indicators have been prepared in the "Paris workshop" and these are included in table 2.4 as well. The differences are rather in the name than in the contents of the variable with the aim to clarify the type of information that the name refer to. The complete list of indicators in DCR and the AER/EIAA is included in the appendix 8.2.

The DCR operates with a minimum programme (MP) and an extended programme (EP), and table 2.4 shows the MP. The extended programme prescribes that the information should be collected on geographical levels that are disaggregated with respect to where the fish is caught.

Table 2.4. Economic variables and indicators used in the EIAA compared to the EC data regulation and the revisions proposed by the Paris workshop

		Review of economic indicators (Paris workshop)
Cost and earnings input to the EIAA from the AER	Indicator required by EC (Com. reg.1639/2001)	Proposed revised heading by the workshop
Gross revenue/value of landings	income – turnover	gross revenue (of which gross value of landings)
Fuel costs	fuel costs	
Vessel costs	repair and maintenance	
Crew share	crew (incl. Social costs)	
Other running costs	other running costs	other costs
Depreciation	fixed costs	capital costs
Interest	n.a. under the minimum program	
Invested capital	investment (asset)	the value of capital
Prices/species	prices/species	

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

The extended programme's fleet categorization is shown in appendix 8.3 with respect to the type of information.

[4] A revision of the DCR has been prepared in 2008

With the aim of narrowing the scope for economic efficiency indicators, the following is based on the AER/EIAA approach.

The first best socio-economic indicator is the resource rent in a steady state or over a number of years discounted to net present value. However, this indicator requires a model to be calculated and extensive data input in terms of economic and biological information which is not available on a wider scale. Hence for practical purposes this indicator is often in-operational.

The second best indicators on a socio-economic level are indicators as described in the FAO and OECD work. They are operational but not founded on economic efficiency theory.

At the business economic efficiency level, profit and the return on capital (ROC) are the first best indicators. However, it requires not only estimates of profit but also of the invested amount of capital, and in many fisheries (fleets) it is difficult or impossible to get reliable information about vessels capital. This is also the case in many other branches – not only in fisheries. In these cases the return on revenue (or sale) ROS, often named operating profit margin, is used as indicator. On a socioeconomic level contribution to the gross domestic product (GDP) or the value added are considered first best indicators. The value added indicator is an approximation to GDP as the value added is easily estimated as crew wages plus remuneration of vessel capital plus profit (including remuneration of owners).

Table 2.5. Other economic indicators

AER/EIAA	Indicator required by EC 1639/2001
Employment on board (FTE)	Employment Full time/part time/FTE
Effort (sea days)	Effort relevant unit accounting for technology and time
Invested capital (€)	Invested capital
Fleet - number of vessels	Fleet – number of vessel
Fleet - total GT	Fleet - total GT
Fleet - total kW	Fleet - total kW
	Fleet in age
	Fleet according to gear used

The economic indicators used in the Concerted Action EAEF (Economic Assessment of European Fisheries) apply to both the data collection of the AER and to the EIAA model. Emphasis has been put on a few well defined indicators that have been divided into indicators of known concepts from vessels accounts and indicators of interest from a socio-economic point of view as shown in table 2.6 concerning the AER and the EIAA. Difficulties as to how to assess investments have caused that an indicator such as 'return on capital' have been avoided. Result from EIAA calculations are basically presented by use of the same indicators as in the AER.

Table 2.6. Economic indicators used in the EAEF

Annual Economic Report	EIAA
Value of landings	value of landings
Gross value added	crew share
Gross cash flow	gross cash flow
Net profit	net profit
	gross value added
	operational profit margin (%)
	classification (words)

From a socio-economic point of view remuneration of capital and labour is of interest. The gross value added expresses the added value that the segment contributes with to the national economy. This includes: salaries, profits, opportunity cost of capital and depreciations. It can be obtained by deducting the fixed (except interest and depreciation) and variable costs (except the labour costs) from the total landing value.

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

2.6.2. Long-term indicators and discount rates

Production surplus models such as the Gordon-Schaefer model predicts a long run bio-economic equilibrium where catch per unit of effort (CPUE) equals the ratio of the cost per unit effort a to the price per unit harvest p, i.e. $CPUE = a/p$. Time series for catch and effort, as well as for effort costs and fish prices, are important sources of information that may be used in cases where fisheries independent stock assessment is not undertaken. CPUE time series should be used with great care as indicators of stock changes due to the unknown stock-output elasticity and efficiency changes, see SEC (2006) for further information.

In the short term (i.e. next year), constant assumptions can be made about the structure of a given fleet and that fleet's activity. The longer term is indicated by either a static equilibrium solution or a dynamic solution. In the former, as used to indicate a "recovered state" in the EIAA model[5], no information can be given as to the length of time it would take to achieve that state, or even if that state can be achieved (especially given assumptions about a constant fleet). Hence, an indication of profitability of a fleet at a snapshot in time (i.e. "now") for any potential future scenario carries obvious misinterpretations. In the dynamic solution, a path (typically by year) to some future situation is given. This can account for changes in activity (i.e. changes in effort allocation by gear/species/area) and can take account of changes in fleet structure. These will clearly be dependent on the management options modelled and assumptions made. However, in the dynamic case, economic indicators over time can be presented that allow the assessment of the full effects of management measures on fleets to be ascertained. With respect to the biology, time to recovery given scenarios for alternative fishing mortalities (or time to some other target) can be provided (e.g. North Sea cod recovery evaluations). These can indicate the probability of recovery at each time step and as such the uncertainty associated with recovery.

In the dynamic case, typical indicators such as gross revenue, intermediate consumption, gross cash flow and net profit can be used, as a yearly path is evident. In addition, a comparison of net present values (NPV) is possible in the dynamic case. In comparing the present values of alternative management strategies in order to achieve a policy objective (e.g. a recovery program or MSY for stocks), it is common to discount net benefits that will accrue in the future compared to net benefits that can be achieved at present. Discounting is included because investment in fisheries must compete with other investment opportunities with a positive rate of return. A second argument is the assumption that future generations are better off because of increase in productivity. This needs to be addressed by the social planner. Typically, a cost–benefit analysis will discount streams of net benefits and compute the NPV as a single number. The theory is that standard discounting is meant to ensure that the present value of net benefit calculations provides a meaningful indication of whether the efficiency criterion is satisfied or not. If NPV of two alternatives is equal but is made up of two different streams of annual benefits, secondary reference point could be applied complimentary. For example is stability to prefer to variability.

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

There are many arguments for and against discounting future benefits and costs; especially controversial is the choice of the discount rate (as the outcomes are highly sensitive to the rate). The discount rates for people are normally very high which means above 20%, see Harrison, Lau, and Williams (2002) and Hillis and Whelan (1992) while the socio-economic discount rates are much lower, for example below 6% before tax. HM Treasury (2003) proposes a discount rate at 3.5%

When evaluating policies, the market interest rate can be used as the discount rate but do not really reflect all long-term effects. High discount rates favour myopic policies that continue to exaggerate unsustainable resources whereas discount rates that are too low can fail to capture the efficiency argument because other opportunities to invest the capital are more profitable. Sensitivity of the outcomes of a range of discount rates (e.g. 2-7%) can be undertaken in order to illustrate the possibilities. The alternative management strategy that achieves the highest NPV (with constraints for other criteria – such as sustainability) is as such the “best” choice.

2.7. Reference points

2.7.1. Operating profit margin intervals

The ‘Operating profit margin’ and ‘Classification’ indicators are based on operating profit margin defined as net profit in proportion to gross revenue, see table 2.7. The indicator is well known from business economics and is often used instead of ‘return on capital’ which is defined as gross revenue minus variable costs in proportion to invested capital. The reference points for these indicators are the intervals in which they lie.

Table 2.7. Reference points used in EIAA

Classification	-------------------- Operating profit margin --------------------		
Profitable	5%	and more	
Stable	-5%	and up to	5%
Unprofitable	-5%	and below	

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

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

- 'Impact' = Impact of the TAC in YEAR+1 on operating profit margin compared to current YEAR
- 'Worsened' = Segment was making losses, losses now greater
- 'Improved' = Segment was making losses, losses now smaller
- 'Lower' = Segment was making profits, profits now lower
- 'Higher' = Segment was making profits, profits now higher
- ' – ' = No significant change.

2.7.2. Break-even as reference point

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

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

The definition of break-even is: *Break-even revenue = current fixed costs / (current cash flow/current revenue).*

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

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

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

2.7.3. Economic sustainability reference points

The economic sustainability depends on the capability of the sector to attract money. To guarantee the investment of financial resources in the long term, it is necessary to protect the fishery investment profitability. So, the economic sustainability could be measured by comparing the profitability of the fishery investments in vessel capital and fish stocks on one hand and in alternative sectors on the other.

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

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

In order to effectively interpret the information obtained through the indicator, some reference points (RP) must be applied. These points can refer to either a sub-optimal (in-efficient) or an optimal (efficient) situation. The former identifies a limit which is necessary to avoid, while the latter represents a target to be pursued.

The indicator suggested to measure the economic sustainability is calculated by comparing the investment profitability rate (ROI) for a specific fleet segment within a specific geographical area with the theoretical risk free rate, for example the long-term treasury bonds rate.

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

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

2.8. Remuneration of spawning stock biomass (SSB)

Remuneration of the biomass (resource rent), e.g. the spawning stock biomass (SSB), is parallel to remuneration of man made capital. While little information about stock biomass is available, information about SSB (older age groups) could be extracted from the ACFM reports produced by the Advisory Committee of Fisheries Management of ICES and be allocated to specific fleet segments according to the share of their landings relative to total EU landings.

The value of the spawning stock biomass (VSSB) could be determined by use of fish prices or the net profit (resource rent) if this information is available. Reference points could be based on $\mathrm{VSSB}_{\mathrm{current}}$ or $\mathrm{VSSB}_{\mathrm{precautionary}}$, cf. figure 2.2, points *A* and *B*, respectively. In well-managed fisheries the resource rent *b* – *c* reflects the remuneration of the biomass of a single species. In fisheries characterised by overcapacity e.g. the intersection between gross revenue and costs at point *a,* the resource rent is dissipated. Ideally, the resource rent should be estimated and included as an opportunity cost of fishing, but such an exercise is data demanding.

An alternative is to use the current VSSB and the precautionary VSSB in combination. Using the VSSB indicators in combination produces a reference point. For a well managed fleet segment or stock the $\frac{VSSB_{current}}{VSSB_{precautionary}} = 1$, while the $\frac{VSSB_{current}}{VSSB_{precautionary}} < 1$

in a fishery that is not managed in an optimal way. The indicator and the reference point are basically of ecological nature. The relevance with respect to economics is connected with the valuation of the stocks.

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

2.9. Aggregation

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

In an economic perspective the ideal indicator is the resource rent, which means that only one indicator and reference point is required for presentation. The underlying model, however, requires and produces a large number of indicators.

The level needed for the use of economic indicators in the models depends on the type of model used. In the EIAA model for example, totals per fleet segment are used to predict the effects of TACs on the economic performance of fleets. In dynamic simulation models working on fisherman's level a fisherman's behaviour is modelled by means of comparison of economic indicators of different fishing strategies.

Since all of the economic models are used for management purposes, the output indicators should fit the data needs for managers. In case of stable fleets, total economic indicators will be sufficiently indicative for developments in the economic performance, but in case of changing fleet structure, other levels of aggregation (per vessel, per kW, per GT) might be more indicative for the actual developments.

2.10. Interpretation

Once indicators are produced and reference points decided the performance of the system can be interpreted. A widely used method that does not refer to fisheries is the traffic light system. The system works with green, yellow and red colours. The system has for example been applied to FAO's Geographical Sub Areas 17 and 18 (GSA 17,

18) in the Mediterranean, see Accadia and Spagnolo (2004), and the following tables 2.8 and 2.9 show the results.

The list of indicators is comprehensive and reference points in terms of absolute or relative numbers have to be determined in advance. Apart from that, the relative development over time of the indicators can in itself be used as reference points. The development of fuel prices, for example, can be viewed in this way. Increasing fuel prices will then be marked with read while decreasing and sufficiently low (in a historic perspective) fuel prices will be marked with green.

Compared to the first best indicators mentioned above the advantage of using a large number of indicators is that it is pinpointed where in the systems problems occur.

Table 2.8. Traffic light method applied to economic indicators for FAO-GSA-17

INDICATORS	1997	1998	1999	2000	2001	2002	2003	2004
Economic performance (ROI - Risk_free_rate) (%)	3.57	1.74	0.89	8.80	10.10	8.87	12.09	14.24
Added Value/Revenue	0.67	0.66	0.63	0.68	0.66	0.65	0.65	0.63
Gross Operative Margin/Revenue	0.30	0.23	0.20	0.30	0.28	0.29	0.30	0.31
ROS (Return on Sale)	0.23	0.16	0.14	0.25	0.23	0.24	0.24	0.26
ROI (Return on Investment) (%)	10.33	6.66	5.60	14.39	15.27	13.82	16.37	18.52
Revenue/Invested Capital (%)	44.75	41.71	41.27	56.51	65.11	58.12	66.95	71.21
Net Profit per vessel (000 €)	60.79	38.82	27.19	82.79	68.94	62.69	63.94	71.61
Landings per vessel (ton)	340.26	306.99	296.37	358.09	310.86	287.09	276.34	283.38
Landings per GRT (ton)	4.49	4.31	4.16	4.95	5.59	5.15	5.73	5.88
Landings per day (ton)	2.02	1.83	1.97	2.05	1.67	1.60	1.75	1.84
CPUE (kg)	27.55	26.22	28.62	29.09	31.21	29.91	35.16	38.48
Revenue per vessel (000 €)	291.38	268.84	239.86	337.87	302.82	274.30	267.73	280.90
Revenue per GRT (000 €)	3.85	3.77	3.37	4.67	5.44	4.92	5.55	5.83
Revenue per day (000 €)	1.73	1.60	1.59	1.94	1.63	1.53	1.69	1.83
RPUE (€)	23.59	22.96	23.17	27.45	30.40	28.58	34.06	38.15
Average price (€/kg)	0.91	0.95	0.89	1.06	1.13	1.14	1.18	1.24
Fuel cost per vessel (000 €)	37.63	35.87	38.08	47.71	44.76	40.40	39.69	43.92
Fuel cost per day (000 €)	0.22	0.21	0.25	0.27	0.24	0.23	0.25	0.29
Maintenance cost per vessel (000 €)	11.92	11.26	9.18	11.78	11.48	10.72	10.76	14.14

Table 2.9. Traffic light method applied to social indicators for FAO-GSA-17								
INDICATORS	1997	1998	1999	2000	2001	2002	2003	2004
Social sustainability (Salary – Minimum salary) (000 €)	3.70	4.77	3.78	8.20	8.08	4.66	4.82	2.84
Employed persons (num.)	1178	1109	997	837	762	744	876	915
Landings per crew (ton)	46.81	42.37	43.40	54.34	51.82	45.90	47.00	47.07
Revenue per crew (€)	40.08	37.11	35.13	51.27	50.48	43.86	45.54	46.66
Crew/GRT	0.096	0.102	0.096	0.091	0.108	0.112	0.122	0.125
Salary per crew (000 €)	14.89	15.96	14.97	19.39	19.27	16.00	16.15	14.80

2.11. Conclusion

The following list is organised according to the items required by an indicator system. First the criteria are listed. The criterion is the name of the type of information that is wanted. Secondly, the indicators are listed, and these describe the exact type of information that is needed to describe the criteria. Thirdly, the reference points describe what type of information the indicators are compared with. Fourthly, the interpretation includes decision rules to reject or approve hypothesis.

The information should be provided on fleet segment level according to the levels specified in the DCR (see appendix 8.3). This means that level one is vessel length, level two is fishing techniques etc.

2.11.1. Criteria (name)

1. Economic efficiency
2. Harvest
3. Fish prices
4. Gross cash flow (profit margin)
5. Net profit
6. Contribution to GDP (gross value added)
7. Employment
8. Effort
9. Fleet capacity

2.11.2. Indicators

- Economic indicators all measured in €:
    - Value of landings

- Variable costs e.g. fuel, provision, repair
- Crew share e.g. payment to the crew including skipper
- Gross cash flow (value of landings minus variable costs and minus crew share)
- Fixed costs (interest payments and depreciation, insurance, administration etc.)
- Net result e.g. value of landings minus all costs
- Gross value added (socio-economic indicator) e.g. remuneration of labour and capital (contribution to gross domestic product).

o Other economic indicators
- Landings of fish by species (tonnes)
- Employment on board measured in persons or full time employment
- Effort measured in sea days or kW-days
- Invested capital measured in €
- Fleet capacity measured in number of vessels, GT and kW

2.11.3. Reference points

1. Maximum economic yield (MEY). This equals maximizing of the resource rent. It is calculated from the short run profit margin (gross cash flow) or the long run net profit. The MEY is an optimal "steady state" situation for a fishery from an economic point of view.
2. Net present value (NPV). The method takes all future in- and outgoing payments and discounts those to a certain point in time usually the present year. It is expressed in absolute values or as a percentage.
3. Return on investment (ROI). It is calculated taking the change in gross cash flow in proportion to the investment. It applies NPV and is expressed as a percentage.
4. Return on capital (ROC). Gross cash flow in proportion to the total invested capital in vessels. It is expressed as a percentage.
5. Operating profit margin (OPM). This is calculated taking gross cash flow in proportion to gross revenue. It is expressed as a percentage.
6. Break even revenue (BER). This is calculated taking the gross cash flow in proportion to the gross revenue and divide the fixed costs with this coefficient.
7. Overcapacity by use of MEY is calculated taking difference between the current number of vessels and the calculated number of vessels at MEY in pro-

portion to the current number of vessels. If possible GT and kW could be applied.

8. Overcapacity by use of BER. It is calculated taking the proportion between the current gross revenue and the calculated BER and subtract that coefficient from 1.
9. Other reference points for example for the development in harvest or the employment are calculated by taking the average value of these indicators for a pre-defined historical period.

2.11.4. Interpretation

The first seven reference point combines information about output and input in a fishery and requires calculations. The reference points under item eight are dealing with indicators separately and are therefore less data demanding. On the other hand these reference points are also more difficult to interpret as the interpretation is not based on economic theory but on political goals.

The choice of reference points depends on the problem that is addressed and the availability of data. The best but also the most data demanding reference point is the MEY. The closer the fishery gets to MEY the more efficient it is with respect to usage of production factors.

The NPV is convenient once two or more scenarios are compared. The one with the highest NPV is usually the one that should be favoured on the expense of the other(s). It is useful for comparison of different management regimes.

The ROI reference point is useful to investigate changes in the fishery caused by changes in investment for example in vessels and fishing gear. The ROC and the OPM are relevant to assess changes in management. The ROC is more data demanding than OPM. OPM has been used for a number of years by the STECF in the assessment of economic repercussions of the quota management.

The interpretation of ROI, ROC, and OPM requires decision rules. Usually these calculated for the fishery is compared to the same type for other sectors or to agreed conventional figures. The ROC and the OPM further have the advantage that they could be produced over time and therefore also historical reference points of these could be used in the interpretation.

The easiest overcapacity reference point in terms of data and calculation is the BER-based reference point. It requires calculation but is less data demanding than the resource rent indicator.

As regards the reference point under item 9 they are less data demanding and requires little processing. They appear directly from the indicators. A convenient way to interpret these indicators is to use the traffic light system. Once the reference points are calculated by taking the average of a certain period the colours can be determined, and a picture can be produced.

Finally it should be mentioned that having produced the entire assessment of the whole system the DPSIR system could be applied.

3. Economic Efficiency in the North Sea Beam Trawl Fleet

3.1. Introduction

This case study concerns economic efficiency in the flatfish beam trawl fishery in the North Sea. The study will test the following hypothesis: Effort based management is, on average, more economically efficient than resource based management. In order to test this hypothesis, the IMARES/LEI simulation model presented in section 3.3 will be used.

The main target species for the beam trawl fishery are sole and plaice. In section 3.2 the state of North Sea plaice and sole stocks will be discussed. In section 3.3 the main features of the management system will be presented. In section 3.4 the development of the Dutch beam trawl fleet is discussed, while section 3.5 presents the economic performance of the fleet over the past few years. Section 3.6 discusses the simulation model and the scenarios considered. Simulation results are presented in section 3.7.

3.2. State of the stocks[6]

3.2.1. Plaice

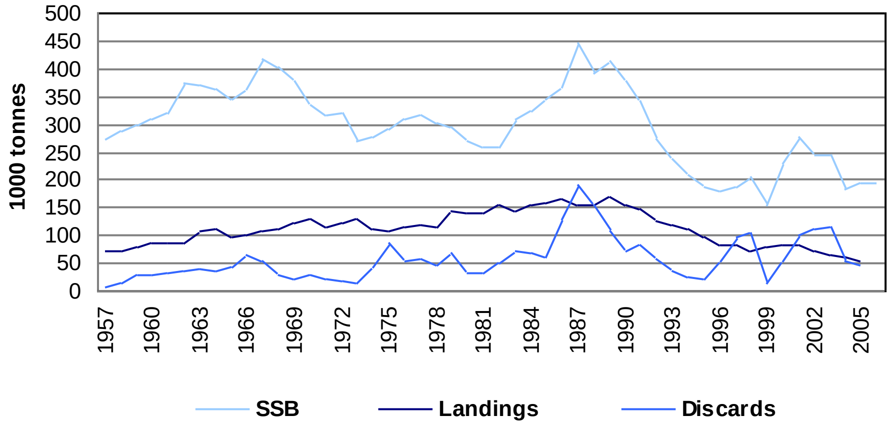
The flatfish stocks in the North Sea are heavily exploited and the ICES advice for 2007 was to reduce catches of North Sea plaice in order to rebuild the stock to safe levels. The plaice stock has been below the biologically recommended level for a number of years and recruitment has generally been low. ICES classifies the North Sea plaice stock as being at risk of reduced reproductive capacity and as being harvested unsustainably. SSB was estimated to be at around 193 000 tonnes in 2005 and at a similar level (194 000 tonnes) in 2006. The spawning stock biomass (SSB) is therefore below the precautionary level B_{pa} at 230 000 tonnes, but above the minimum biomass (B_{lim}) at 160 000 tonnes, below which recruitment is expected to be 'impaired' or the stock dynamics are unknown. Fishing mortality in 2005 was estimated at 0.52 which is below the precautionary level of fishing mortality (F_{pa} at 0.60) and recruitment since 2003 has been below the time-series average.

[6] This section has been based of ICES advice from October 2006: Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems, 2006.

Table 3.1.	Plaice in sub-area IV (North Sea)					
	Recruitment age 1 (thousands)	SSB tonnes	Catch tonnes	Landings tonnes	Discards tonnes	Ftot (2-6)
1990	1035975	378509	228218	156240	71978	0.58
1995	1158562	186469	120215	98356	21859	0.66
2000	1301974	228710	135002	81148	53854	0.53
2001	763592	276865	182750	81963	100787	0.71
2002	1929171	243394	180652	70217	110435	0.76
2003	488754	246132	181302	66502	114800	0.80
2004	880836	182637	116551	61436	55115	0.54
2005	579514	193408	104080	55700	48380	0.52
2006	704238	194051				

Source: ICES (2006)

Figure 3.1. North Sea plaice, spawning stock biomass (SSB), landings and discards



Source: ICES (2006)

3.2.2. Sole

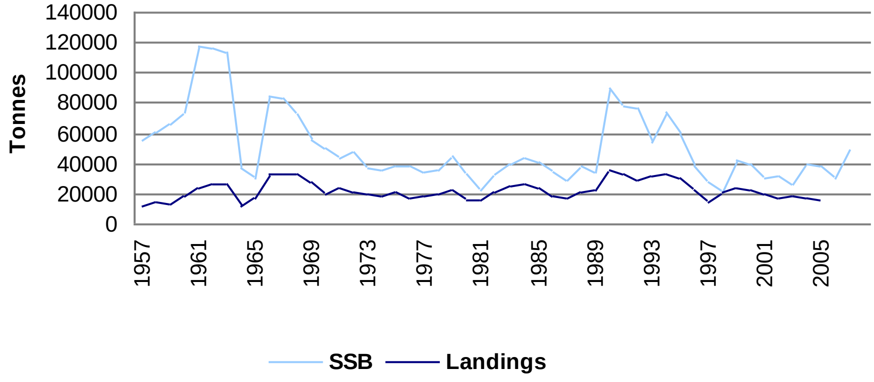
The stock of sole in the North Sea is also considered to be over exploited and ICES has advised a reduction in both fishing mortality and catches in 2007. Based on the most recent estimates of SSB and fishing mortality, ICES classifies the stock as being at risk of reduced reproductive capacity and at risk of being harvested unsustainably. SSB in 2006 was estimated at 30,000 tonnes which is below B_{pa} (35,000 tonnes), and fishing mortality in 2005 (0.45) was above the precautionary level (0.4). Recruitment in recent years has been very low but the 2006 year class appears to be above average. Discards of sole are not generally considered to be a problem for physical reasons, seeing that they are smaller than plaice, and that sole is the primary target species.

Table 3.2. Sole in sub-area IV (North Sea)

Year	Recruitment Age 1 (thousands)	SSB tonnes	Landings Tonnes	Mean F Ages 2-6
1990	177673	89462	35120	0.46
1995	96090	58780	30467	0.53
2000	124495	39187	22641	0.61
2001	66740	30424	19944	0.58
2002	198090	31094	16945	0.58
2003	90852	25863	17920	0.58
2004	49375	40155	17147	0.36
2005	45173	38011	16355	0.45
2006	96733	30077		

Source: ICES (2006)

Figure 3.2. North Sea sole, spawning stock biomass (SSB) and landings



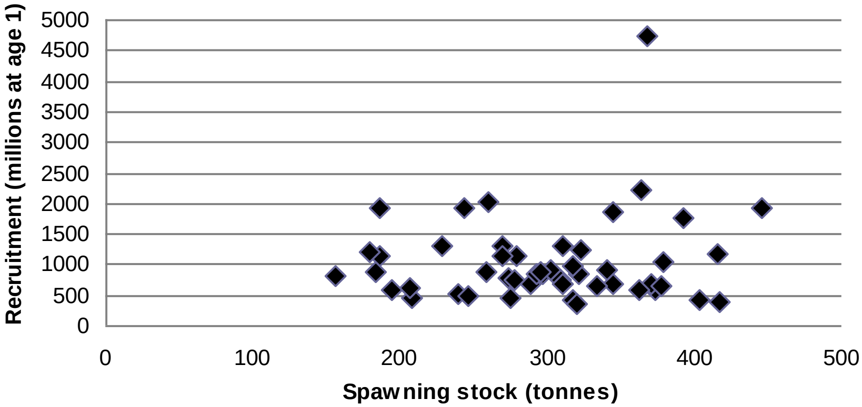
Source: ICES (2006)

3.2.3. Stock - recruitment relation

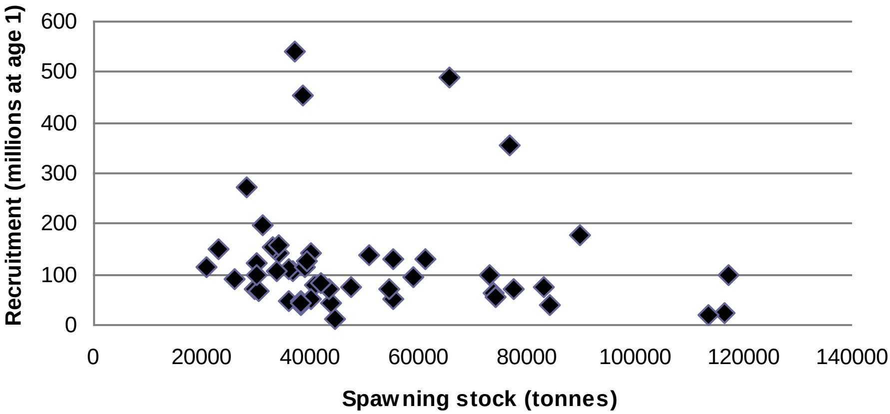
The pattern of recruitment for both sole and plaice shows little evidence for any observable stock-recruitment relationship as long as biomass is above certain minimum levels. For plaice, ICES has defined a minimum biomass (B_{lim}) of 160,000 tonnes. Below this value recruitment is expected to be 'impaired' or the stock dynamics are unknown. B_{lim} for sole has been estimated at 25,000 tonnes. Given the precautionary principle, the unpredictability of the recruitment relationship emphasizes the importance of following a cautious fishing policy.

Figure 3.3. Plaice and sole stock recruitment as a function of spawning stock biomass (SSB)

Plaice



Sole



3.3. Management regime

3.3.1. Introduction

The Dutch beam trawl fishery is managed through a combination of output regulations (quota) and input regulations (capacity and effort management).

3.3.2. Output management

3.3.2.1. ITQs and co-management[7]

Since 1975, because of severe overfishing, the European system of TAC's has been expanded to more than 20 species. In order to allocate the national quota, an ITQ system has been gradually introduced in the Netherlands. When the IQ system was introduced in 1976, flatfish quotas officially were only transferable together with a vessel. Soon, however, it proved possible to circumvent this rule by using legal constructions and an informal ITQ system evolved. In 1985, quotas became officially transferable without a vessel; ITQ's can be bought, sold or rented. The allocation of quotas in a period is based on quotas received in the previous period, for instance, if a fisher received 5% of a quota in the previous period, and the total quota is reduced by half in the new period, then the fisher in the new period receives a quota of 2.5% of the previous years quota.

In the early nineties, problems of non-compliance and bad relations between the national government and the fisheries sector led to the introduction of a set of diverse management tools, developing into a co-management system which was implemented in 1993. The key ideas of the new management scheme (*Biesheuvel system*) were:

- sharing of responsibilities between government and fishing industry and,
- cooperation between fishermen.

In the co-management system, responsibilities in the management of individual quotas have been devolved to groups of fishermen. These co-management groups are formally independent legal persons. All group members have to be member of the same producer organization (PO). In practice, the management functions of PO's and groups are often carried out by the same staff of people.

[7] This section has been based on Buisman en Hoefnagel (2007)

Group membership is not compulsory. To induce fishermen to enter a group, fishers were offered more favourable treatment than non-group fishers. This led to high participation in the groups.

The group management board is responsible for management of the pooled quota. The board is entitled to impose penalties/fines and other sanctions, including the closing of fishing activities for the group or a group member. Fines have to be applied in such a way that in the end the transgressor is never favoured by the transgression. The government remains responsible for controlling the national quota and tasks pertaining to CFP (Hoefnagel and Smit, 1996).

3.3.3. Input management

3.3.3.1. Capacity management

Capacity licensing[8] was introduced in the Netherlands in 1985[9] in order to limit the total engine power of the fleet. On a licence the engine power of a vessel is registered. According to the *Fish Licensing Order*, only fishing vessels in possession of a fishing license are allowed to fish for species subject to a quota. The licensing scheme was associated with the EU Multi-annual Guidance Programme. No new capacity licenses have been issued since 1985.

When the licensing system was introduced in 1985, fishermen could get a license for their existing engine capacity and for engine capacity for vessels under construction. However, the provision in the scheme for vessels under construction resulted in additional new capacity. By the end of 1988, the engine capacity of the fleet had expanded by 14% compared with the position before licensing. The total number of licenses in Dutch fisheries is now circa 754.

In 1987, measures[10] were taken to restrict the constantly increasing engine power of individual fishing vessels in the beam trawl-fleet. The maximum engine capacity of new vessels was specified at 2000 HP. At the time of establishment of the measure some 80 beam trawlers exceeding 2000 HP were already in operation or were on order. These existing and ordered vessels were allowed to operate. But in the case of the transfer of (or part of) these licenses to another vessel, the engine power exceeding 2000 HP cannot be transferred. Also, when a beam trawler becomes 20 years old, en-

[8] This paragraph has been based on (Buisman en Hoefnagel 2007)
[9] Beschikking Visserijlicentie (27 December 1984, Stcrt. 253).
[10] Beschikking visserijlicentie (modification 23 September 1987, Stcrt. 184).

gine power needs to decrease to 2000 HP. Currently, only a few vessels are operating with more than 2000 HP.

3.3.3.2. Transferable licences

In the Dutch system, licences are allocated to persons or holdings and not to vessels. As previously stated, the licences are transferable. In practice, licences have been transferred in various ways including being sold with or separately from a vessel. It is also possible to combine the licences of two or more old vessels into one vessel with higher HP. Vessel owners can keep their licence if their vessel is sold or brought under the flag of another Member State. This means that exports of vessels and quota hopping do not necessarily reduce the (potential) Dutch fleet. In case of decommissioning of a vessel, the licence is cancelled. However, the fisherman is in principle free to buy another licence and remain active in the fishery.

3.3.3.3. Other measures

Other significant capacity limiting measures include requirements in relation to the fishing gear, i.e. the maximum beam length of beam trawlers (12 metres outside the 12 miles zone and 4.5 meters within the 12 miles zone) is considered to be an effective measure to limit the overcapacity of the fleet fishing for flatfish.

3.3.3.4. Effort

The introduction of a national days-at-sea system in 1987 was an important development in the Dutch management regime.[11] The system was intended to restrict fishing effort by limiting the amount of days that fishing vessels can spend at sea. According to this regulation, days at sea were calculated on the basis of the size of the allocated quotas. The maximum amount of days at sea was further subdivided into three months periods.

The national system of days at sea has now been replaced by the limitations laid down in the present EU cod recovery plan. The effort limitations for 2007 are specified in Council Regulation (EC) No 41/2007, Annex IIa. Days at sea are allocated to fishing vessels on the basis of the fishing area and the type of gear (table 3.3). The total number of days at sea per vessel depends on the types of gear used and on the fishing areas.

[11]. Zeedagenregeling 1987 (Stcrt 1987;32, 1988, 253.)

Table 3.3. Number of days at sea between 1-2- 2007 and 31-01-2008			
Gear and mesh size	Skagerrak/Kattegat	II, IVa, IVb, IVc	VIId
Trawls: ≥16 – <32 mm	228	228	228
Trawls: ≥70 – <90 mm	n.a..	204	221
Trawls: ≥ 90 – <100	95	209	209
Trawls: ≥100 – <120 mm	95	95	95
Trawls: ≥ 120 mm	96	96	96
Beam trawl: ≥ 80 – <90 mm	132	132	Unlimited
Beam trawl: ≥ 90–<100 mm	143	143	Unlimited
Beam trawl: ≥ 100 – <120 mm	143	143	Unlimited
Beam trawl: ≥ 120 mm	143	143	Unlimited
Gillnets: <110 mm	140	140	140
Gillnets: ≥110 – <150 mm	140	140	140
Gillnets: ≥150 – <220 mm	130	130	130
Gillnets: ≥ 220 mm	140	140	140
Trammelnets	140	140	140
Longlines	173	173	173

Source: Council Regulation (EC) No 41/2007, Annex IIa.

Under this EU system, days at sea can still be transferred, but only within the same category (gear and fishing area). Days at sea can be transferred as HP-days, for instance, 1 day at sea for a vessel of 1500 HP equals 5 days at sea for a vessel of 300 HP.

3.4. Vessels and catches

3.4.1. Fleet segments

The Dutch beam trawl fleet consists of two major segments, namely, large beam trawlers > 24m, see table 3.4, and beam trawlers <= 24 (eurocutters), se table 3.5. Most of the vessels in the eurocutter fleet do not target only flatfish. Many of the vessels are multi-purpose vessels which can switch between flatfish and shrimp, depending on quota, season and catch opportunities.

During the past six years, the eurocutter fleet increased in terms of number of vessels by approximately 20%. The number of vessels in the segment of large beam trawlers decreased significantly by 20%. This is because in the present situation with high fuel prices, it is in general more profitable to fish with less engine power.

Table 3.4.	**Beam trawlers > 24 m, capacity indicators, 1998-2004**						
	1998	1999	2000	2001	2002	2003	2004
Volume of landings (1000t)	68.0	72.0	68.0	64.0	57.9	56.3	44.2
Fleet - number of vessels	163	159	157	150	141	128	131.0
Fleet - total GT (1000)	67	66	67	65	61.1	56.6	57.1
Fleet - total kW (1000)	269	262	260	249	233	212.2	212.1

Source: AER, 2005

Table 3.5.	**Beam trawlers <= 24 m, capacity indicators, 1998-2004**						
	1998	1999	2000	2001	2002	2003	2004
Volume of landings (1000t)	20	18.6	17	18	17	20.3	23.4
Fleet - number of vessels	142	143	159	163	173	173	171
Fleet - total GT (1000)	11	11	12	12	13.6	13.9	13.8
Fleet - total kW (1000)	31	32	35	36	38	37.9	37.0

Source: AER, 2005

3.4.2. Catches

The main target species of the North Sea beam trawl flatfish fishery are plaice and sole, with important by-catches of cod, whiting, dab, turbot and brill, together with a variety of benthic invertebrates and other non-commercial species as unwanted by-catch. The general minimum allowed mesh size for this fishery is 100 mm.

Sole is only caught in the southern North Sea below 55°N. In this area the beam trawl fishery is a mixed fishery for sole and plaice. As a derogation from the general rule, the minimum allowed mesh size below 55°N is 80 mm when fishing for sole because this mesh size corresponds to the minimum landing size of sole of 24 cm. (One is assumed to be fishing for sole if the on board catch is composed of at least 5% of sole and less than 10% of cod, haddock and saithe.) With this mesh size, however, it is inevitable that significant amounts of undersized plaice have to be discarded.

The beam trawl fishery above 55°N is essentially a plaice fishery, as not much sole is found in this area. There, the general minimum mesh size of 100 mm applies. This mesh size is still not in line with the minimum landing size for plaice of 27 cm and, consequently, the plaice fishery also has considerable amounts of undersized plaice discards.

In recent years, fishing effort of the major fleets targeting sole and plaice has decreased. Because of a decreasing TAC for plaice and a relatively stable TAC for sole, fishing effort has concentrated more in the southern part of the North Sea. In addition, because of days-at sea regulations and high fuel prices, fishing effort has shifted to more coastal areas. These changes have caused increasing discards of juvenile plaice during the last few years.

Table 3.6 shows the landings of sole, plaice and cod by the Dutch flatfish fleet. Since 1999, landings of these species have gradually decreased.

Table 3.6. Total landings by species of Dutch flatfish beam trawl fleet (1000t)

	1998	1999	2000	2001	2002	2003	2004
	---------- Beam trawlers > 24m ----------						
Sole	13.3	14.5	13.3	11.9	10.4	10.5	10.5
Plaice	26.6	34.9	32.2	30.2	24.7	24.6	19.7
Cod	5.8	4.3	2.8	1.6	1.8	1.4	0.7
Other	22.7	18.7	20.0	20.6	21.0	19.8	13.3
Total	68.4	72.4	68.3	64.3	57.9	56.3	44.2
	---------- Beam trawlers <= 24m ----------						
Sole	2.2	2.2	2.1	1.8	1.4	1.6	2.5
Plaice	2.7	3.4	2.5	2.1	1.4	1.9	3.1
Cod	4.1	1.3	1.3	0.8	1.6	0.6	0.7
Shrimp	5.3	7.5	6.9	8.7	7.9	11.7	8.3
Other	5.3	4.2	4.1	4.5	4.7	4.5	8.8
Total	19.6	18.6	16.9	17.9	17.0	20.3	23.4
	---------- Total beam trawl fleet ----------						
Sole	15.5	16.7	15.4	13.7	11.8	12.1	13.0
Plaice	29.3	38.3	34.7	32.3	26.1	26.5	22.8
Cod	9.9	5.6	4.1	2.4	3.4	2.0	1.4
Shrimp	5.3	7.5	6.9	8.7	7.9	11.7	8.3
Other	28.0	22.9	24.1	25.1	25.7	24.3	22.1
Total	88.0	91.0	85.2	82.2	74.9	76.6	67.6

Source: AER, 2005

Table 3.7 shows partial fishing mortality rates for plaice and sole in the Dutch beam trawl fleet. The partial fishing mortality (F_{part}) incurred by the Dutch beam trawl fleet has been calculated by multiplying total fishing mortality (F_{tot}) with the ratio of the fleet landings and total landings per species. Because F_{tot} for plaice also includes discards, this figure assumes that the discard rate of plaice in Dutch beam trawl fleet is the same as in other North Sea beam trawl flatfish fleets.

Table 3.7.	Partial fishing mortality of plaice and sole in Dutch beam trawl fleet						
	1999	2000	2001	2002	2003	2004	2005
F_{part} plaice	0.21	0.24	0.30	0.31	0.32	0.21	0.18
F_{part} sole	0.38	0.43	0.42	0.43	0.40	0.26	0.25

3.5. Economic performance

The economic results for large beam trawlers (>24m) have deteriorated during the last seven years, see table 3.8. Gross value added of the large beam trawlers has decreased by 36% since 1998, and net profit has been negative since 2002. Employment decreased by 21% between 1999 and 2004. Fuel costs of the large beam trawlers increased by 47%, while the crew share decreased by 32%.

Table 3.8.	Beam trawlers > 24 m, economic and capacity indicators, 1998-2004						
	1998	1999	2000	2001	2002	2003	2004
	---------------------- Economic indicators (m €) ---------------------						
Value of landings	201	217	213	211	182.4	179.6	165.1
Fuel costs	34	37	66	62	50	49.7	49.9
Other running costs	36	36	36	34	31.2	30.1	26.3
Vessel costs	24	23	23	23	22.1	21.3	20.2
Crew share	57	63	51	53	48	47.2	39.0
Gross cash flow	49	58	37	39	31.1	31.2	29.7
Depreciation	29	28	28	30	27.3	27.1	28.0
Interest	8	7	7	6	5.9	5.8	3.5
Net profit	12	23	2	3	-2.1	-1.7	-1.8
Gross value added	107	121	87	92	79.1	78.4	68.7
	---------------------- Other economic indicators ----------------------						
Employment on board (FTE)	1,138	1,127	1,127	1,049	991	900	900
Invested capital (m €)	350	348	335	307	323	312	310
Effort (1000 days at sea)	31	30	30	29	26	25	24

Source: AER, 2005

For the beam trawlers below 24m there is no clear trend. Gross revenue has increased by 23% from 1998 to 2004 with some variation over time. Net profit and gross value added have followed the same pattern. Investments, employment and effort have all increased from 1998 to 2004, see table 3.9.

Table 3.9. Beam trawlers <= 24 m, economic and capacity indicators, 1998-2003

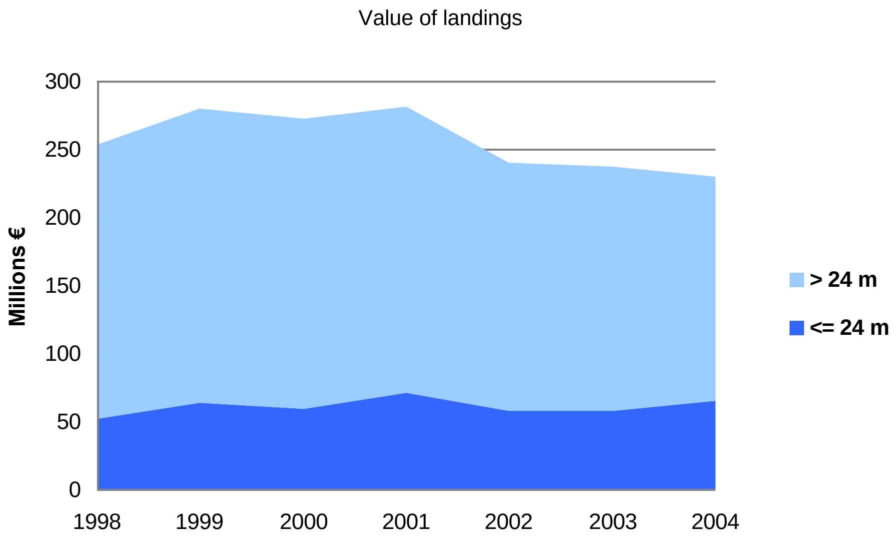
	1998	1999	2000	2001	2002	2003	2004
	-------------------------- Economic indicators (m e) ---------------------						
Value of landings	52	63	59	70	57.8	56.7	64.0
Fuel costs	4	5	10	9	7.8	7.9	9.5
Other running costs	10	10	11	10	10.7	10.7	11.0
Vessel costs	7	8	8	8	7.2	7.3	10.2
Crew share	20	23	21	26	22.5	22	20.9
Gross cash flow	11	17	9	17	9.6	8.8	12.5
Depreciation	6	6	7	8	8.2	8.3	9.7
Interest	2	2	3	2	1.8	1.8	1.3
Net profit	3	9	-1	7	-0.4	-1.3	1.5
Gross value added	31	40	30	43	31.6	30.8	33.3
	------------------------- Other economic indicators ---------------------						
Employment on board (FTE)	476	481	508	519	575	575	570
Invested capital (m €)	80	76	83	81	96.2	96.2	95.1
Effort (1000 days at sea)	20	20	22	23	22.7	22.5	23.0

Source: AER, 2005

The main reasons for the decrease in profitability is the reduction of TAC's for sole and plaice and the increasing fuel costs. Particularly rising fuel prices have had a dramatic effect on the economic results of this fleet because beam trawling is a very energy-intensive fishing method.

The development for the Dutch beam trawl fleet with respect to four important economic indicators appears from figure 3.4 and 3.5.

Figure 3.4. Value of landings and gross value added (1998-2004)



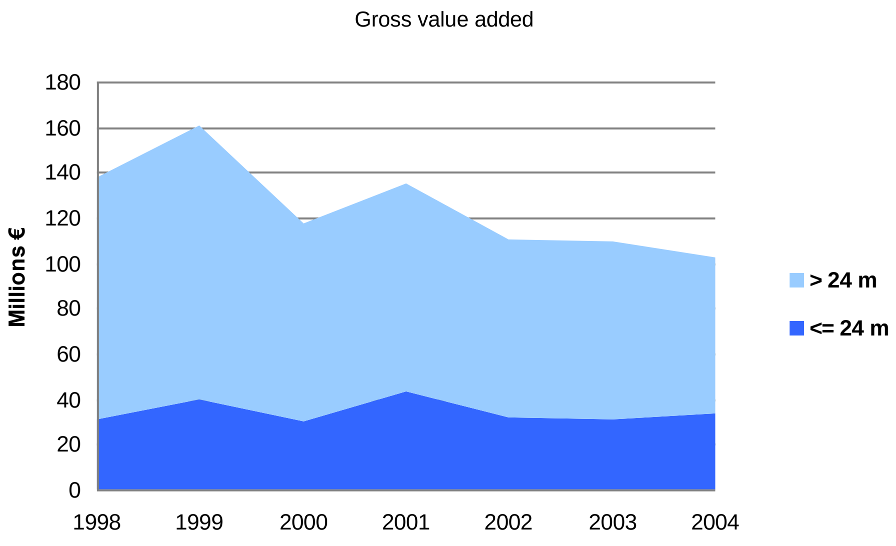
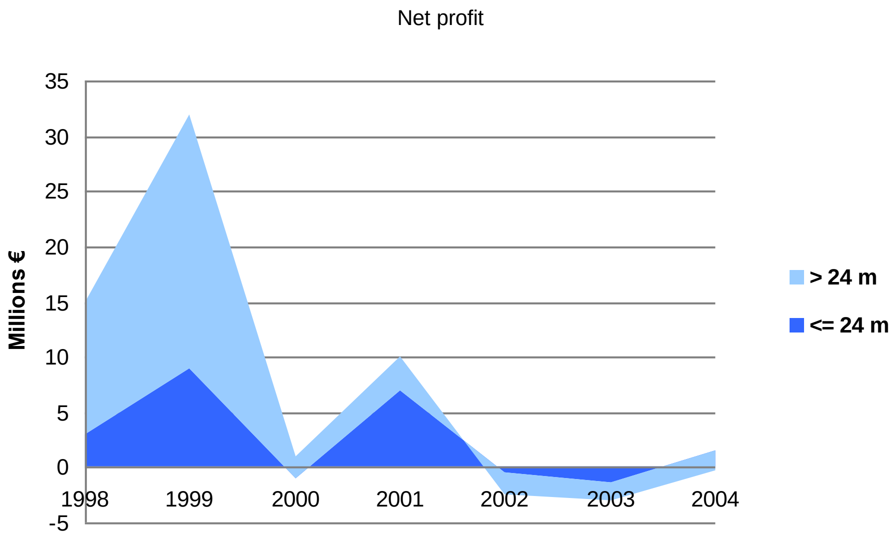
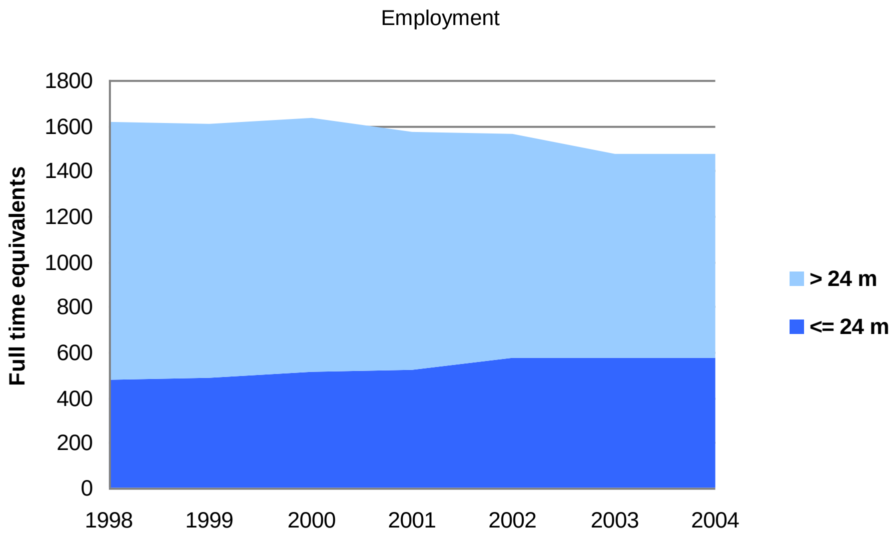


Figure 3.5. Net profit and employment (1998 – 2004)





3.5.1. Prices of species

Table 3.10 presents prices of main species during the last seven years. During this period the price of sole has gradually increased, while the price of plaice remained more or less stable.

Table 3.10. Prices of main species for Dutch beam trawl fleet (€/kg)

Species	1999	2000	2001	2002	2003	2004	2005
Plaice	1.90	1.53	1.70	1.77	1.98	1.78	1.90
Sole	7.22	7.73	8.83	8.88	8.62	8.47	10.07
Cod	1.95	2.06	2.22	2.23	2.18	2.02	2.05
whiting	0.82	0.81	0.79	0.76	0.78	0.98	1.02
Dab	1.19	1.32	1.30	0.99	0.83	0.88	0.80
Turbot and brill	8.85	6.93	7.40	8.36	7.99	7.77	8.30

3.6. Modelling the optimizing behaviour by fishermen under TAC and effort constraints

3.6.1. Introduction

This section investigates the consequences for economic efficiency of managing fisheries through either TAC or effort limitations. In order to address our main hypothesis, a bio-economic simulation model for the North Sea flatfish fishery is used. The core of the economic module of this model consists of Cobb Douglas production functions for sole and plaice, where catches depend on fishing effort and spawning stock biomass. A direct implication of using this type of production function is that catchability varies with the amount of fishing effort. This means that the optimizing behaviour by fishermen is presumed to affect the productivity of fishing effort.

Moreover, optimizing behaviour by fishermen is presumed to be influenced by the particular nature of the management constraint that is applied to the fishery. In short, fishers are presumed, and modelled, as to optimize their fishing activities in a different way when the output (TAC) of the fishery is constrained than when the fishing input (effort) is constrained. This will cause the production function and the level of catchability to vary with the nature of the management constraints applied and thereby raising the question of how economic results of the fishery are influenced by a given management policy. The rest of this section compares the economic consequences of effort and TAC management in the Dutch beam trawl fleet.

3.6.2. The management scenarios

Two management scenarios will be investigated: TAC management and effort management. Both scenario's are based on the present management plan for North Sea plaice and sole[12] which contains both effort and TAC constraints. In the effort management scenario, the TAC restriction of the management plan is disabled so that the fishery is only constrained by the effort restriction. In the TAC scenario, the effort constraint is disabled, so that the fishery is only restricted by the TAC's. The management plan aims at: "reducing the fishing mortality rate on plaice and sole by 10% each year, with a maximum TAC variation of 15% per year until safe biological limits are reached for both stocks". In the second stage, fishing mortality for both species will be kept at a level corresponding to MSY, which is assumed to be 0.3 for plaice and 0.2 for sole.

3.6.2.1. TAC management

The procedure for setting TAC's for sole and plaice has been described in article 7 and 8 of the multi-annual management plan for plaice and sole in the North Sea. Basically, the TAC is set at a level that corresponds to a 10% lower fishing mortality than in the year before, unless the resulting fishing mortality would be smaller than F_{MSY}. In the latter case, the TAC is set at a level that corresponds to F_{MSY}.

Procedure for setting the TAC for plaice and sole

1. The Council shall adopt the TAC for plaice and sole at that level of catches which, according to a scientific evaluation carried out by STECF is the higher of:
   (a) that TAC the application of which will result in a 10% reduction for plaice and sole in the fishing mortality rate in its year of application compared to the fishing mortality rate estimated for the preceding year;
   (b) that TAC the application of which will result in the level of fishing mortality rate of 0.3 on ages two to six years for plaice and 0.2 on ages two to six years for sole in its year of application.
2. Where application of paragraph 1 would result in a TAC which exceeds the TAC of the preceding year by more than 15%, the Council shall adopt a TAC which is 15% greater than the TAC of that year.

[12] Council Regulation (EC) No 676/2007 of 11 June 2007 establishing a multi-annual plan for fisheries exploiting stocks of plaice and sole in the North Sea

3. Where application of paragraph 1 would result in a TAC which is more than 15% less than the TAC of the preceding year, the Council shall adopt a TAC which is 15% less than the TAC of that year.

3.6.2.2. Effort management

The procedure for setting the effort limitation is less straightforward than that for TAC's. Article 9 of the multi-annual management plan requires that the effort limitation of those fleets where either or both plaice and sole comprise(s) an important part of the landings will be annually adjusted to the *maximum* of the effort needed to deplete the TAC for sole and plaice as set according to article 7 and 8. As the Dutch beam trawl fleet clearly belongs to this class of fleets, this effort limitation will be one of two effort management scenarios that we will explore in the simulation model. In the simulation we will ignore the fact that the Commission may deviate from the advice given by STECF. In a second effort scenario we will explore the implications of annual effort limitations to the *minimum* of the effort needed to deplete the TAC for sole and plaice.

Fishing effort limitation as described in the multi-annual management plan:

1. The TAC's referred to in Chapter II shall be complemented by a system of fishing effort limitation established in Community legislation.
2. Each year, the Council shall decide by a qualified majority, on the basis of a proposal from the Commission, on an adjustment to the maximum level of fishing effort available for fleets where either or both plaice and sole comprise an important part of the landings or where substantial discards are made and subject to the system of fishing effort limitation referred to in paragraph 1.
3. The Commission shall request from STECF a forecast of the maximum level of fishing effort necessary to take catches of plaice and sole equal to the European Community's share of the TAC’s established according to Article 6. This request shall be formulated taking account of other relevant Community legislation governing the conditions under which quotas may be fished.
4. The annual adjustment of the maximum level of fishing effort referred to in paragraph 2 shall be made with regard to the opinion of STECF provided according to paragraph 3.

5. The Commission shall each year request the STECF to report on the annual level of fishing effort deployed by vessels catching plaice and sole, and to report on the types of fishing gear used in such fisheries.
6. Notwithstanding paragraph 4, fishing effort shall not increase above the level allocated in 2006.
7. Member States whose quotas are less than 5% of the European Community's share of the TAC's of both plaice and sole shall be exempted from the effort management regime.
8. A Member State concerned by the provisions of paragraph 7 and engaging in any quota exchange of sole or plaice on the basis of Article 20(5) of Regulation (EC) No 2371/2002 that would result in the sum of the quota allocated to that Member State and the quantity of sole or plaice transferred being in excess of 5% of the European Community's share of the TAC shall be subject to the effort management regime.
9. The fishing effort deployed by vessels in which plaice or sole are an important part of the catch and which fly the flag of a Member State concerned by the provisions of paragraph 7 shall not increase above the level authorized in 2006.

3.6.3. Modelling the behaviour of the Dutch beam trawl fleet

The simulation model is, with some adjustments, based on the model developed by IMARES and LEI in the EU project EFIMAS. The model has been extensively described in Oostenbrugge (2008). Here the description will be restricted to the main features of the model.

The IMARES-LEI model has been designed as a short-term, bio-economic, model which can be used to predict adjustments within the existing fleet to different management policies. Possible simulations which can be run include the effects of changes in the number of effective days at sea, adjustments of fishing gear or fishing areas. Effects on investment and disinvestment are beyond the scope of the model.

The model consists of a biological sub-model in which spawning stock biomass (SSB) is calculated on the basis of recruitment, natural mortality and catches in the year before, a management sub-module in which the management decision is simulated on the basis of stock size and a harvest control rule, and an economic sub-model that consists of Cobb-Douglas production functions for sole and plaice, the two target species of the fishery, and cost equations where costs are a function of effort. The economic sub-model uses information on stock size from the biological sub-model and the TAC from the management module and returns information on fishing effort and catches of plaice and sole back into the biological sub-model.

A basic assumption of the economic sub-model is that for every restriction of the fishery, the least efficient fishing trips will be cancelled first. These are the trips with lowest net revenues per unit of the restricted factor in the management scenario concerned. This means that under effort management the trips with lowest net revenues per day at sea will be dropped first while under TAC management the trips with lowest net revenue per unit used of the TAC will be dropped. This optimizing behaviour will cause the coefficients of the production function to differ according to the management regime applied.

At the core of the economic sub-model are the Cobb-Douglas production functions for sole and plaice. An important feature is that the output elasticity of effort (β) is smaller than 1. Catches increase with fishing effort but the rate of increase in catches decreases with increasing effort. This reflects the assumption that if the fishery is restricted, the least efficient trips will be dropped first.

$$H_i = \alpha_i * E^{\beta_i} * B_i \tag{3.1}$$

Where i denotes sole and plaice, H catches, E fishing effort, B spawning stock biomass, and α and β coefficients of the production functions of sole (s) and plaice (p).

As stated, under TAC and effort constraints fishermen will optimize their behaviour differently implying that the coefficients of these functions will differ under different management regimes resulting in different catches per unit of effort and consequently lead to different economic results.

3.6.4. Optimizing behaviour under TAC management

A central assumption in the TAC management scenario is that sole is the main target species that drives the effort of the beam trawl fleet; consequently, plaice catches are derived from the effort that is needed to deplete the fleet's share of the sole TAC (Q). After the TAC has been set according to article 7 and 8 of the management plan, the model calculates the effort needed to deplete the fleet's share of the sole TAC (equation 3.2). This effort is used in the production function for plaice to calculate the plaice catches (equation 3.4). The plaice catches can be lower or higher than the plaice quota. In the latter case, landings L are assumed equal to Q and the over quota catches are assumed to be discarded so that discard D is the difference between catches and landings (equation 3.7). The sole catches and landings are always equal to the fleet's share Q of the TAC (equation 3.3).

(3.2) $$E = \left(\frac{Q_s}{\alpha * B_s} \right)^{1/\beta_s}$$

(3.3) $$H_s = \alpha_s * E^{\beta_s} * B_s$$

(3.4) $$H_p = \alpha_p * E^{\beta_p} * B_p$$

(3.5) $$L_p = H_p \text{ if } H_p \leq Q_p$$

(3.6) $$L_p = Q_p \text{ if } H_p \geq Q_p$$

(3.7) $$D_p = H_p - L_p$$

3.6.5. Optimizing behaviour under effort management

In the case of effort management, the effort restriction is set by the management authorities. The procedure for determining the total allowed catch for sole and plaice is the same as in the TAC scenario. In this case, however, the TAC is not imposed on the fishery, but the authorities calculate the effort that would be needed to deplete the Dutch share of the plaice and sole TAC and, based on that calculation, impose an effort restriction. Here it is assumed that the management authorities know the coefficients of the production functions for sole and plaice. Catches of plaice and sole are subsequently calculated by inserting the effort restriction in the production functions under the implicit assumption that the fleet deploys the total allowed effort[13].

Two effort management scenarios are considered by applying (3.8-3.13). The "maximum effort" scenario follows the effort limitation procedure of the flatfish management plan. In this scenario, the effort constraint is annually adjusted to the *maximum*

[13] If this would not be the case, then the management restriction would not be binding and the management regime would have no influence on economic results.

of the effort needed to deplete the TAC for either sole or plaice (equation 8). In the *maximum* scenario one of the species will be overexploited each year. In the “minimum effort” scenario, the effort constraint is set at the *minimum* of the effort needed to deplete the TAC for either sole or plaice (equation 3.9). Consequently, in the *minimum* scenario one of the stocks will be underexploited each year.

(3.8) $$E = MAX\left(\left(\frac{Q_s}{\alpha * B_s}\right)^{1/\beta_s}, \left(\frac{Q_p}{\alpha * B_p}\right)^{1/\beta_p}\right)$$

(3.9) $$E = MIN\left(\left(\frac{Q_s}{\alpha * B_s}\right)^{1/\beta_s}, \left(\frac{Q_p}{\alpha * B_p}\right)^{1/\beta_p}\right)$$

(3.10) $$H_s = \alpha_s * E^{\beta_s} * B_s$$

(3.11) $$H_p = \alpha_p * E^{\beta_p} * B_p$$

(3.12) $$L_p = H_p$$

(3.13) $$L_s = H_s$$

Catches and landings of both plaice and sole may be higher or lower than the Dutch share of the TAC that would have been imposed in the TAC management scenario, depending on which of the TAC’s requires the most effort to be depleted. Catches of both species are equal to landings as there is no reason to discard marketable fish.

3.6.6. Calculation of prices, costs and revenues

Prices costs and revenues are calculated similarly in both scenarios by equations 3.14-3.21.

(3.14) $$P_i = P_i^0 * \left(\frac{L_i}{L_i^0}\right)^{e_i}$$

(3.15) $$R_O = R_O^0 * \left(\frac{E}{E^0}\right)$$

(3.16) $$R_T = \sum (L_i * P_i) + R_O$$

(3.17) $$C_F = C_F^0$$

(3.18) $$C_v = C_v^0 \frac{E}{E^O}$$

(3.19) $$C_T = C_F + C_V$$

(3.20) $$R_N = R_T - C_V$$

(3.21) $$\Pi = R_T - C_T$$

e : price flexibility; for sole e_s = -0.3; for plaice e_p = 0
P: price of species
P^0: price of species in base year
L: Landings of species
R_T: Total revenue
R_O: Other revenue
R_N: Net revenues
C_T: Total costs
C_V: Variable costs
C_F: Fixed costs
Π: Net profit

3.7. Simulation Results

3.7.1. Development in indicators over time

Three management scenarios are tested, two scenarios in which allowed effort is restricted and one in which the total allowable catch (TAC) is restricted. These scenarios are described in section 3.6. In section 3.7.2 the modeling results are discussed. The hypothesis is that effort management will result in better economic performance than TAC management.

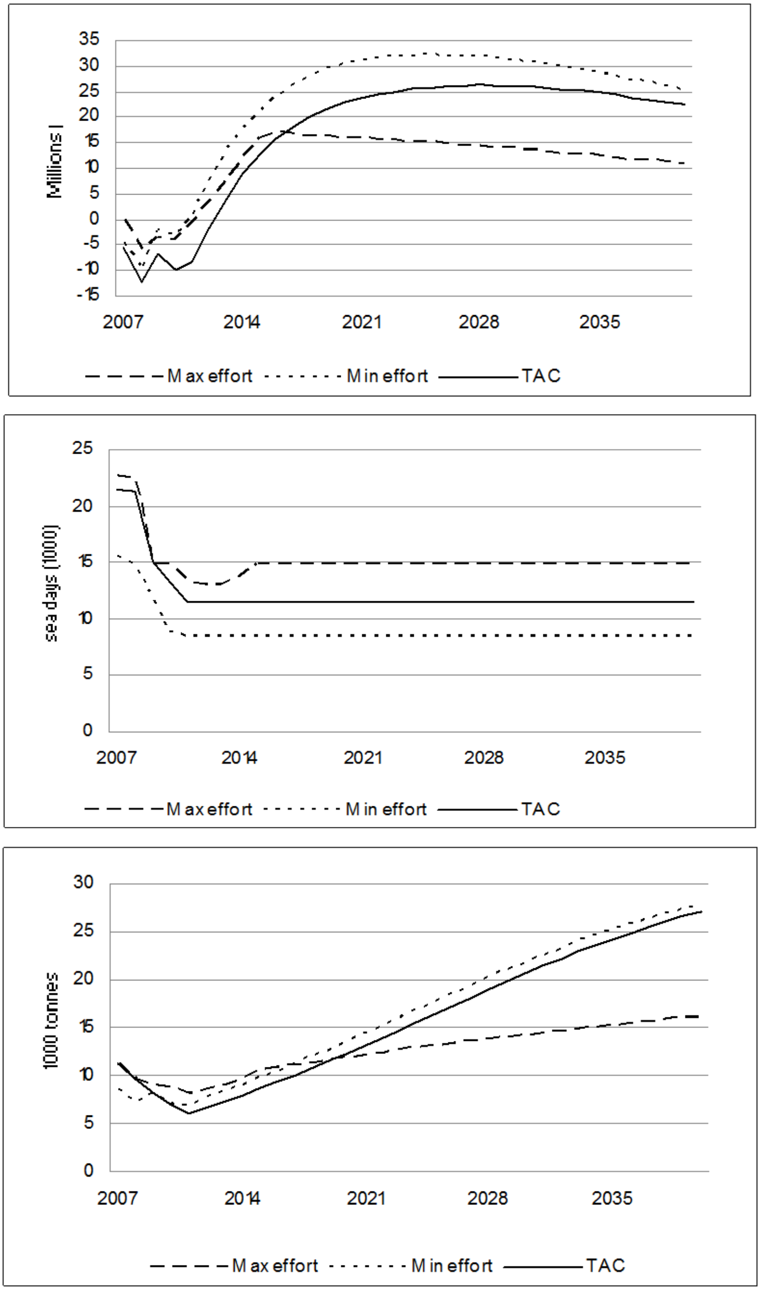
Figure 3.6 shows the development of net profits in the three scenarios. In the first year, these are lower for the minimum effort scenario than for the TAC scenario due to lower landings. The maximum effort scenario shows higher profits in the first years due to higher effort and higher landings of plaice and sole. This scenario, in a sense, "pays" for the initially higher profits through a decrease in the spawning stock biomass (SSB) which eventually leads to lower landings and thereby profits. The maximum effort scenario has the highest effort over the whole simulation period because SSB of sole and plaice doesn't rise as much as in the other two scenarios.

In direct contrast, the minimum effort scenario shows higher profits because it "invests" in SSB by initially reducing effort. The investment pays off with higher landings and profits in the future.

Results for TAC scenario follow a middle path between the maximum and minimum scenarios and, consequently, profits are between the two other scenarios.

The development of gross cash flow and gross value added, for all three scenarios, follows the same pattern as net profits. In the long term, catchability of both sole and plaice is highest in the minimum effort scenario, followed by the maximum effort scenario and the TAC scenario. This is caused by the combined effect of development of SSB and the difference in the production functions in the TAC and effort scenarios.

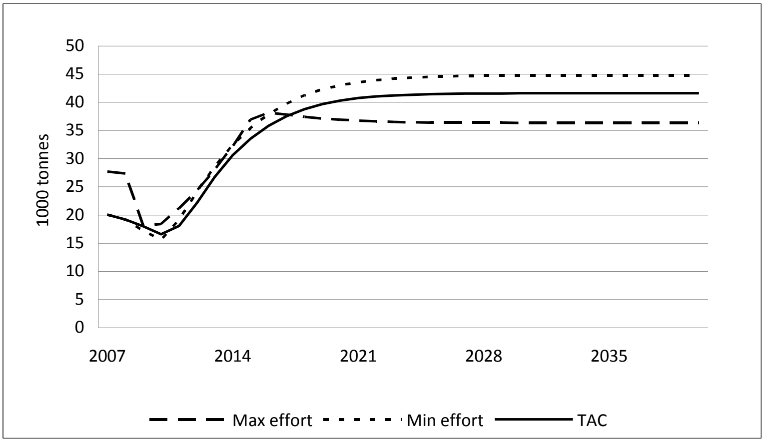
Figure 3.6. Development in indicators 2007-2040



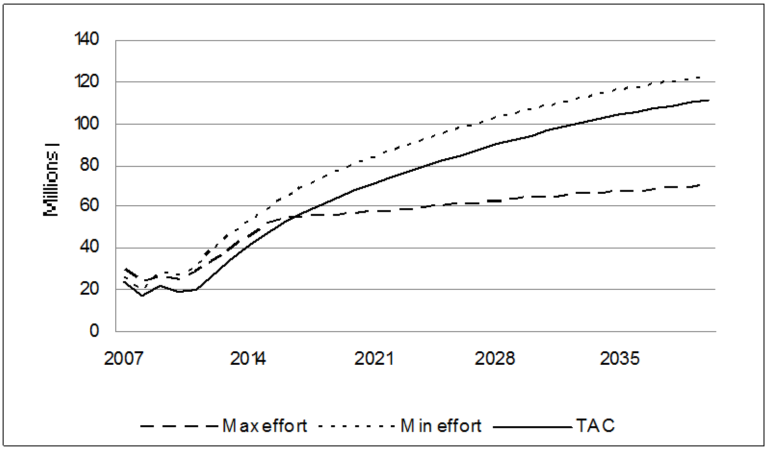
Net profit

Effort

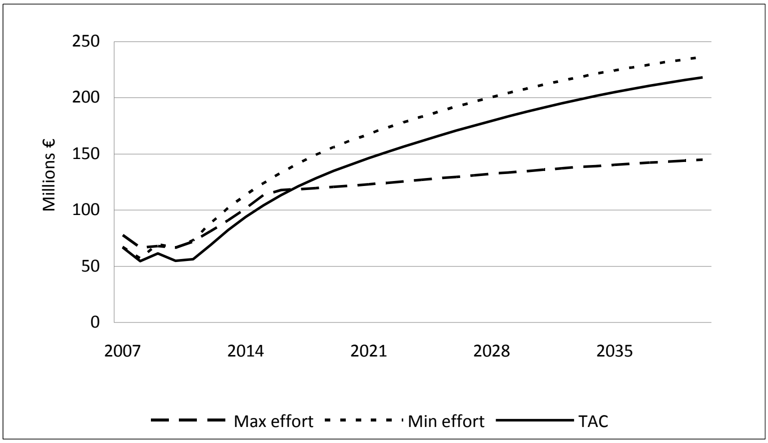
Landings of sole



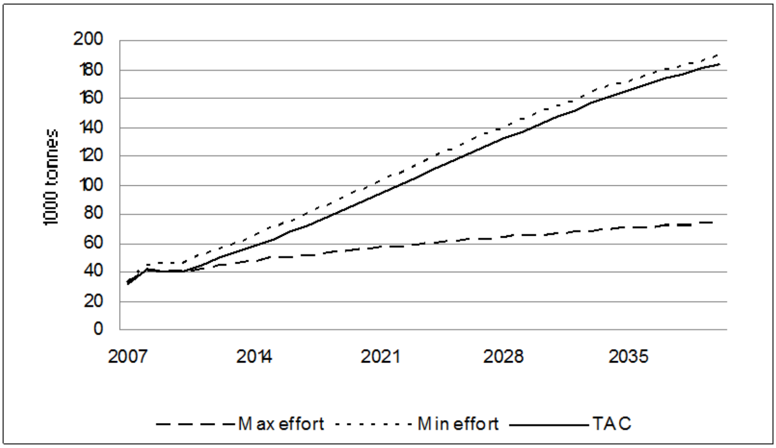
Landings of plaice



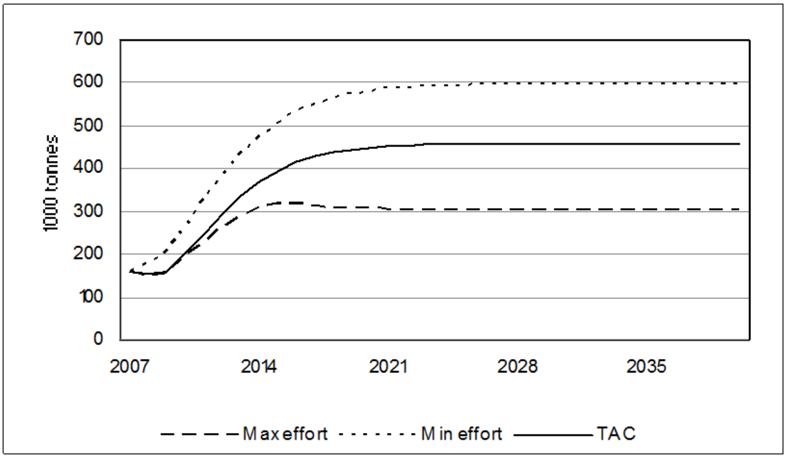
Gross cash flow



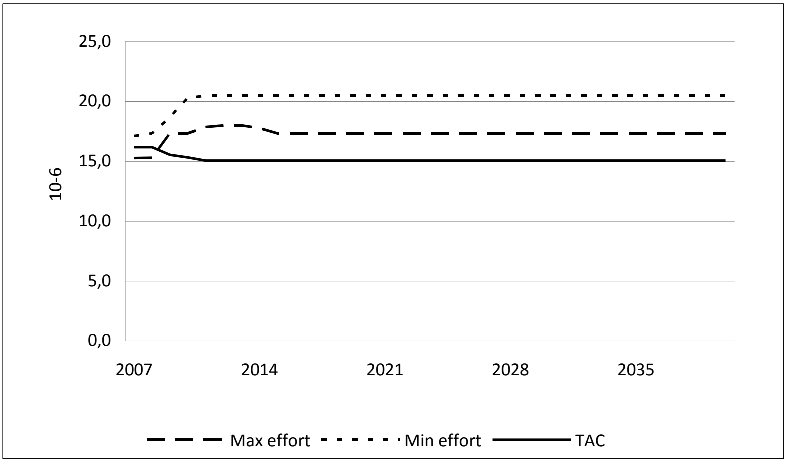
Gross value added



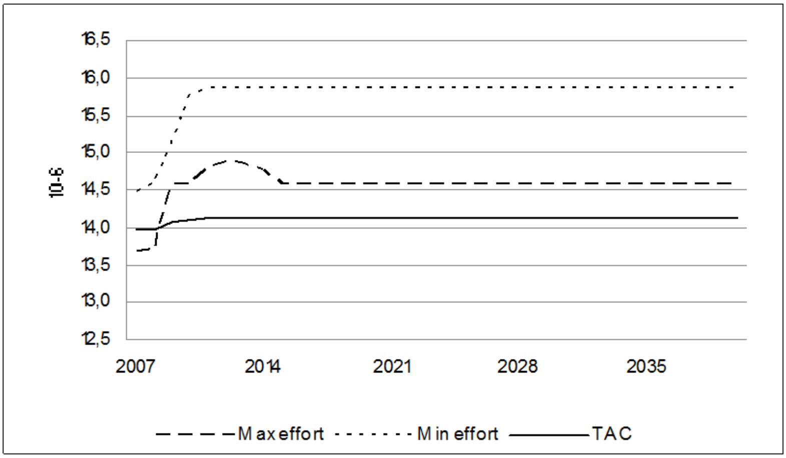
Spawning stock biomass of sole



Spawning stock biomass of plaice



Catch-ability of sole



Catch-
ability
of plaice

3.7.2. Results in terms of Net Present Value

In this section the economic results in terms of net present value (NPV) are discussed. Using a discount rate of 4%, the NPV over the years 2007 – 2037 is € 484 millions for the TAC scenario, € 671 millions for the minimum effort scenario and € 328 millions for the maximum effort scenario. From this we may conclude that over the whole simulation period the minimum effort scenario performs better than the TAC scenario followed by the maximum effort scenario. However, the single value result of an NPV hides the variation that occurs between scenarios over the simulation years. Table 3.10 shows that all three scenarios have negative NPV in the first few years and positive NPV after twenty years or longer. This is not surprising because net profit in the base year (2006) is also negative. The effort minimum scenario is the first to move to a positive value while the TAC is the last. All scenarios remain positive over the remainder of the simulation.

The colors in table 3.11 mark the relative ranking of the scenarios in terms of NPV over several periods, green, yellow and red for first, second and third rank respectively. During the first three years the maximum effort scenario shows better results than the other two scenarios. After seven years the NPV of the minimum effort scenario has the highest relative rank, followed by the effort maximum and TAC scenarios. After thirty years, the effort maximum moves from second to third rank.

Table 3.11. Comparison of NPV (millions €) in the three scenarios						
Scenario	One Year	Three Years	Seven Years	Ten Years	Twenty Years	Thirty Years
Effort Minimum:	-4.524	-16.376	1.101	63.779	368.443	670.730
TAC:	-5.795	-24.958	-41.610	-4.698	228.158	483.906
Effort Maximum:	-.064	-9.598	-4.316	40.157	196.297	329.204

3.8. Conclusion

Whether effort management results in better economic performance than TAC management, depends on how the effort restriction is set. While the effort maximum scenario shows relative good results in the short run, it shows worse economic performance than the TAC scenario in the long run. However, both in the short run and in the long run, the more cautious effort minimum scenario shows better economic results than the TAC scenario.

4. Economic consequences of marine protected areas in the Baltic Sea

4.1. Description of the fishery

This case study considers the cod fishery in the Baltic Sea. Two populations of cod inhabit the Baltic area, eastern and western cod, with different *morphometric* conditions and population genetics (WWF, 2006). The stocks, of which the eastern is the biggest and constitute around 90% of the total resource, with the eastern stock found in the eastern and northern part of the Baltic Sea, and the western stock found west of Bornholm island and in the Danish Straits. The eastern stock is fished by Denmark, Sweden, Poland, Russia, Lithuania, Latvia and Estonia while the western stock is mainly taken by Denmark, Germany and Sweden. The eastern stock has by ICES been classified to be outside safe biological limits, and to be harvested unsustainably at present. The western stock is at present around the precautionary limit. The case study will consider closed areas and seasons for cod fisheries as an innovation aimed at improving the management of the cod stocks. The following hypothesis will thus be tested for this case study:

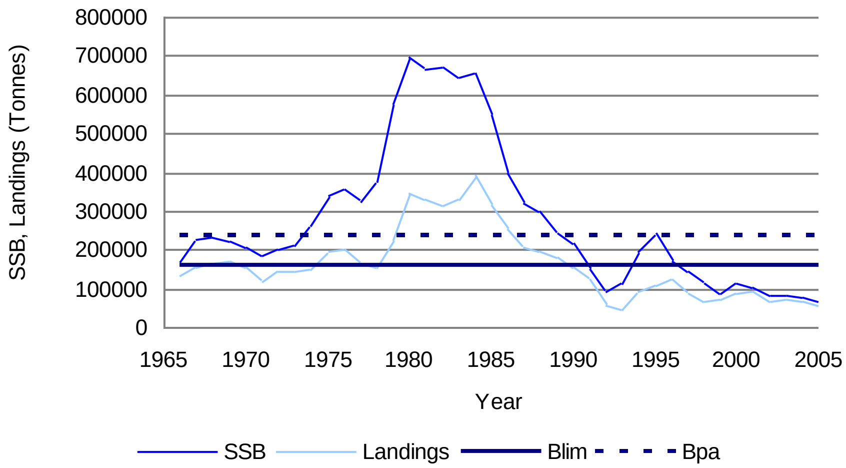
Technical measures and Marine Protected Areas (MPA's) are likely to reduce economic efficiency.

4.1.1. State of the stocks

4.1.1.1. Eastern cod (ICES area 25-32)

The eastern cod is mainly fished by demersal and pelagic trawls, and gillnets (ICES, 2007). Figure 4.1 shows the development in Spawning Stock Biomass (SSB) and landings since 1965. The figure shows how the stock was exploited heavily during the 1970's and especially through the 1980's, followed by a steep decline in landings as well as SSB in the 1990's and later. The SSB has been below precautionary SSB (240 000 tonnes) as well as the lowest limit SSB (160 000 tonnes) since 1997, and is as such at present at risk of reduced reproductive capacity.

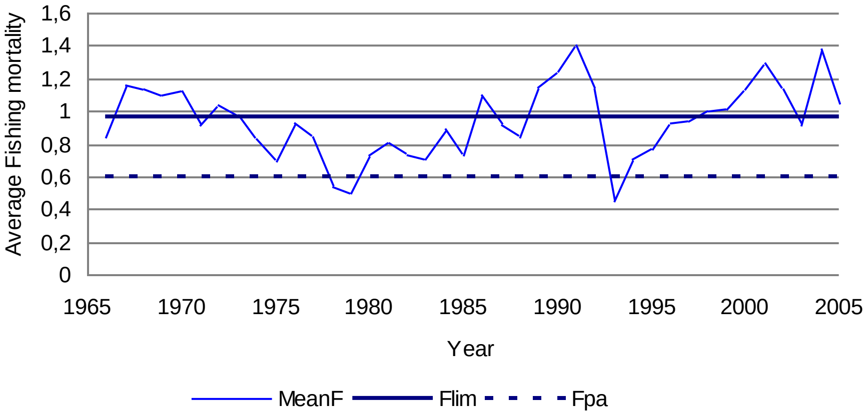
Figure 4.1. Cod in the eastern Baltic (Area 25-32): Spawning stock biomass and landings



Source: ICES (2007)

Figure 4.2 shows the development in fishing mortality for eastern Baltic cod. The figure shows that the fishing mortality has not experienced a significant decrease during the last 10 years even though the there have been large fluctuations. This in spite of that the size (measured in kW) of the Danish and the Swedish fleets fishing in the Baltic have decreased by about 25% since 1995 (WWF, 2006). It is seen that the fishing mortality is well beyond the precautionary limit of F_{pa}=0.6, and since 1998 also have been above F_{lim}=0.96 almost all the time. Based on these observations, ICES has pointed out that the present management plan for eastern Baltic cod has a number of weaknesses and is difficult to implement. ICES and STECF recommends that the stock fishing mortality should be reduced significantly to ensure high yields and low risk to the stock. Based on this advice the EU commission suggests a revised long term management plan for eastern cod including stepwise reduction of fishing effort over a number of years (EU, 2006).

Figure 4.2. Cod in the eastern Baltic (Area 25-32): Average fishing mortality



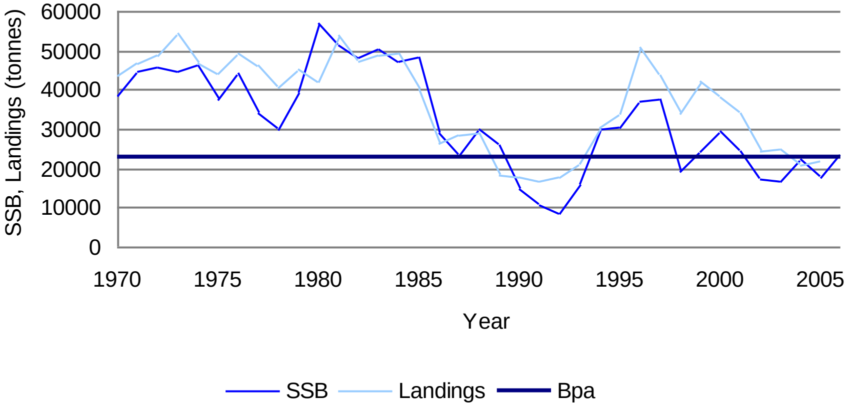
Source: ICES (2007)

4.1.1.2. Western Cod (ICES area 22-24)

The western Baltic cod is fished mainly by Denmark, Sweden and Germany using trawl and gillnet. In most of the Sound (area 23) there is a ban on trawl. Figure 4.3 shows the development in SSB and landings for western Baltic cod since 1970[14]. The figure shows that the stock and landings approximately follow the same pattern with high values until around 1985 where a steep decline in stock is followed by a similar decline in catches, while some recovery of both is seen around the mid 90s. Towards 2005 the stock however declines to below B_{pa}.

[14] Blim, Fpa and Flim have not yet been defined by ICES for western Baltic cod (EC, 2007).

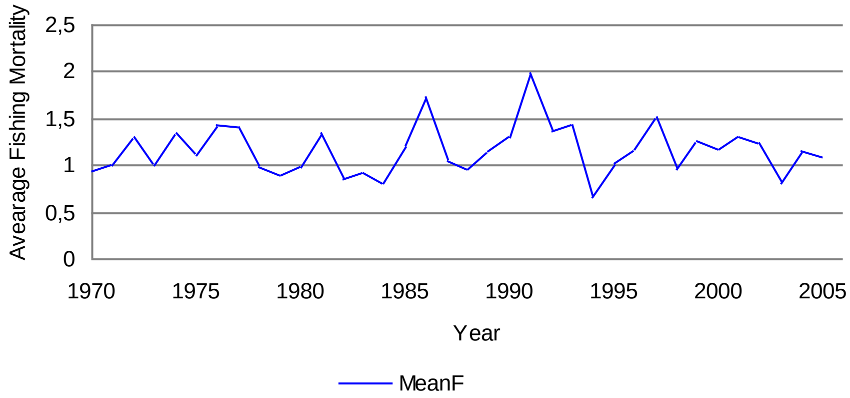
Figure 4.3. Cod in the western Baltic (Area 22-24): Spawning stock biomass and landings



Source: ICES (2007)

Figure 4.4 shows the development in average fishing mortality for the western Baltic cod. The figure shows that the fishing mortality fluctuates around a mean value at around 1.2 during the entire period. ICES has not set any precautionary limits for fishing mortality, as estimation of F_{pa} is problematic due to the large exchange of cod with adjacent stocks. Regarding the sustainability of the western Baltic cod stock, which at present is just below B_{pa}, the situation is at present difficult to assess. ICES states that the exploitation of the stock to a high degree depends on the strength of the incoming year-classes (ICES, 2007). There is at present no agreed management plan for the stock, but ICES has recommended a target fishing mortality rates at 0.3-0.6, which would result in low risk to reproduction and high long-term yields.

Figure 4.4. Cod in the western Baltic (Area 22-24), average fishing mortality



Source: ICES (2007)

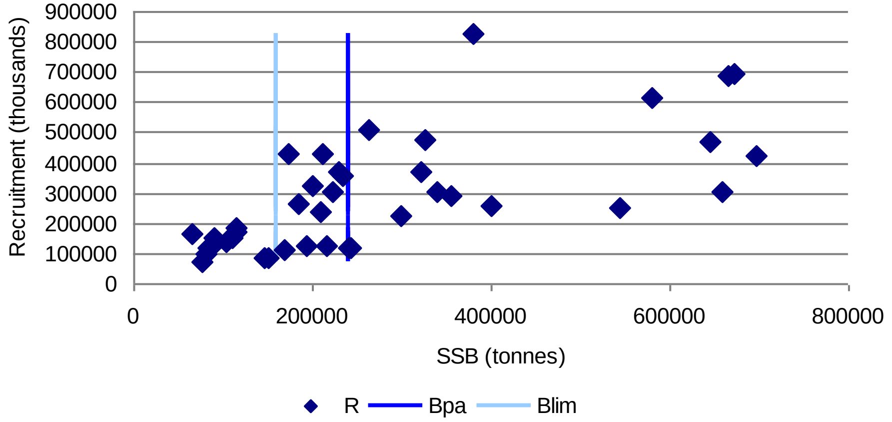
4.1.1.3. Eastern and Western Baltic Cod

ICES recommends separate management areas for the western and the eastern cod, subdivision 22-24 and subdivision 25-32 respectively. The stocks overlap in subdivision 24 and 25, in which landings can not be assigned to the one or the other stock. Biological reference points differ significantly for the two stocks illustrating estimated differences in the reproductivity. Seeing these differences and the differences outlined above, STECF recommends further studies on the interplay between the two stocks, as this may improve management considerations (EC, 2007).

4.1.2. Stock – recruitment relationships

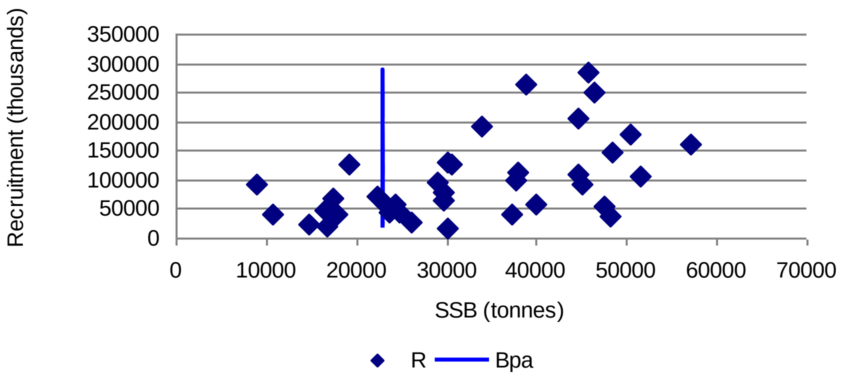
Figure 4.5 and 4.6 shows the stock recruitment relationships for eastern and western Baltic cod. For the eastern stock figure 4.5 indicates that there is a significantly positive relationship between spawning stock biomass (SSB) and recruitment for $SSB > B_{lim}$. For $SSB < B_{lim}$ the recruitment seems be rather uncertain, and generally below 200 millions individuals a year. This uncertainty coupled with the fact that SSB for the eastern cod stock has been below B_{lim} since around 1997 emphasises the fact that the eastern stock is outside safe biological limits.

Figure 4.5. Spawning stock (SSB) – recruitment relationship for eastern Baltic cod (area 25-32)



Source: ICES (2007)

Figure 4.6. Spawning Stock (SSB) – Recruitment relationship for Western Baltic cod (area 22-24)



Source: ICES (2007)

For the western stock in figure 4.6 indicates a positive stock-recruitment relationship for $SSB > B_{pa}$. Below B_{pa} there seems to be no clear relationship between stock and recruitment, which can vary from almost no recruitment to around 150 millions individuals a year.

4.1.3. Management regime

4.1.3.1. General management for the Baltic Sea

The Baltic Sea fishery has until 2006 been managed by the International Baltic Sea Fishery Commission (IBSFC), established in 1973 with contracting parties: Denmark, Sweden, Germany, Finland, Estonia, Latvia, Lithuania, Poland and the Russian Federation. The contracting parties shared the responsibility for protecting and making rational use of the living marine resources in the Baltic Sea. It has been the responsibility of IBSFC to co-ordinate the management in the Baltic Sea and Belts and to submit advice for management based on scientific research. The regulation measures put into force by IBSFC comprised:

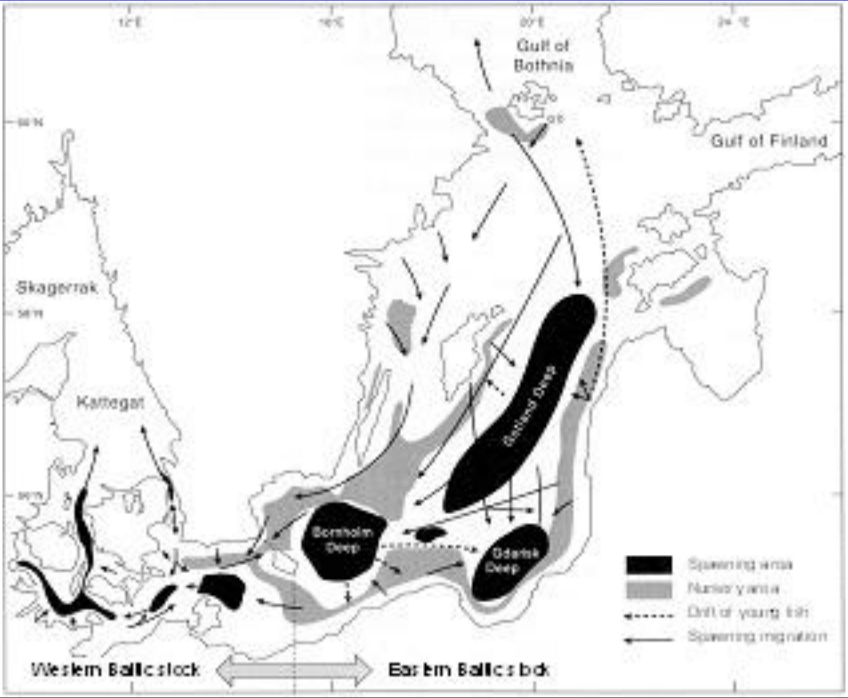
- Total allowable catches (TAC's) for the four main commercially explored species in the Baltic Sea: Cod, sprat, herring and salmon.
- Technical regulation measures, including minimum landings sizes, restrictions on engine size and gear, panels in demersal trawl targeting cod, and closed areas and seasons.
- Strengthen enforcement and control through increased exchange of information between the contracting parties.
- Adoption of long term management plans.

The IBFSC ceased to exist on 1. January 2007, and the EU has not been a member since 1. January 2006. This happened after the inclusion in the EU of Poland, Lithuania, Latvia, and Estonia May 1. 2004. This left only Kaliningrad (Russia) outside the countries fishing in the Baltic Sea. The Russian EEZ constitutes only 5.8% of the Baltic Sea.

Thus, until 2006 the Baltic cod stocks have been managed through a combination of TAC's and technical measures, including seasonally closed areas, aiming at protecting the stocks when spawning and avoiding fishing when the quality and the prices were low. The extend of the closed areas and the seasons in which they have been closed have varied from year to year. In the mid 1990's two closures were introduced, (i) a summer ban on targeting cod from 15. April to 31. August (with some variation of dates during the years, and (ii) a closure of all fisheries in the Bornholm Basin (see figure 4.7) from 15. May to 31. August (Council reg. 3362/94).

Seeing that the cod stock did not recover in spite of the closed areas and seasons, more extended closures were introduced in 2005 by the EU (not binding for Russia). The main aim of the closures were to reduce the overall fishing mortality for cod in the Baltic, but also to some extend to protect the stock when spawning. The closures included (i) an extended summer ban on fishing cod in the eastern Baltic Sea from 1. May to 15. September, (ii) a spring ban on cod fishing in the western Baltic Sea from 1. March to 30. April, and (iii) cod fishing prohibited for the EU fleet all year round in the Bornholm Deep, the Gotland Deep and the Gdansk Deep (see figure 4.7). In 2006 however the three areas were only closed in the spawning season from 1. May to 31. October due to new EU regulations.

Figure 4.7. The Bornholm Deep, The Gotland Deep and The Gdansk Deep in the Baltic Sea.



Source: Aro 2000, redrawn after Bagge, et al. 1994

The IBFSC managed the eastern and western cod stocks as one unit, covering subdivisions 22-35 (22-24 west; 25-35 east), while ICES considers the eastern and western cod as separate units and thus gives advice separately for the two stocks, stressing that this division of management is important in order to adapt the exploitation to the very different developments of the two stocks. Up until 2006 the advice for Baltic cod set by ICES has by far been exceeded by the actual TAC's set by the IBSFC and later by the EU Commission (WWF, 2006), the reasons being to take into consideration the short-term economic and socioeconomic interests of the fishing sector. Attempts have been made to close down the cod fishery with the EU as the driving force. However, before the enlargement of the EU in the Baltic region these proposals were objected by Poland and Russia, and did not come into force. Game theoretical considerations advice such actions as the player(s) that do not seek an agreement will gain at the expense of the players who keep agreements (Kronbak, 2005; Kronbak and Lindros 2007; Nielsen 2006), which may be seen as one of the explanations for the management failures.

It is thus clear from the continuously falling stocks of especially the eastern Baltic cod that the management measures used so far for Baltic cod have not been sufficient to ensure sustainability. It has thus been concluded that the IBFSC management plans cannot be implemented and enforced to a satisfactory level, and therefore the EU Commission forwarded a proposal in July 2006 for a multi-annual management plan (EC, 2006), aiming at reducing the exploitation of Baltic cod gradually towards long-term sustainable levels, while at the same time ensuring that the reduced effort hereby introduced would be acceptable to the fishing industry.

The means for achieving this target is two-fold. Firstly, an annual decrease of 10% in fishing mortality is proposed until the stocks have reached levels that with high probability ensure sustainability. Secondly, various technical measures are maintained especially the closed areas and seasons (EC, 2006). As such it is prohibited to target cod in the western Baltic Sea from 15. March to 14. May, and in the eastern Baltic Sea from 15 June to 14 September. Moreover it is prohibited to perform any fishing in the three areas shown in figure 4.7 from 1.May to 31.October.

4.1.3.2. Management of the Danish fleet

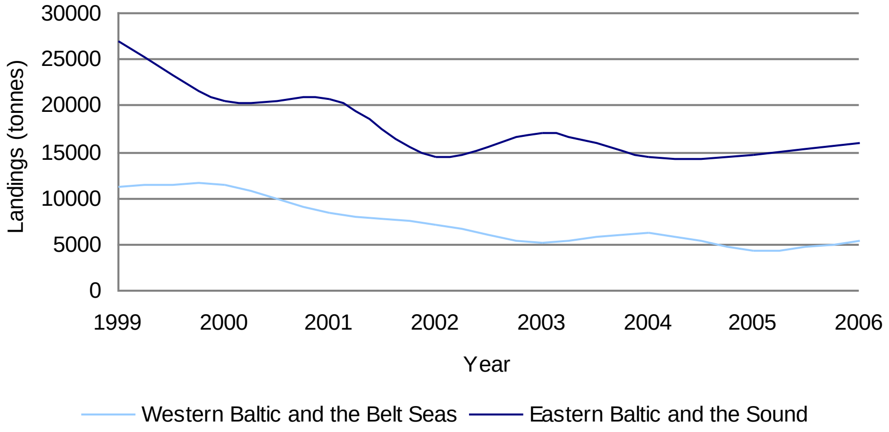
Until 2007 the Danish fishery for cod in the Baltic Sea was regulated through rations or yearly quotas (individual non transferable time limited quotas). The Danish management must be considered very restrictive, as all vessels could apply for a cod quota, but if a quota was granted it was prohibited to fish for cod in any other area, which entailed that the fishermen would have to take their opportunity costs into consideration, see Frost and Jensen (2003). When choosing ration regulation, a vessel was given cod rations in the Baltic on a half- or full-monthly basis, the amount of which depended on the length of the vessel. When a ration was fished up, the vessel was not allowed to fish more cod before the next ration period. Alternatively a vessel could choose to be allocated a yearly quota, based on its historical landings. The individual vessel owners choice between rations or yearly quotas would depend on an assessment of which would give the highest earnings during a year.

In 2007 the Danish regulation (including the regulation for cod in the Baltic Sea) was changed to individual yearly vessel shares of the Danish quotas. The shares are distributed according to the vessels historical catches for three years with most weight put on the catch the previous year. The shares are tied up to the specific vessel and can only be traded with the vessel. Vessel shares can however be exchanged between vessels according to a set of specific rules, or can be put together to form pool fishery. The Danish fleet is, like the other nations fishing in the Baltic Sea, also subject to the long-term recovery plan for cod in the Baltic described above. The yearly vessel quotas will be based on the actual TAC advice following the recovery rule.

4.1.4. The Danish Fleet fishing in the Baltic Sea

In the Danish fishing fleet, trawlers, Danish seine, and netters and liners land cod in the eastern and western Baltic. In 2006 the catch of cod in the Baltic Sea and the belts constituted around 72% of the total Danish catch of cod from all fishing grounds. Figure 4.8 shows the Danish landings of cod in the Baltic areas in the period 1999-2006. It is seen that the cod catches in especially the eastern Baltic Sea drop during the period 1999-2002, corresponding to the decline in stock during the same period (figure 4.1). In the western Baltic Sea the catches also declined to some degree during the period 1999-2003.

Figure 4.8. Danish cod landings in the Baltic in the period 1999-2006.

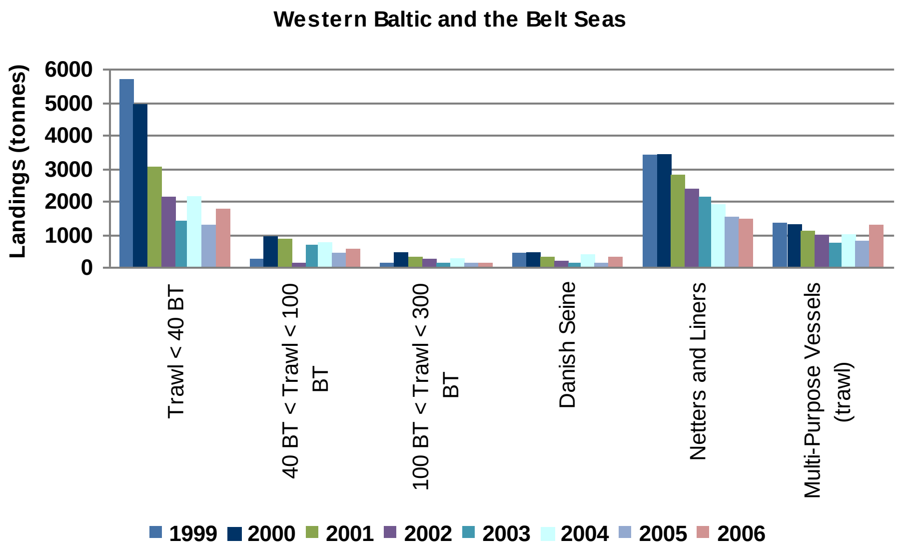


Source: Danish Directorate of Fisheries, Year Book of Fisheries Statistics, 1999-2006.

Figures 4.9 and 4.10 show the landings in the Baltic areas distributed on vessel types during the period 1999-2006. In the western Baltic the cod landings for especially trawlers < 40 GT (< 18m) [15] and for netters and liners fall significantly during the period and it is thus these two segments that represent the overall decline in cod landings shown in figure 4.8. In the eastern Baltic the landings of cod have shown an overall decrease from 1999 to 2006 for trawlers < 40 GT, trawlers between 40 and 100 GT (18m – 26m), and for netters and liners. It is as such these segments that carry the decline in total Danish cod catches in the eastern Baltic Sea during the period. It is however interesting to notice that even though the trawlers < 40 GT have an overall decrease in cod landings during the period, there has actually been a slight increase in cod catches from 2002 and forward, in accordance with that the total cod landings level out from 2003 (cf. figure 4.8).

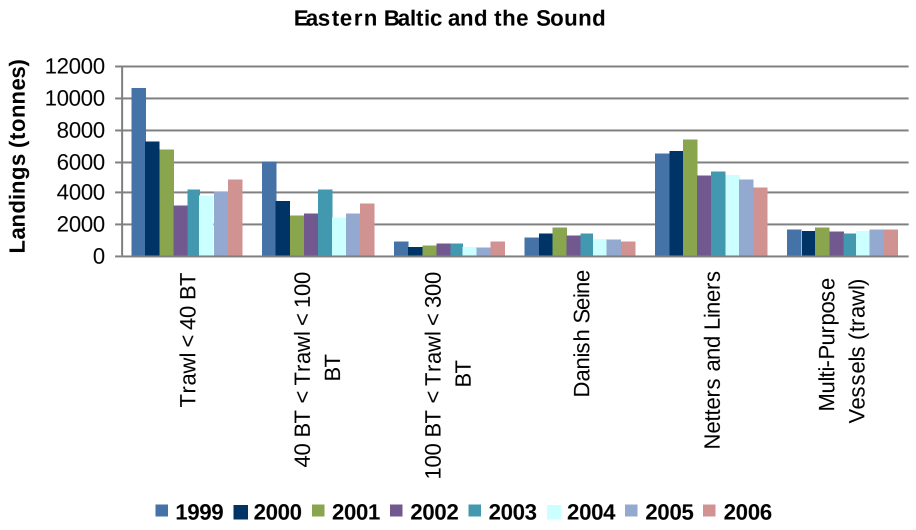
[15] Analysis of the Danish fishing fleet has shown that the relationship between Length Overall (LOA) and Gross Tonnage (GT) follows the relationship: $\ln(GT) = -3.31 + 2.41 * \ln(LOA)$

Figure 4.9. Cod landings distributed on vessel groups in the western Baltic Sea and the Belts during the period 1999-2006



Source: Danish Directorate of Fisheries, Year Book of Fisheries Statistics, 1999-2006.

Figure 4.10. Cod in the eastern Baltic (Area 25-32): Average fishing mortality

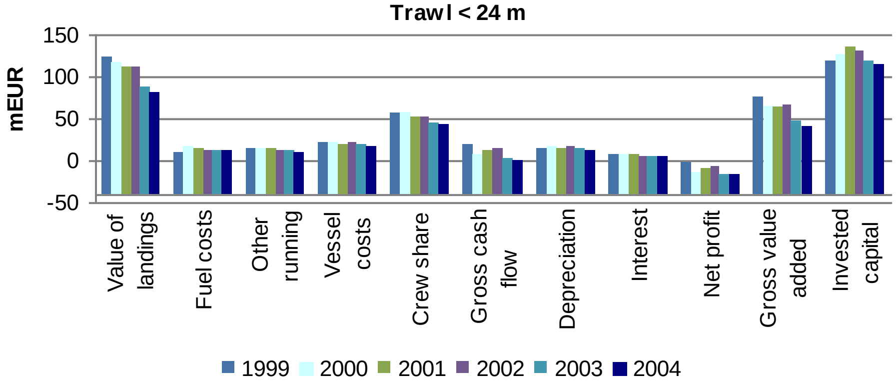


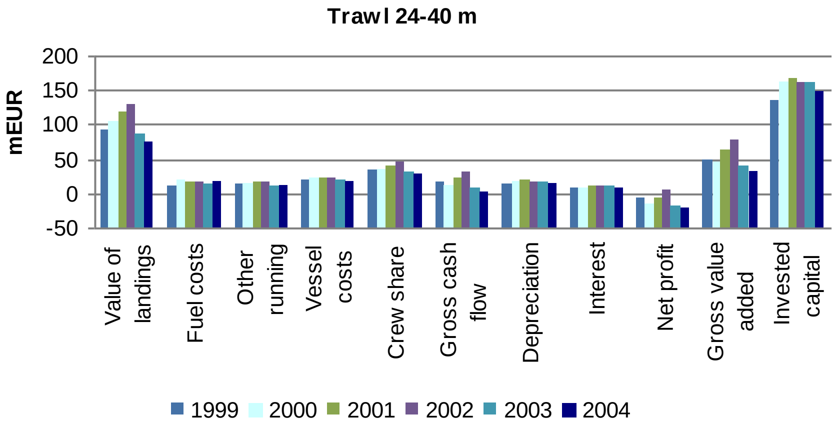
Source: Danish Directorate of Fisheries, Year Book of Fisheries Statistics, 1999-2006.

4.1.5. Economic Performance

The Danish vessels fishing for cod in the Baltic Sea comes from most of the Danish fishing ports, however, mainly from the ports in the Baltic Sea. A description of the economic performance of the full segments of trawlers, Danish seine, netters and liners, and purse seiners will thus be given, as this approximately reflect the economic performance of the specific vessels fishing cod in the Baltic. Data of economic performance is taken from AER (2005). Due to the restructuring of the data collection in connection with the Data Collection Regulation (DCR) (Commission reg.1639/2001), economic data can at present only be shown until 2004. Figure 4.11 and 4.12 thus shows the development in selected economic indicators for the Danish fleet segments, as defined by AER, during the period 1999-2004. Figure 4.11 shows the development of a number of economic indicators (corresponding to the indicators used in AER, 2005) for the Danish trawl fleet.

Figure 4.11. Economic indicators for the Danish trawl fleet 1999-2004

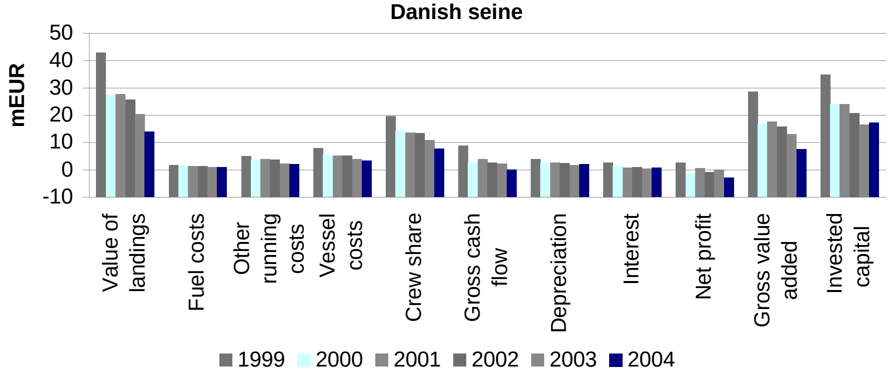


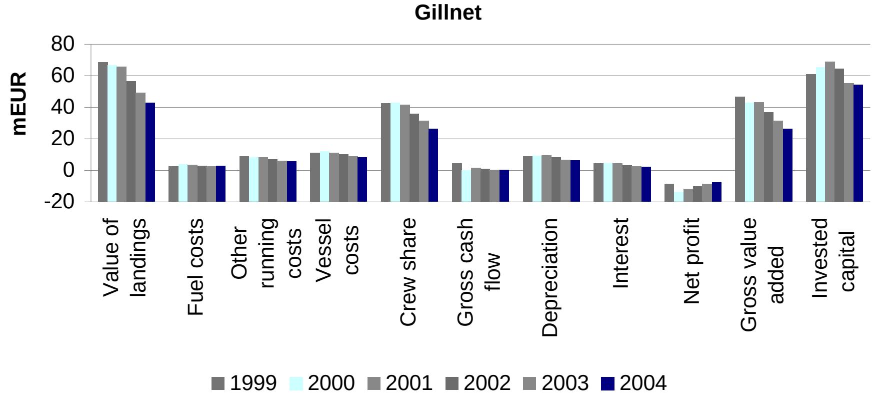


Source: AER, 2005.

Figure 4.12 shows the indicators for Danish seine and gillnet. The figures firstly show that the gross value added decrease during the entire period for trawlers smaller than 24m (around 100 GT), Danish seine and gillnet. In all three cases this seems to be caused by a steady decrease in landings value during the period, probably due to falling quotas given the increased pressure on the most important stocks for the Danish fleet. The net profit for these three segments however does not fall at the same speed as the gross value added, as the loss in landings value are compensated by a corresponding decrease in crew share. The net profit for trawl smaller than 24m and for gillnet is negative during the entire period, indicating some overcapacity for these two segments. For Danish seine the net profit is around 0 during the period.

Figure 4.12. Economic indicators for the Danish seine and gillnet fleet 1999-2004





Source: AER, 2005.

For trawl 24-40m the gross value added increases from 1999-2002 and then decreases in 2003 and 2004, again following the trend in landings values. The net profit for these two segments follows the same trend, in spite of the crew share. The net profit is less than 0 in most of the period for trawlers 24-40m while it oscillates around 0 for the large trawlers and purse seiners. In all it can be concluded that none of the Danish fleets seems to have made a significant positive profit during the period 1999-2004, and there is thus room for improvement. The reason might be found in the overcapacity still present in the Danish fleet in spite of a severe reduction of fleet capacity from 1987 to 2002. Table 4.1 shows the development in a number of capacity indicators for the Danish fleet in the period 1999-2004 in a traffic light exposition.

Table 4.1. Capacity indicators for the Danish fleet during the period 1999-2004							
		1999	2000	2001	2002	2003	2004
Trawl < 24m	Effort (1000 days at sea)	82.1	86	76.7	73.4	63.5	62.6
	Volume of landings (1000t)	144.3	152.7	202.6	171.9	133	135.6
	Fleet - number of vessels	467	499	461	439	376	370
	Fleet - total GT (1000)	13.7	15.2	15.8	15.3	15.9	16.7
	Fleet - total kW (1000)				97.7	85.5	82.4
Trawl 24--40m	Effort (1000 days at sea)	28.8	32.2	32.1	31.4	29.7	26.3
	Volume of landings (1000t)	553.6	691.2	667.3	609.7	382.2	368.2
	Fleet - number of vessels	129	140	138	134	124	118
	Fleet - total GT (1000)	27.9	32.1	33.3	32.4	31.2	29.2
	Fleet - total kW (1000)				81.3	75.4	70.3
Danish seine	Effort (1000 days at sea)	17.8	16.7	15.5	15	12.2	9.9
	Volume of landings (1000t)	18.9	15.2	14.6	13.7	9.1	9.2
	Fleet - number of vessels	105	103	96	95	69	69
	Fleet - total GT (1000)	5.2	3.9	3.4	3.4	3.2	3.4
	Fleet - total kW (1000)				16.2	12.2	11.8
Gillnet	Effort (1000 days at sea)	65.1	64.8	74.4	59	48.2	45
	Volume of landings (1000t)	28.9	27.2	25.9	23	20	18.9
	Fleet - number of vessels	491	476	495	435	379	367
	Fleet - total GT (1000)	6.9	6.7	7.4	6.4	6	6
	Fleet - total kW (1000)				46.2	37.3	35.2

Source: AER (2005)

The colours specify whether the value of the indicator has increased or decreased compared to the year before. Green means increase while red means decrease. Total kW numbers for the fleets have first been available from 2002. It is clear from table 1 that there has been an overall decrease in capacity for the Danish fishing fleet during the period, with few exceptions. The Danish seine fleet seems to be most severely affected by capacity decreases during the period. The fleet only experiences a slight increase in volume of landings from 2003 to 2004. The remaining fleet segments also mostly experience decreases in the capacity indicators, and in all it must be concluded that the capacity indicators shown in table 4.1 reflects the general reduction in fleet capacity during the period coupled with an increasingly strict management.

4.1.6. Species prices

The main species caught in the Baltic are cod, herring and sprat. Table 4.2 shows the price development for these species in the different areas of the Baltic Sea.

Table 4.2. Price (€/kg) development for the main target species in the Baltic sea, from 1999 to 2006.

		1999	2000	2001	2002	2003	2004	2005
Western Baltic and the Great Belt	Sprat	0.0985	0.0923	0.1072	0.1247	0.1278	0.1183	0.1234
	Herring	0.1055	0.0896	0.1149	0.1384	0.1617	0.1387	0.1151
	Cod	1.6532	1.8509	2.1875	2.2099	1.9954	1.6926	2.1198
The Sound	Sprat	-	0.0836	0.0141	0.0226	-	0.0898	0.0811
	Herring	0.2042	0.1009	0.1851	0.1996	0.2347	0.2084	0.1843
	Cod	1.6489	1.803	1.9847	2.0822	1.7742	1.614	1.9015
Eastern Baltic	Sprat	0.1005	0.0957	0.103	0.1278	0.1479	0.1122	0.1081
	Herring	0.1552	0.1397	0.1944	0.2346	0.2427	0.1968	0.2303
	Cod	1.5462	1.6444	1.8093	1.7973	1.5562	1.4111	1.6554

Source: Danish Directorate of Fisheries, Year Book of Fisheries Statistics, 1999-2006.

The colour specifies whether the price has increased or decreased compared to the previous year, where green indicates increase and red decrease. It is seen that the prices more or less follows the same trends with an increase in 2001 and 2002, a general decrease in 2004, and some fluctuations in 2003 and 2005. Further descriptions of the forces ruling the fluctuations in the Danish prices can be found in FOI (2001-2007).

4.2. The bioeconomic model BEMCOM

4.2.1. Introduction

In order to assess the effect of Marine Protected Areas (MPA's) and other effort control schemes on economic performance of the fishing industry, a bioeconomic optimisation model has been developed. Following Cunningham, Dunn and Whitmarsh (1985) a bioeconomic model can be defined as "*a special kind of model for fisheries analysis to take account both of biological and of economic forces*". The acronym of the model is BEMCOM (BioEconomic Model to evaluate the COnsequences of Marine protected areas). The model has also been applied in the EU 6FP PROTECT (Marine Protected Areas as a tool for Ecosystem Conservation and Fisheries Management), to evaluate the economic effects of MPA's in the North Sea and in the Baltic Sea.

In the present context, BEMCOM is applied to assess the consequences for the economic performance of the Danish fleet fishing in the Baltic, of extending the MPA's aiming at limiting fishing effort and protecting juvenile cod. The model simulates the fishery over a 10 year period, which is an adequate time-span for capturing possible effects of the different scenarios considered.

The fishery in the Baltic Sea is mainly focused on three species, i.e. cod, herring and sprat. Many types of vessels fish in this area, but do not necessarily obtain all their income from their activities in the Baltic Sea. All nations around the Baltic Sea have a fishing fleet, but it has unfortunately not been possible to obtain detailed data from other countries besides Denmark in order to reach the level of detail required by BEMCOM. The assessments of economic performance presented here thus only includes vessels from Denmark, but will in connection with the biological stock estimations include overall estimates of the catches of the remaining countries surrounding the Baltic Sea[16].

The Danish fleet fishing in the Baltic consists of 15 distinct fleet segments. Seeing that most of these also fish outside the Baltic, the economic performance of their total fishery has been assessed under different assumptions about MPA closures in the Baltic. The economic performance has been assessed under the assumption that the total fleet seeks to maximise the net present value of its net profit, i.e. the value of landings minus all costs (variable, fixed and crew costs), which is a close approximation to the resource rent.

4.2.2. Description of BEMCOM

BEMCOM is set up as a flexible modelling framework, which is programmed in a generic way in order to be able to handle different case studies reflected through the utilised dataset and parameter values. Different management strategies can thus be investigated with respect to marine protected areas, as well as other technical restrictions (e.g. minimum mesh sixe, closed seasons and fishing day limitations).

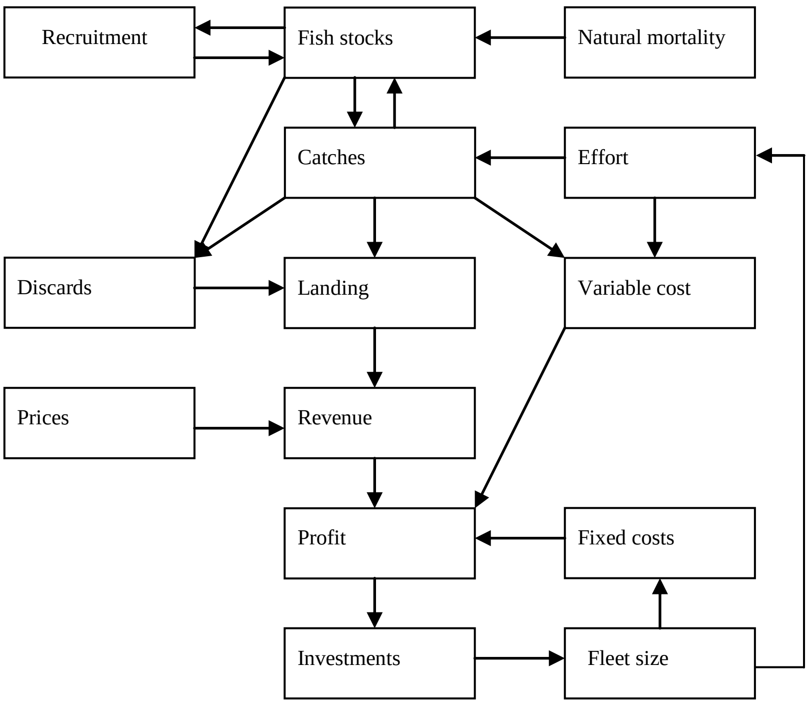
[16] As more data becomes available in the future through for instance the data collection initiated within the European Union, this can of course be included in order to increase coverage. Nevertheless, it is important to stress that BEMCOM will still require some data that only the individual countries have access to.

BEMCOM operates with several dimensions (years, quarters, fishing areas, fleets etc.), where some of these have an extensive number of alternatives. For instance, fishing area can be detailed down to ICES-square or an even finer grid size. In the Baltic Sea this means that instead of just having one fishing area the model includes in this case more than 100 fishing squares covering the total Baltic Sea. The high level of detail is necessary in order to address the questions related to the economic consequences of marine protected areas. However, this detailed structure increases the data requirements in order to obtain a well-functioning model and relevant answers to the proposed questions.

4.2.3. Model overview

An overview of the interactions within a bioeconomic model is given in Figure 4.13. BEMCOM follows along the lines given in Figure 4.13, and even though the model is more complex than shown, the figure gives the basic flows.

Figure 4.13. Basic interactions in a bioeconomic model



At present the model does not include any direct investment function, but the fleet capacity (number of vessels) is included as a variable, and will thus change during the optimisation period in order to find the maximum net present result. The variation in fleet capacity is at present limited by a 20% band around the initial value, together with limitations on overall fleet capacity (GT).

The reason for the exclusion of a more refined investment structure is the lack of knowledge and empirical information, which can be utilised when modelling. Describing the investment environment is a complex case, where many factors should be considered, including the fisherman's individual desires towards investing in the fishery, the surrounding financial environment, and regulatory restrictions limiting the desired behaviour. The seminal paper within investment theory of fisheries is considered to be Clark, Clarke and Munro (1979). Despite that this paper was published more than 25 years ago, there has not been performed much empirical analysis within this area although it is very important.

Currently one the EU-project CAFÉ (EU Contract no. 022644) is investigating which factors influence the investment decisions of fishermen. Moreover investment behaviour has been discussed and implemented in the EU-project EFIMAS (EU Contract no. 502516), and reported in Hoff and Frost (2006, 2008). Future developments of BEMCOM thus aim to include investment behaviour.

4.2.4. Dimensions, variables and parameters

BEMCOM has in its current form seven dimensions in order to reflect different relevant aspects of the fishery. The dimensions are as follows:

- year	y =	1,…,Y
- month/quarter	m =	1,…,M
- vessel/fleet segment	f =	1,…,F
- primary fishing ground (area)	g =	1,…,G
- sub-fishing areas (squares)	a =	1,..., A
- species	s =	1,…,S
- cohort	c =	1,…,C

It is of course possible to include additional dimensions in BEMCOM, such as home port. However, this will increase complexity of the model, solving time plus increase data demand, when quantifying the model.

Observe that the model differentiates between primary fishing ground and sub-fishing areas. Primary fishing grounds are e.g. North Sea, eastern Baltic, Western Baltic etc, while sub-fishing areas are sub-divisions of the primary fishing areas, i.e. ICES sub-areas. This differentiation has been necessary in order to include a detailed description of the fishery down to the level of sub-fishing areas, while at the same time performing stock estimations on the level of primary fishing ground.

The variables estimated in BEMCOM, can be divided between economic, biological and production variables

The economic variables in BEMCOM are:

- profit	P
- revenue	R
- total costs	TOTC
- variable costs	VC
- fuel and lubricants costs	OC
- provision costs	PC
- ice costs	IC
- sales costs	SC
- crew costs	CC
- fixed costs	FC
- maintenance costs	MAIN
- insurance costs	INSUR
- other fixed costs	OTH

The biological variables are:

- fish stocks	$N_{c>1}$
- recruitment	$N_{c=1}$

while the production variables are:

- catches	C
- effort	E
- fleet size (number of vessels)	NV

- landings L
- landings weight WL
- discards D

All variables are determined within the model framework, when the net present result function is optimised.

The input parameters to the model are also divided between economic, biological and production parameters, respectively.

The economic parameters in BEMCOM are:

- fish prices P
- fuel price Fp
- provisions price Pp
- ice price Ip
- sales share Sp
- crew share Cp
- Price flexibility rate α

while the biological parameters are:

- natural mortality coefficient M
- discard coefficient Df
- fish weight per cohort Wt
- Stock Biomass SB
- Spawning Stock Biomass SSB

Finally, the production parameters are:

- landings per unit effort LPUE
- Landings fraction per cohort cf
- Total catch of other nations Coth
- Quota Q

The values of the parameters are determined outside the model based on the utilised dataset or by using knowledge about these. The level of detail for the variables and parameters can be reduced or expanded, if this is desired. The choice is dependent on several things including the available information and the wish to obtain a functional model.

4.2.5. Equations

The model equations are differentiated between biological stock development equations and equations for the short term economic development of the fishing vessels.

Starting with the biological equations, it is firstly assumed that fish stock dynamics are evaluated on the primary fishing ground level e.g. the cod stock in the eastern Baltic Sea. The number of fish recruited to cohort *1* of species *s* in fishing ground *g* at year *y* depends on the size of the spawning stock biomass (SSB) at year *y-1* and the recruitment coefficients *Rc,* through a chosen stock-recruitment function *f* (e.g. Ricker, Beverton-Holt, or constant recruitment):

(4.1) $$N_{y,g,s,c=1} = f(SSB_{y-1,s,g})$$

The Beverton-Holt stock recruitment function has the form:

(4.2) $$N_{y,g,s,c=1} = \frac{r \cdot SSB_{y-1,s,g}}{s + SSB_{y-1,s,g}}$$

while the Ricker relationship has the form:

(4.3) $$N_{y,g,s,c=1} = r \cdot SSB_{y-1,s,g} \cdot \exp(-s \cdot SSB_{y-1,s,g})$$

The fish stocks are reduced through natural mortality and through fishery. Thus when total catches C in the previous year and natural mortality *MORT* are known[17], the stock size *N* (measured in number of fish) of cohort *c>1* of species *s* in fishing ground *g* can be estimated using the Pope approximation (Sparre, 1998):

(4.4) $$N_{y,g,s,c} = N_{y-e,g,s,c-1} \cdot \exp(-M_{g,s,c-1}) - (C_{y-1,g,s,c-1} / wt_{s,c}) \cdot \exp(-M_{g,s,c-1} / 2) \quad ; \quad c > 1$$

Where $wt_{s,c}$ is the weight per individual of species *s* in cohort *c*.

Unwanted catches are an almost unavoidable part of fisheries, and it is therefore necessary to divide the total catches between a discarded and a landed part. The discarded part can for instance be of no value to the fishermen or be illegal to land, and therefore thrown back into the sea. Unfortunately the survival rate of the discarded fish is very low. The number of fish discarded *D* in year *y* from the average vessel in fleet *f* in area *a* of cohort *c* of species *s* is:

[17] Possible predation is in the present context assumed to be included in the natural mortality.

(4.5) $$D_{y,f,a,s,c} = df^{obs}_{f,a,s,c} \cdot C_{y,f,a,s,c}$$

where $df^{obs}_{f,a,s,c}$ is an observed discard fraction in are *a* for species *s* of cohort *c* for fleet *f*.

The remaining part of the total catch is landed. The landings are dependent on the type of vessels (selectivity, primary gear type etc.) and an array of other things such as age of fishermen, experience etc. The average landings *L* (measured in kg) of species *s* in cohort *c* taken in sub-fishing area *a* of fishing ground *g* in month *m* of year *y* by a vessel in fleet *f* is determined by the (observed) landings per unit effort (*LPUE*), the effort (*E*) of the vessel, the stock size *SB*, and the catch distribution fraction (*cf*) on cohort *c*:

(4.6) $$L_{y,m,f,g,a,s,c} = LPUE_{y,m,f,g,a,s} \cdot E_{t,f,g,a} \cdot cf_{f,g,s,c}$$

where $E_{t,f,g,a}$ is effort and $cf_{f,g,s,c}$ the landings fraction per cohort (i.e. the percentage of the landings constituted by cohort *c*). Catches, and thus landings, are also assumed dependent on the stock abundance, which is included in the *LPUE* that varies over time with stock according to:

(4.7) $$LPUE_{y,m,f,g,a,s} = LPUE_{y=0,m,f,g,a,s}\left(\frac{SB_{y,s,g}}{SB_{y=0,s,g}}\right)^{\gamma_{f,s,g}} \quad ; \quad \gamma_{f,s,g} \geq 0$$

Where $SB_{y,s,g}$ is the stock biomass of species *s* in fishing ground *g* in year *y*, and $\gamma_{f,s,g}$ is scaling parameter reflecting that landings may not vary proportionally with stock changes (more likely decreasing returns to scale should be expected).

The economic equations can be divided between revenue (or landings value) and cost, where the latter can further be separated into variable and fixed costs. The economic variables are characterised by not having species and cohorts as their dimensions, but on the contrary including fleet and fishing characteristics.

The revenue obtained from the landed catch is obtained by multiplying with fish price *p*. The average revenue *R* in year *y* for a vessel in fleet *f* is:

(4.8) $$R_{y,f} = \sum_{m,g,a(g),s,c} L_{y,m,f,g,a,s,c} \cdot p_{y,f,g,s,c}$$

Landing prices $p_{y,f,g,s,c}$ for each species and cohort are not dependent on the total amount of fish landed. Prices on fish are on the contrary generally considered to be determined on the global market. A correct modelling approach would therefore be to consider total global landings, but this is a time consuming and cumbersome process, which has therefore been excluded from the model. A more straightforward approach, used in the model at present, is to assume that the prices vary with the quota levels *Q*:

$$(4.9) \qquad p_{y,f,g,s,c} = p_{y=0,f,a,s,c} \cdot \left(\frac{Q_{y,g,s}}{Q_{y=0,g,s}} \right)^{\alpha_{g,f,c}} \quad ; \quad \alpha_{g,f,s} \leq 0$$

Where $Q_{y,g,s}$ is the quota in year *y* of species *s* in fishing ground *g* and $\alpha_{g,f,s}$ is the price flexibility rate.

As mentioned above, the average total costs at year *y* for a vessel in fleet *f* is the sum of variable costs (*VC*), which varies with the short term activity of the vessel, or fixed costs (*FC)* that varies with the long term activity of the vessel[18]:

$$(4.10) \qquad TOTC_{y,f} = VC_{y,f} + FC_{y,f}$$

Looking first at the variables costs, these consist of costs related to the use of oil (fuel) and lubricants (O*C*), provisions costs (*PC*) and ice costs (*IC*), auction related sales costs (*SC*) and finally payment to the crew onboard (*CC*):

$$(4.11) \qquad VC_{y,f} = OC_{y,f} + PC_{y,f} + IC_{y,f} + SC_{y,f} + CC_{y,f}$$

The fuel costs (O*C*) at year y for an average vessel in fleet *f* is determined by the fuel price *fp* per effort unit, and the effort used by the vessel:

$$(4.12) \qquad OC_{y,f} = \sum_{g,a(g)} fp_{f,g} \cdot E_{y,f,g,a}$$

Fuel costs per effort unit is used, rather than fuel price per unit fuel used, as the total fuel costs will then vary with the choice of area to fish in. If the area is close to the

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[18] Despite that BEMCOM is a dynamic model; there is no inclusion of inflation in the cost equations. This is straightforward to include such considerations by applying a parameter in each relevant equation, but obtaining qualified information about future cost developments, for instance in fuel price, is very complex

vessels home port, fuel consumption is low and vice versa. No division is made between steaming time and fishing time[19].

It is necessary to bring supplies on every trip in order to feed the crew. The amount of supplies is related to the number of days at sea. The provision costs at year *y* for an average vessel in fleet *f* are therefore determined as:

$$(4.13) \qquad PC_{y,f} = \sum_{g,a(g)} pp_{f,g} \cdot E_{y,f,g,a}$$

Observe that the provisions price $pp_{f,g}$ vary between fleets, because crew size differ.
When catching fish, it is necessary to store the landings cold in order to preserve the fish. This requires ice, and the costs of ice at year *y* for an average vessel in fleet *f* are thus determined as:

$$(4.14) \qquad IC_{y,f} = \sum_{g,a(g),s,c} ip_{f,g} \cdot L_{y,f,g,a,s,c} \cdot wt_{s,c}$$

Where $ip_{f,g}$ is the price of ice needed per *kg* landed fish.

When selling the landing, auctions usually require a fee in order to cover costs for the auctioneer, packing and transporting. The fee is often a share of the revenue, and the sales cost at year y for an average vessel in fleet *f* is therefore:

$$(4.15) \qquad SC_{t,f} = sp_f \cdot R_{t,f}$$

The final variable cost is payment of the crew. Normally, this is considered to be a share of the revenue deducted some specific types of variable costs. However, for easiness the crew payment at year *y* for an average vessel in fleet *f* with home port *h* is calculated as:

$$(4.16) \qquad CC_{y,f} = cp_f \cdot R_{y,f}$$

With the basic equations for the variable costs in place, it is time to consider the fixed costs. The fixed costs are considered to be composed of three elements: 1) maintenance costs, 2) insurance costs, and 3) other costs (rent of buildings on share, accoun-

[19] It has not been possible in the case studies to model fuel costs in this detailed way due to lack of data.

tancy assistance etc.). Thus, the fixed costs at year y for an average vessel in fleet f are:

(4.17) $$FC_{y,f} = MAIN_{y,f} + INSUR_{y,f} + OTH_{y,f}$$

None of these costs varies with the daily activity of the individual vessel, nor the areas and types of species caught, and are therefore determined through the values from the utilised data.

Having defined how revenue and cost is determined, the profit P (or net result) in year y for an average vessel in fleet f is defined as:

(4.18) $$P_{y,f} = R_{y,f} - TOTC_{y,f}$$

4.2.6. Objectives and restrictions

The model is run by optimising certain objectives given certain restrictions. Within the economic literature, it is generally assumed that fishermen will seek to maximise their profit and society will seek to obtain the highest resource rent which means that the fish stock abundance is taken into account. As discussed in chapter 2 in this report, it is difficult to evaluate the resource rent exactly as stock estimates are required. A good approximation to the resource rent is, however, the net profit (or net result), i.e. value of landings minus all costs, the deviation from the exact resource rent being how well the crew payment reflects the actual opportunity costs.

Thus in the present application the objective function will be a summarization net profit, measured in present values, for all the individual vessels over all time periods:

(4.19) $$\max_{E_{t,f,g,a}} \quad TOTP = \sum_{y,f} P_{y,f} \cdot \frac{1}{(1+\rho)^t}$$

where ρ is the discount rate.

Society may also have other objectives such as the highest possible employment, and this could justify the use of a multi-objective approach. This will however not be pursued further here.

Obtaining the highest profit for the society does however not necessarily need to be done without including other considerations. This can be done through imposing restrictions on the endogenous variables in the model. These of course include the fundamental restrictions, securing that catches and effort are not negative.

Furthermore specific restrictions are included in the present application regarding landings, effort and capacity. Firstly the landings in year *y* in fishing ground *g* of species *s* are restricted by the quotas, i.e.:

(4.20) $$\sum_{m,f,c,a(g)} L_{y,m,f,a,s,c} \leq Q_{y,g,s} \quad ; \quad Q_{y,g,s} = Q_{y=0,g,s} \cdot \left(\frac{SB_{y-1,g,s}}{SB_{y=0,g,s}} \right)$$

where it is assumed that the quota in year *y* is set through assessment of the stock in the previous year.

Secondly the total number of sea days used by an average vessel of fleet *f* in month *m* of year *y* is limited from below and above by a minimum respectively maximum value:

(4.21) $$E_{y,m,f} \leq \ (\geq) E_{m,f,a}^{\min \ (\max)}$$

Thirdly the number of vessels (capacity) in fleet segment *f* in year *y* is limited within a 20% band around the number of vessels in the start year:

(4.22) $$0.8 \cdot NV_{y=0,f} \leq NV_{y,f} \leq 1.2 \cdot NV_{y=0,f}$$

While the total number of vessels in the fleet is bounded from above by the original capacity measured in GT:

(4.23) $$\sum_f NV_{y,f} \cdot GT_f \leq \sum_f NV_{y=0,f} \cdot GT_f$$

Where GT_f is the average gross tonnage per vessel in fleet segment *f*.

With regard to biology, it is assumed that the spawning stock biomass of cod in year *y* does not fall below the biomass of cod in the start year in any area:

(4.24) $$SSB_{y,g} \geq SSB_{y=0,g}$$

And finally it is assumed that the catch in any sub-area of a fishing ground does not exceed the biomass divided by the total number of sub-areas n_g in the fishing ground (thus assuming equal distribution of the stock over the total fishing ground):

(4.25) $$\sum_{f,m,c} L_{y,m,f,a(g),s,c} \leq SSB_{s,g} / n_g$$

Other types of restrictions can be included in BEMCOM. These may for instance consider the quota and effort distribution between fleets.

4.3. Application to the Baltic Sea fishery

This case study includes evaluation of catches of the three target species in the Baltic mentioned above (cod, herring and sprat), together with an alternative covering ‘other species’. The focus will be on assessing economic fleet performance of 15 Danish vessel segments fishing in the Baltic Sea under different scenarios, given the assumption that the total net present profit of the Danish fleet is maximised over the modelling period, i.e. over a 10 year period (cf. equation 4.19 above). Moreover some focus will be given on stock development of Baltic cod (eastern and western stock), seeing that the recovery of this species has primarily been in focus, when discussing use of closed areas in the Baltic Sea. Catches of the remaining species are included in order to evaluate total profit of the fleets in question.

Three scenarios are considered. The first correspond to the status-quo situation in the Baltic Sea at present, i.e. finds the economically optimal allocation of effort for the Danish fleet under the current management regime in the Baltic sea. Scenario 1 then considers extended closures of the Bornholm and Gotland Deep, which are both considered spawning areas for eastern Baltic cod. And finally scenario 2 considers a further extension of the closure around the Bornholm Deep, recognizing that this is the most important spawning area for eastern Baltic cod.

Generally, data is obtained from three main sources: 1) International Council for the Exploration of the Sea (ICES), 2) Danish Directorate for Fisheries (FD) and 3) Institute of Food and Resource Economics (FOI) in Denmark. Data from the two latter sources only cover 2005, which is the latest year available.

4.3.1. Dimensions and alternatives

The dimensions and alternatives within each dimension in case study 1 are as follows:

-	year	y =	2006,...,2015
-	quarter	m =	1Q,2Q,3Q,4Q
-	vessel/fleet segment	f =	GKu12m, JOLRUSu12m, SGTu12m, TRAu12m, GK1215m, SGT1215m, TRA1215m, GK1518m, SGT1518m, SNV1518m, TRA1518m, SNV1824m, TRA1824m, TRA2440mINDU, TRA2440mAND
-	fishing ground	g=	3B, 3C, 3D, 4ABC, 3AN, 3AS, 2,5,6,7,9
-	fishing sub-area	a =	36G4,37G3,37G4,37G5,37G6,38G3,38G4,38G5,38G6,38G7, 38G8,38G9,39G3,39G4,39G5,39G6,39G7,39G8,39G9,39H0, 40G4,40G5,40G6,40G7,40G8,40G9,40H0,41G4,41G5,41G6, 41G7,41G8,41G9,41H0,42G6,42G7,42G8,42G9,42H0,43G6, 43G7,43G8,43G9,43H0,43H1,43H3,44G6,44G7,44G8,44G9, 44H0,44H1,44H2,44H3,45G6,45G7,45G8,45G9,45H0,45H1, 45H2,45H3,46G6,46G7,46G8,46G9,46H0,46H1,46H2,46H3, 47G8,47G9,47H0,47H1,47H2,47H3,48G8,48G9,48H0,48H1, 48H2,48H3,48H4,48H5,48H6,48H7,48H8,49G8,49G9,49H0, 49H1,49H2,49H5,49H6,49H7,49H8,50G7,50G8,50G9,50H0, 50H1,51G7,51G8,51G9,51H0,51H1,52G7,52G8,52G9,52H0, 52H1,53G7,53G8,53G9,53H0,53H1,54G7,54G8,54G9,54H0, 54H1,55G8,55G9,55H0,55H1,56H0,56H1,56H2,57H1,57H2, 57H3,58H1,58H2,58H3,58H4,59H1,59H2,59H3,59H4,60H2, 60H3,60H4, 2,3AN,3AS,4ABC,5,6,7,9
-	Species	s =	COD,HER,SPR,OTH
-	Cohort	c =	1,…,7

With respect to year, ten years are included in order to sufficiently illustrate the effects of technical measures enforced in the different scenarios. The gains expected from effort control management systems must likely be obtained in the long run, and therefore it is not sufficient only to include a few years in the model.

In order to allow for seasonal closures, every year is divided into four quarters. Initial model runs were made with a monthly division, but unfortunately the model complexity increased to a level requiring more computer memory than the used GAMS solver was able to accommodate[20].

The economic unit in the model is the fishing vessel. However, it is not possible to model each vessel individually. Therefore, vessels have been distributed into groups reflecting their size and the vessel type. Thus besides the length categories, a deduction is made between 5 vessel types: 1) trawlers (TRA), netters/liners (GK), dinghies/potters (JOLRUS), multi-purpose (SGT) and Danish seiners (SNV). Furthermore, the large trawlers above 24 meters are divided into industrial vessels (INDU) for who industrial species comprise more than 80% of their catch value, and vessels where this is not the case (AND).

With respect to fishing areas, the Baltic Sea covering the Sound, Belts, Western Baltic and eastern Baltic is divided into ICES-squares. A total of 142 ICES-squares are thus included in the model, but there are not registered fishing activities in all of them. Furthermore eight other areas outside the Baltic Sea are included in the model in order to be able to evaluate the total landings value for each vessel group.

A deduction is made between three primary species, cod, herring and sprat, while an ‘other’ group includes all other species caught by the fishermen.

Within the biological part of BEMCOM, the age structure of cod is assumed to be split between seven age classes (cohorts), where the latter covers fish at and above age 7.

4.3.2. Biological data and assumptions

As discussed above, evaluation of stock development (equation 4.2) has only been performed for the eastern and western cod stocks in the Baltic, as these are the focus species when discussion MPA’s and other technical measures. For the remaining species only evaluation of catches are included in the model. It has thus only been necessary to obtain biological information for the cod stocks in the Baltic Sea.

[20] The used solver is CONOPT3 for GAMS, which at present works with a maximum memory of 2GB.

Biological data for Baltic cod has primarily been obtained from ICES 'Baltic Fisheries Assessment Working Group' (WGBFAS). Biological data for 2005 has been used to initialise the model, i.e. the initial data for stock etc. are all taken from the data collected for 2005 by WGBFAS.

Biological data is only given on the level of total ICES fishing area, i.e. not at the ICES square level. The biological data has been divided between western Baltic (3BC) and eastern Baltic (3D) seeing that the cod stocks east and west of the island of Bornholm have different biological characteristics and do almost not overlap (WWF, 2006).

Stock numbers at age, individual weight at age, maturity index at age, and natural mortality at age have been extracted for the two cod stocks from the WGBFAS 2007 report (ICES (2007). Table 4.3 shows these initial values used in the model.

Table 4.3. Initialisation data (year=2005) for the eastern and western cod stocks

	3BC (western)				3D (eastern)			
	Stock number (thousands)	Natural mortality rate	Maturity rate	Weight per fish (kg)	Stock number (thousands)	Natural mortality rate	Maturity rate	Weight per fish (kg)
1	30,495	0.242	0.01	0.08	0	-	0	0
2	56,823	0.2	0.1	0.36	172,258	0.2	0.13	0.344
3	6,467	0.2	0.64	0.83	65,175	0.2	0.36	0.626
4	5,752	0.2	0.87	1.69	36,353	0.2	0.83	0.916
5	1,183	0.2	0.93	1.93	11,789	0.2	0.94	1.201
6	298	0.2	0.91	3.37	2,510	0.2	0.96	1.924
7	129	0.2	0.91	8.84	699	0.2	0.97	2.719

Source: ICES (2006).

Furthermore, a Ricker stock-recruitment relationship (equation 4.3) is used to estimate recruitment at age 2in area 3D. The Ricker parameters for this relationship have been estimated from spawning stock biomass and recruitment in the period 1966-2005 for eastern cod, and are given by $r = 1.6458 \cdot 10^{3}$ (recruits per tonnes SSB) and $s = 0.0126 \cdot 10^{-4}$ (tonnes^{-1}). In are 3BC a stepwise recruitment (at age 1) is assumed, based on spawning stock biomass and recruitment data in the period 1970-2005 for western cod. It is thus assumed that $R = 57815 \cdot 10^{3}$ (recruits per tonnes SSB) for *SSB<30.000* tonnes, while $R = 108807 \cdot 10^{3}$ (recruits per tonnes SSB) for *SSB>30.000* tonnes. Data for both stocks are also found in the WGBFAS 2006 report.

Finally international catch data for the period 2000-2005 for all countries surrounding the Baltic Sea have been used to estimate how much Danish cod catches in 3B, 3C and 3D constitute of total cod catches in the respective areas These fractions are shown in table 4.4. It is seen that Denmark dominates the cod catches in area the sound and the western Baltic Sea (are 3B+3C) and for these areas the Danish catches are scaled up, using the catch fractions, to reflect the expected total cod catches used to perform stock estimates (equation 4.4). In area 3D, however, Denmark only takes around 11% of the total cod catches, and the total catches must thus be assumed to be more or less independent of the Danish catches. Constant measures of the cod catch in 3D taken by all other nations than DK are thus included to perform stock estimates. In the 'status quo' scenario corresponding to the present state of the fishery this is set to 47 752 tonnes corresponding to the minimum observed catch by other nations in the period 1996-2006[21].

Table 4.4. Fraction Danish cod catches constitute of total cod catches in the Baltic Sea with catches measured in weight

	The Sound	Western Baltic Sea	Eastern Baltic Sea
Fraction of cod catches	0.78	0.56	0.11

4.3.3. Technological assumptions and restrictions

The initial catch per unit effort for a vessel in the included fleets is calculated from the available dataset for 2005. However, as the cod stock increases, it is assumed that the catch per day at sea of cod will also increase. Because cod and 'other-species' (i.e. all other species than cod, herring and sprat) are most often caught together, it is assumed that the catch of other-species decrease with increasing cod stocks. Several reasons can justify this, first the eggs of other-species will be eaten by cod, and second a vessel has limited holdings, and given that the price of cod generally is higher than the price of other-species, the latter will be discarded.

It must be noticed that if a fleet did not have observed catches in a fishing area/ICES-square in 2005, it will neither have this in the future, because catches in the model are a linear function of the initial CPUE distribution. This is most likely a questionable assumption. It can to some extend be reduced by combining the ICES-squares into

[21] The minimum has been chosen for technical reasons, as the model will for higher value reveal infeasible results.

larger areas, but this will on the other hand reduce the level of detail possible, when closing some areas.

In order to obtain realistic results, several technical restrictions have to be included. If not, the model would most certainly give results, which are not consistent with reality. For instance the number of days at sea used by a vessel must be kept below the number of days in a year.

As shown in equation (4.22) the number of vessels in the model is allowed to vary with 20% compared to the number of vessels in the initial year (2005), which are given in table 4.5. The Danish fishing fleet has already been reduced by more than 20% (measured in number of vessels) in the period 1994-2006 in connection with capacity reduction programmes. As this reduction has brought the Danish fleet below the GT and kW ceilings set by EU for Denmark, it cannot be expected that the Danish fleet will be reduced significantly in the future, and a maximum 20% reduction thus seems realistic. The 20% upper limit is more problematic, seeing that it is not allowed to bring new capacity into the Danish fishing fleet. This restriction is however covered by equation (4.23), which in combination with the 20% upper limit on variation in vessels allows some exchange of capacity between vessel groups.

Table 4.5. Number of vessels in 2005

	Number of vessels
Netter/liner <12m	130
Dinghy <12m	30
Multi-purpose <12m	35
Trawlers <12m	14
Netter/liner 12-15m	25
Multi-purpose 12-15m	34
Trawler 12-15m	77
Netter/liner 15-18m	5
Multi-purpose 15-18m	8
Danish seine 15-18m	9
Trawler 15-18m	52
Danish seine 18-24m	21
Trawler 18-24m	42
Trawler 24-40m industrial	24
Trawler 24-40 mixed	9

Another restriction relates to the maximum number of days that each vessel is allowed to have in a quarter (equation 4.21). Instead of basing this restriction on the actual number of days in each quarter, it is based on what is observed in the dataset. Thus for every fleet and quarter, the vessel with most days at sea is identified, and this is used as the maximum number of days a vessel within this fleet can have in a quarter. This will be less than the total number of days in a quarter, because time is also used for repairs, weekends and vacation.

Furthermore, a restriction is included about the minimum number of days at sea for each vessel (equation 4.21). Given that it is assumed that the number of vessels cannot go below 80% of the initial number, it is considered relevant to include this. If not, the fishermen would just be laying in the ports bearing their fixed costs. By giving them a minimum activity, these fixed costs could possibly be covered. The number of minimum days is calculated in the same way as maximum number of days with the opposite sign.

A restriction is also needed on the maximum allowable catch (equation 4.20). If such a restriction is not imposed the model could in principle fish the species to extinction. Initially, it is assumed that the maximum allowable catches (the 'quotas') are set equal to the observed catches taken by the included vessels in 2005. Over the years, the maximum allowable catch of cod is scaled with the development in the cod stock in the Sound, western and eastern Baltic Sea, i.e. an increased stock gives higher quotas of cod. The cod quota in other fishing areas are not changed, but kept at the initial level. None of the quotas for herring, sprat and other-species are changed, neither in the Baltic Sea or other areas.

Besides the above quota restriction, it is also necessary to include a restriction regarding the stock (equation 4.24). In order to secure that the model does not end up with a solution, where the cod stock is fished to extinction in the last period (because there is no tomorrow), a restriction must be included. Therefore it is assumed that the cod stock must at no time be below the initial stock level.

Finally it is assumed that the catch in each fishing area (ICES square) cannot exceed the stock biomass divided by the number of total areas in the fishing ground (equation 4.24). This is done to make sure that not all fishing activity is concentrated in one or two sub-areas, which would be unrealistic.

4.3.4. Economic data and assumptions

4.3.4.1. Catches, prices and revenue

As previously mentioned, vessel catches are calculated in BEMCOM through the distribution of days at sea. Based on these catch levels for each fleet, the revenue is calculated by multiplying with the assumed price on fish.

Initial prices are calculated from the same data set used to calculate the CPUE matrix. Prices are not assumed to be different between each ICES-square in the Baltic. Instead, prices for each of the four species are assumed to vary between the fleet segments and three aggregated areas in the Baltic Sea 1) the Sound, 2) western Baltic and 3) eastern Baltic plus the areas outside the Baltic Sea.

Prices are not assumed to vary within a year, but instead between years. The yearly variation is assumed to depend on the development in the quotas. Thus if quotas increase, this will generally be expected to have a negative influence on the obtained price, because more fish is becoming available on the fish markets, and the other way around with reduced quotas. Changes in quotas are however not completely reflected in the prices, and price flexibility is therefore included. Price flexibilities reflect the responsiveness of price to changes in own or other quantities. For the Baltic Sea cod fishery, a price flexibility of 0.2 is assumed as also done SEC (2004, 2005). Table 4.6 shows the average prices observed in 2005 for the primary fishing areas.

Table 4.6. Fish prices in 2005 (DKK)

	The Sound	Western Baltic Sea	Eastern Baltic Sea	Skagerrak	Kattegat	North Sea
Cod	12.64	13.41	11.19	17.65	4.39	20.20
Herring	1.43	1.05	1.70	1.99	1.63	2.04
Sprat	0.60	0.92	0.79	0.87	0.82	0.82
Other	25.76	12.30	7.03	15.34	29.57	1.92

Note: 1 € = 7.45 DKK

4.3.4.2. Costs

Cost information for the included vessels is obtained from the Danish fisheries account statistics published by the Institute of Food and Resource Economics. The information is collected for a stratified sample of approximately 330 vessels, corresponding to one-third of the commercial Danish fishing fleet. Information from the 2005 Account Statistics are utilised in the following.

Generally, costs can be divided into variable and fixed costs, where the former varies with the activity of the vessels, while the latter have to be paid irrespective of vessel activity. All costs are calculated as average costs for a vessel within each of the included fleet segments.

The variable costs have for different reasons been modified. The utilised economic data is not collected on a trip level, but on a yearly level. Because BEMCOM operates on a daily level, approximations have to be made for the costs that vary with the number of days at sea in order to obtain reasonable figures for the daily cost structure. This is thus done by dividing the variable costs, except sales and crew costs (i.e. fuel, ice, provisions and maintenance costs), with the observed average number of days. These daily variable costs do not vary during a year, and are not dependent on trip length and fishing area. Other variable costs (sale costs and crew payments) are dependent on fishing revenue, and the percentage that have to be used for this is determined by dividing the observed costs in the data set with the observed revenue in the dataset.

Afterwards, these modified figures have to be further changed. The reason for this is that the figures in the Danish account statistics cover all vessels in Denmark. It is thus not possible to extract economic figures solely on vessels fishing in the Baltic Sea, because these vessels only constitute a small fraction of the 330 vessels in the total Danish fleet. To accommodate this problem the economic figures for the total Danish fleet have been scaled in order to approximate costs of the vessels fishing in the Baltic Sea. This is done by using a scaling factor, which is set as the proportion between the average catch revenue observed for vessels fishing in the Baltic Sea and the average catch revenue generally observed for a Danish vessel.

Sales and crew costs are in BEMCOM calculated as a percentage of catch revenue. The percentage is calculated from the initial economic dataset without making any modifications.

Fixed costs are not changed, because these are not dependent on vessel activity. It is not reasonable to adjust these in the same way as done with the variable costs dependent on vessel activity. Thus, it is assumed that the vessels operating in the Baltic Sea have the same fixed costs as an average vessel in the Danish fleet. The cost figures used in the Baltic Sea case study for the included vessels are shown in Table 4.7.

Tabel 4.7. Cost figures

	Variable costs			Variable costs		Fixed costs		
	Fuel	Ice/provi -sions	Mainte-nance	Sales	Crew	Rent of plant and equip.	Insuran-ce	Miscel-laneous
	---- DKK/day at sea ----			% of -- catch revenue --		---------- DKK/year ---------		
Netter/liner <12m	307	120	657	0.11	0.10	3,466	22,228	34,647
Dinghy <12m	388	153	1,363	0.04	0.11	16,586	24,762	34,419
Multi-purpose <12m	365	16	565	0.08	0.04	19,459	35,063	34,433
Trawlers <12m	363	16	561	0.08	0.04	19,459	35,063	34,433
Netter/liner 12-15m	572	64	727	0.09	0.21	7,975	48,338	57,327
Multi-purpose 12-15m	476	164	753	0.13	0.01	574	32,103	47,019
Trawler 12-15m	1,118	111	809	0.11	0.19	6,101	53,524	55,854
Netter/liner 15-18m	908	212	1,516	0.10	0.38	5,719	96,725	100,493
Multi-purpose 15-18m	2,362	123	1,213	0.11	0.22	1,911	39,478	87,486
Danish seine 15-18m	741	160	1,355	0.10	0.29	7,931	65,273	81,561
Trawler 15-18m	1,767	131	1,116	0.08	0.22	7,584	78,636	82,853
Danish seine 18-24m	1,102	351	1,534	0.10	0.36	240	104,365	102,191
Trawler 18-24m	2,749	232	1,458	0.10	0.28	5,688	135,077	113,656
Trawler 24-40m industrial	5,480	1,157	2,106	0.11	0.26	8,989	250,193	172,282
Trawler 24-40 mixed	6,683	458	3,410	0.10	0.29	9,248	224,524	173,664

As mentioned, costs do not vary during the year. Neither is costs assumed to vary within the analysed period. It is highly problematic to foresee future development in costs, for instance fuel prices, and therefore no assumptions are made in relation to this. This is of course a questionable assumption, which can be discussed.

4.4. Scenarios and results

Given the flexibility of BEMCOM it is possible to analyse many different scenarios. Here 3 scenarios have been considered in order to investigate the influence of technical measures on economic efficiency of the Danish fishing fleet.

The first scenario is the base case, which is basically illustrating the 'status quo' situation, where the management situation in 2005 is assumed to continue for the analysed period. This management includes (i) an all year ban for the EU fleet on fishing cod in the Bornholm Deep, the Gotland Deep, and the Gdansk Deep, (ii) an extended summer ban on fishing cod in the eastern Baltic from 1. May to 15. September, and (iii) a spring ban on fishing cod in the western Baltic from 1. March to 30. April. In this scenario, the model optimises the economically optimal distribution of catches, and thus allocation of days at sea, disaggregated down to ICES-square for the Sound, western and eastern Baltic Sea and for the main areas for the areas included outside the Baltic. This is done for the analysed period, i.e. 2006-2015.

It has been observed in the available data that extensive fishing activity is taking place on the boundaries of the currently closed areas in the eastern Baltic Sea. This of course has a significant influence on the possibilities for the cod to go in and out of the spawning areas without getting caught. Therefore, a scenario is analysed where the currently closed areas are expanded. Thus, cod fishing in the following ICES-squares 39G5, 39G6, 40G5, 40G6 (areas around Bornholm Deep), 40G8, 40G9, 41G8 and 41G9 (areas around Gotland Deep) is completely prohibited all year.

Finally the area in and around the Bornholm Deep is the most important spawning area for eastern Baltic cod. As such it can be argued that an even larger area around the Bornholm Deep should be permanently closed to cod fishery. Therefore the last scenario closes most of the ICES area 25 around the Bornholm Deep, together with the extended closure around the Gotland Deep used in scenario 1.

The extra ICES squares closed in scenario 1 and 2 described above are characterised by having high catch- and CPUE-levels. Therefore a closure will have an economic impact on the vessels fishing there. However, they have the opportunity to reallocate their activity to other areas in and outside the Baltic Sea, and in this way reduce the economic repercussions. Furthermore, it is expected that the cod stock in especially the area 3D, in which the deeps are located, will increase and in this way give rise to an improvement in catches.

It must be noticed for all three scenarios that if a fleet did not have observed catches in a certain ICES-square in 2005 (i.e. in the initial CPUE matrix), it will neither have this in the optimal solution, seeing that the catches in the model are linear in the initial CPUE distribution. As such the model implicitly assumes compliance with the management schemes implied by the CPUE matrix, throughout the total optimisation period.

A large amount of output becomes available when running BEMCOM. This extensive output will not be described in the following. Instead the focus will be on the development in the following indicators:

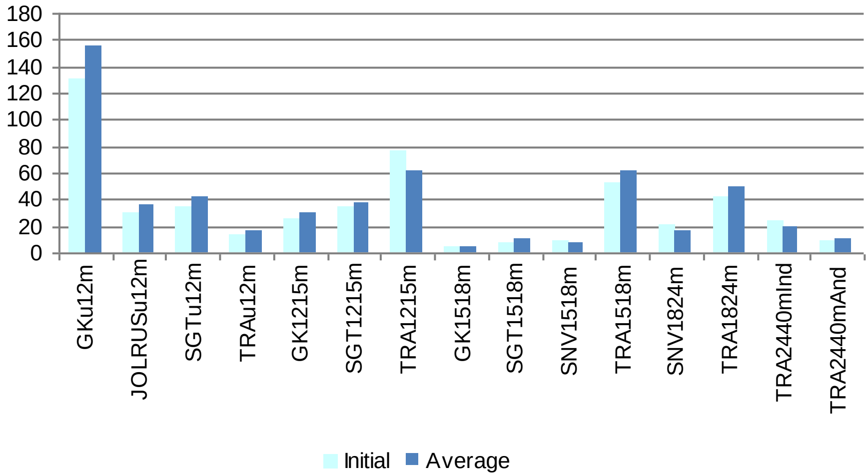
- cod stock (SSB)
- number of days at sea

- profit

4.4.1. Base scenario

Figure 4.14 shows the initial number of vessels in 2005 (table 4.5) together with the average number of vessels over the modelling period for each vessel group. For all small vessel groups less than 15 m, except the trawlers 12-15 m (TRA1215m)), the average number of vessels is higher than the initial number of vessels, i.e. it is optimal for these groups to invest in more capacity in the present management situation. For the larger vessels there is not clear pattern in whether it is optimal to invest or disinvest in capacity, even though it seems that most large trawlers have more vessels on the average in the optimal situation than the initial number.

Figure 4.14. Average number of vessels over the simulation period in the base scenario, together with the initial (2005) number of vessels.



The total optimal profit (measured in present values), defined as catch revenue minus variable and fixed costs, summarised over the optimisation period of the included vessels is in the base status-quo scenario DKK 6,331 million (€ 850 millions) for the total fleet. Figure 4.15 shows the average profit per vessel in the different fleet segments summarised over the optimisation period, measured in present values. It is seen that especially the small vessels <15m will be profitable over the optimisation period, while Danish Seine (SNV) will on the other hand have a small or negative profits. Generally most trawl segments (TRA) seem profitable as well as the multipurpose vessels (SGT).

Figure 4.15. Average present value profit per vessel summed over the optimization period (million DKK) in the Base scenario

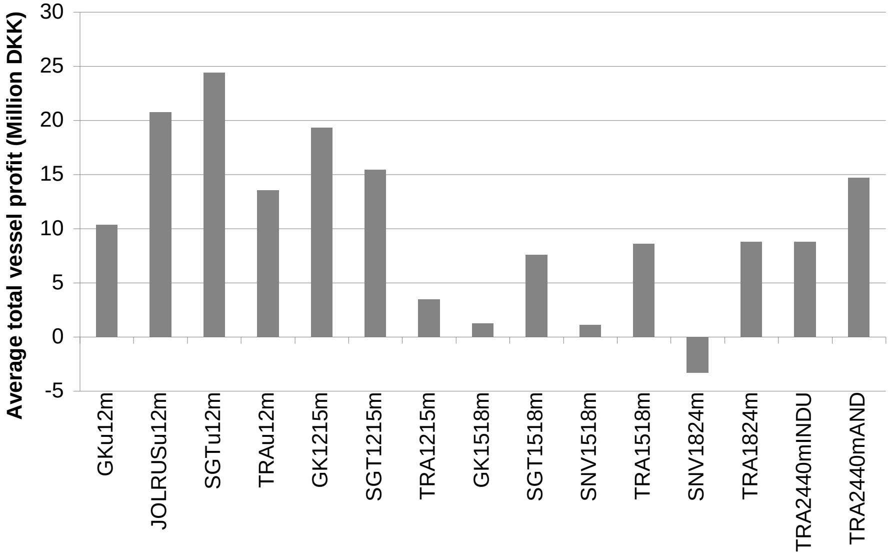


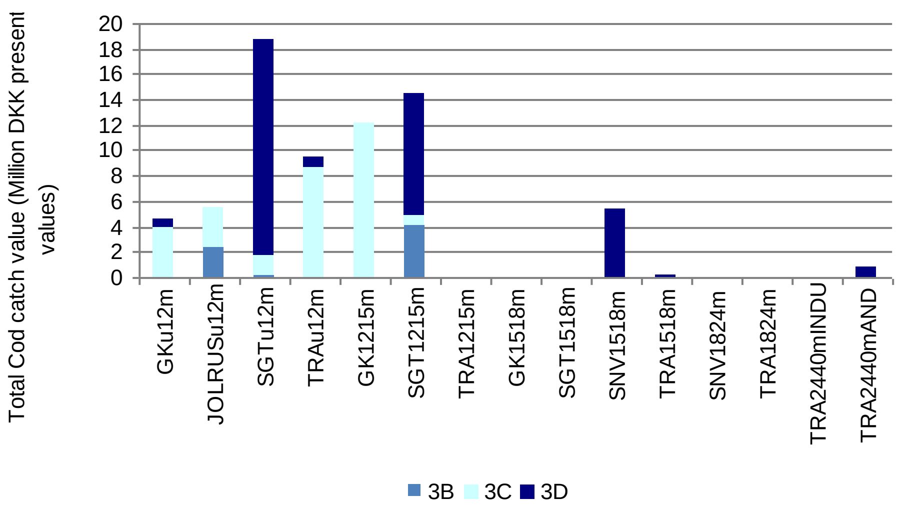
Table 4.8 shows the total catch value summed over the ten years optimisation period per vessel disaggregated between species and areas in the Baltic. It is seen that cod is the most important species in 3C and 3D, while herring is as important as cod in 3B. Sprat is relatively important in 3C, while the catch value of other species is approximately zero in the Baltic areas.

Table 4.8. Total catch value per vessel (millions DKK, present values), distributed over species groups and summed over the optimisation period, base case

	COD	HER	SPR	OTH
3B	6.87	6.21	0.00	0.00
3C	29.97	9.47	7.80	0.01
3D	34.15	7.11	0.32	0.06

Figure 4.16 shows the distribution of the total catch value of cod, summed over the optimisation period (million DKK, present values), per vessel in the Baltic areas for the different vessel groups. It is seen that it is mainly the small vessels below 15 m that catch cod in the Baltic, with the exception of the Danish seiners 15-18m (SNV1518m) that catch some cod in the eastern Baltic (3D). Together with these it is mainly the multipurpose vessels (SGT) that catch cod in the eastern Baltic.

Figure 4.16. Total Cod catch value (million DKK, present values) per vessel in the Baltic areas summed over the optimisation period, base case



The development in the eastern (3D) and western (3B+3C) Baltic cod spawning stock biomasses (SSB) during the optimisation period is shown in figure 4.17 for the status-quo base case. The figure shows that the cod SSB in the eastern as well as western Baltic can be expected to increase to above the precautionary limit (B_{pa}) during the optimisation period, given the assumptions that the fishing fleets operate in an economically optimal way (maximising the total net profit of the fishery) and that the fishery comply with the management scheme, i.e. do not fish in the closed areas etc.

The spawning stock biomass in the eastern Baltic generally increases throughout the optimisation period, but not unrealistically so, as the eastern cod SSB has been observed to be up to a max of 700 thousand tonnes during the period 1966-2006. The stock in the western Baltic generally increases with the exception of the last simulation year, but still stays above the precautionary limit. The observed increase of both stocks to above B_{pa} implies that the present management scheme may in the long run lead to the desired stock recovery in the Baltic Sea, if vessels are allowed to behave in an economically optimal way.

Figure 4.17. Development in cod spawning stock biomass (SSB), base scenario (1000 tonnes)

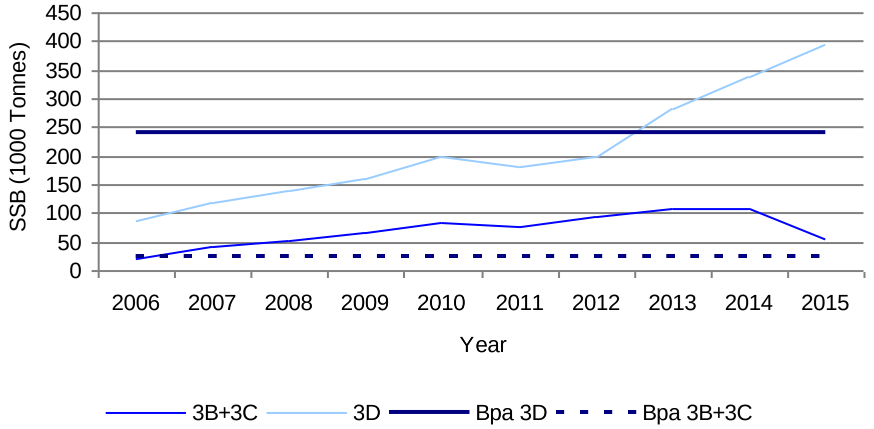


Figure 4.18 shows the development in the number of days at sea used on the average per vessel in the Danish fishing fleet in the Baltic areas 3B, 3C, and 3D together with the number of days at sea used per vessel in the remaining fishing grounds, during the optimisation period in the base scenario. The total number of days at sea used by a vessel in the fleet increases by around 20% during the period, which is caused by an increase by the number of days used in 3C (western Baltic). The number of days used in 3D (eastern Baltic) decreases a bit during the period, while the number of days used in 3B and in other areas stays approximately constant.

It is not surprising to see that the included fleets use relatively little time in 3B, i.e. in the Sound, which is a small area with a lower CPUE compared with the remaining areas[22]. Contrary to this, the included vessels allocate a relatively large part of their effort in 3C and in 'other areas' compared to 3D. Thus, the vessels allocate the largest

[22] The average CPUE in the Sound was in 2005 687 kilos of cod per day at sea, where the average CPUE in 3CD was 750 kilos of cod per day at sea.

part of their effort in areas close to the majority of the Danish ports (except Bornholm).

Figure 4.18. Figure 4.18 Development in number of days at sea per vessel in the Danish fishing fleet, base scenario

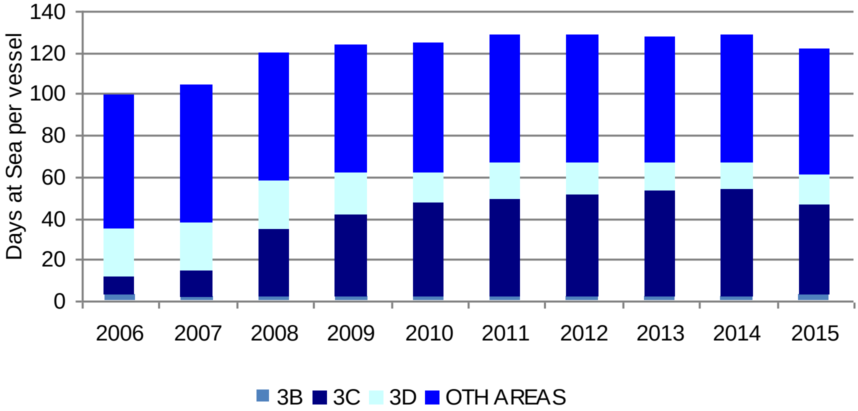
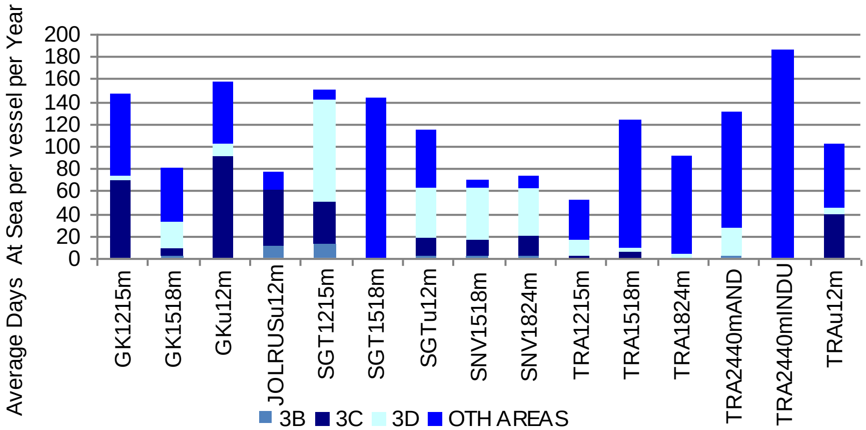


Figure 4.19 shows the average distribution of days at sea per vessel per year over the simulation period for each vessel group. It is seen that especially multipurpose vessels (SGT) 12-15m and below 12m (u12m) together with Danish seine (SNV) spend a large amount of their time in the eastern Baltic (3D), while multipurpose vessels 15-18m and large industrial trawlers spend all their time in other areas. Generally the trawlers spend most of their time in other areas, with the exception of the small trawlers (<12m) that spend some time in the eastern Baltic (3C).

Figure 4.19. Average days at sea per vessel per year over the simulation period, base case

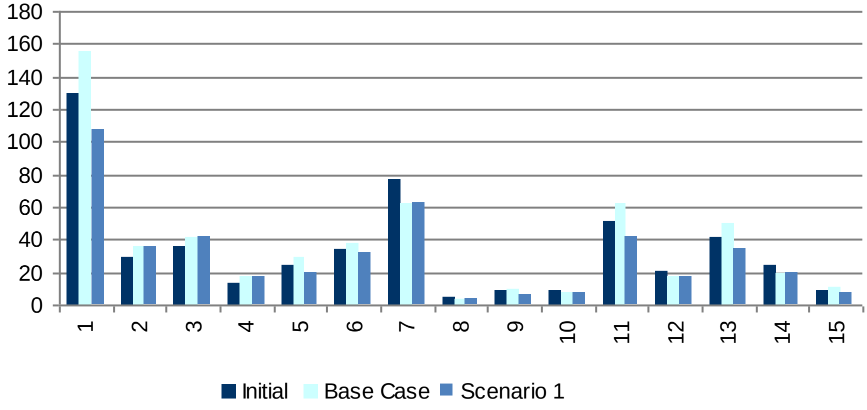


4.4.2. Extended closure of Bornholm and Gotland Deep (Scenario 1)

This scenario has extended closures around the current marine protected areas in the Bornholm and the Gotland Deep, corresponding to closing 8 of the 58 ICES squares in the eastern Baltic (3D) throughout the year. Especially the area around the Bornholm Deep is characterised by large catches and CPUE for the included Danish fleets. It is in this scenario assumed that the total cod catches taken by the other nations in 3D are scaled down with a factor 50/58, i.e. that these catches are distributed homogeneously over the eastern Baltic and are therefore proportionally reduced by the closure of 8 ICES squares. Closure of these areas is thus expected to have a positive impact on the spawning stock biomass, but a negative impact on the economic performance of the included fleets.

Figure 4.20 shows the average number of vessels per year during the simulation period in fleet segment in scenario 1 and in the base scenario together with the initial number of vessels in each group. It is seen that the average number of vessels in scenario 1 either stays equal to or decreases relative to the number of vessels in the base scenario for all vessel groups. No increase in number of vessels relative to the base case is observed. Thus the extended closures seem to lead to reduced overall capacity in the Danish fleet, compared to the optimal status quo situation. It should also be noticed that the optimal number of vessels in scenario 1 is lower than the initial number of vessels for most vessel groups, except some of the smaller vessels. Thus extended closures in the Baltic may lead to a general decrease of the Danish fleet when compared to the present situation.

Figure 4.20. Average number of vessels per year in Scenario 1 and in the base scenario, together with the initial number of vessels (2005)



The total maximum profit (measured in present values) in scenario 1, defined as catch revenue minus variable and fixed costs, summarised over the optimisation period of the included vessels is DKK 3,640 millions (€ 489 millions) for the total fleet, i.e. a reduction of 43% compared to the base scenario. Figure 4.21 shows the average profit per vessel in the Danish fleet in scenario 1 and in the base scenario measured in present values and summarised over the optimisation period. It is seen that with few exceptions all vessel groups experience decreasing profitability under the extended closures when compared with the status quo situation. Three vessel groups even go from positive to negative profitability. The exceptions are the small dinghys (JOLRUSu12m) and small multi-purpose vessels (SGTu12m) that experience increases in profitability during the period.

Figure 4.21. Average present value profit per vessel summed over the optimization period (millions DKK) in the scenario 1 and in the base scenario.

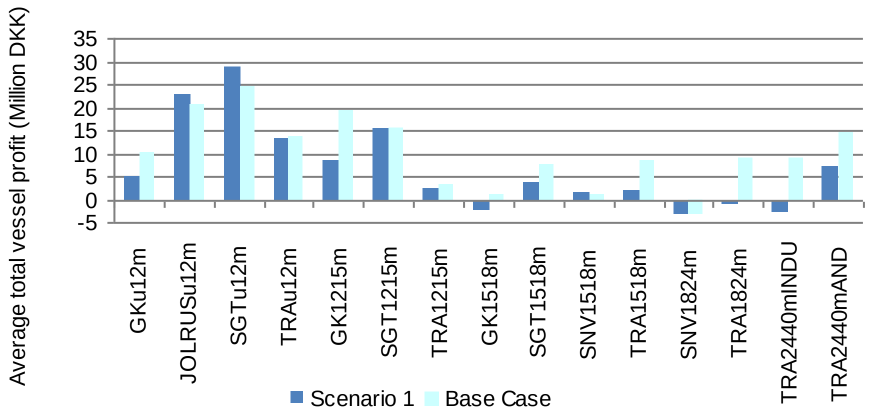


Table 4.9 shows the total catch value per vessel summed over the ten years optimisation period in Scenario 1. Cod is still the most important species, followed by herring. Comparison with table 4.8 shows that the catch value of cod has increased in all three areas. The largest relative increase compared with the base case is in area 3B where the cod catch value has increased with 116%. In area 3C and 3D the cod catch value has increased with around 52%. Contrary to this the catch value of the other species has all decreased significantly compared with the base case. It is interesting to notice that the Danish fleet stops fishing Sprat in area 3C in this scenario.

Table 4.9. Total catch value per vessel (millions DKK, present values), distributed over species groups and summed over the optimisation period, scenario 1

	COD	HER	SPR	OTH
3B	14.81	0.00	0.00	0.00
3C	45.54	7.04	0.10	0.00
3D	52.50	0.39	0.96	0.00

Figure 4.22 shows the distribution of the catch value of cod per vessel in the Baltic areas for the different vessel groups, summed over the optimisation period. This is shown both for Scenario 1 and for the Base case, with the left hand columns for each vessel group representing scenario 1. It is seen that the two vessel groups that primar-

ily catch cod in 3D in the base case, namely SGTu12m and SGT1215m (multipurpose vessels below 12m and 12-15m) still catch a significant amount of cod in 3D but also starts catching cod in 3C. It is interesting to notice that vessel groups that caught none or little cod in 3D in the base status-quo scenario increase their catches of cod in this area. This is probably connected to the increased stock of cod in 3D (cf. below) resulting from the extended closure.

Figure 4.22. Total Cod catch value (million DKK, present values) per vessel in the Baltic areas summed over the optimisation period, Scenario 1 (left hand columns) and base case.

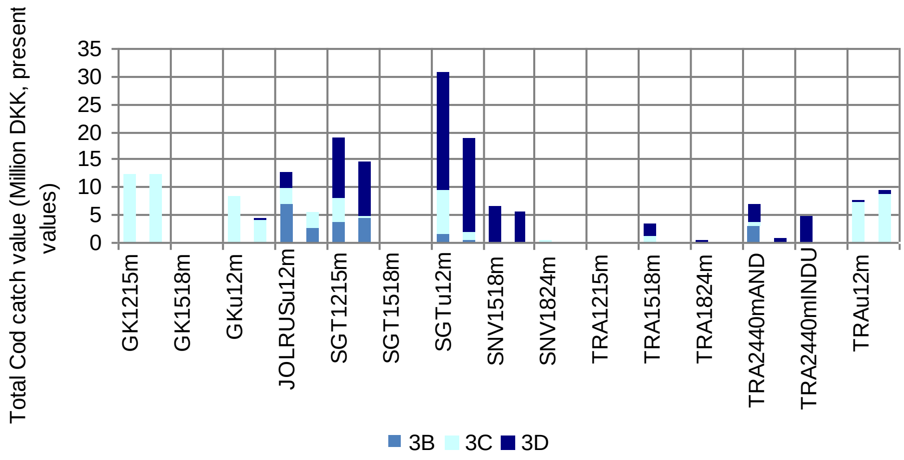


Figure 4.23 shows the development in cod spawning stock biomass (SSB) in the eastern (3D) and western (3B+3C) Baltic during the modelling period in scenario 1. Figure 4.23 shows SSB in scenario 1 relative to the SSB in the base case. The cod stock in the eastern Baltic reaches the precautionary level within 4 years with the extended closure assumption. This is an improvement compared to the base case where it takes 7 years for the 3D stock to reach the precautionary limit. Generally the stock in 3D is higher in the case of extended closures than in the status quo case, cf. figure 4.17. The stock in the western Baltic also rises above the base case stock after 6 years, which is probably a consequence of changed fishing patterns due to the closure in 3D.

Figure 4.23. Development in cod spawning stock biomass (SSB), scenario 1 (1000 tonnes)

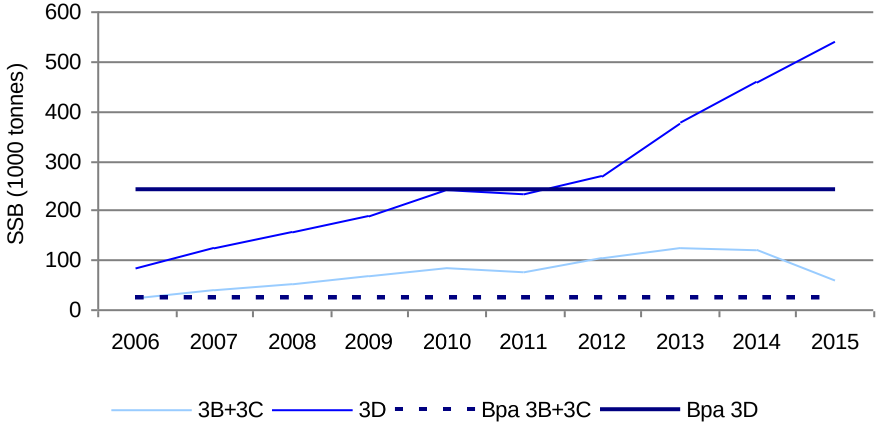


Figure 4.24. Cod spawning stock biomass (SSB) in scenario 1 relative to SSB in base scenario

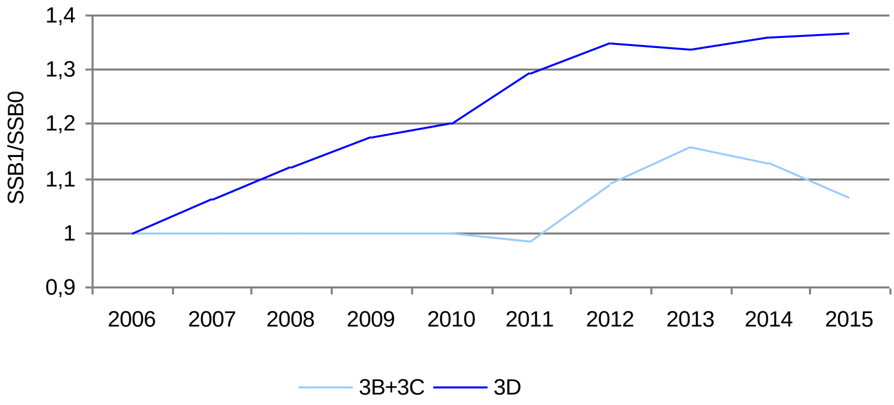


Figure 4.25 shows the average number of days per sea per vessel in the total Danish fleet in each of the simulation years in scenario 1 and in the base scenario. The average number of days at sea used by a vessel in the fleet is lower relative to the base case throughout the simulation period when additional closures are introduced in the eastern Baltic (3D). The cause of this is especially a decrease in effort in other areas,

while the effort in both the eastern and western Baltic increases some in scenario 1 compared to the base case. The latter effect is expected as the stock in both areas increases during the simulation period (cf. figure 4.23). The effort in 3B is unchanged compared to the base case.

Figure 4.25. Development in number of days at sea, scenario 1 and base scenario

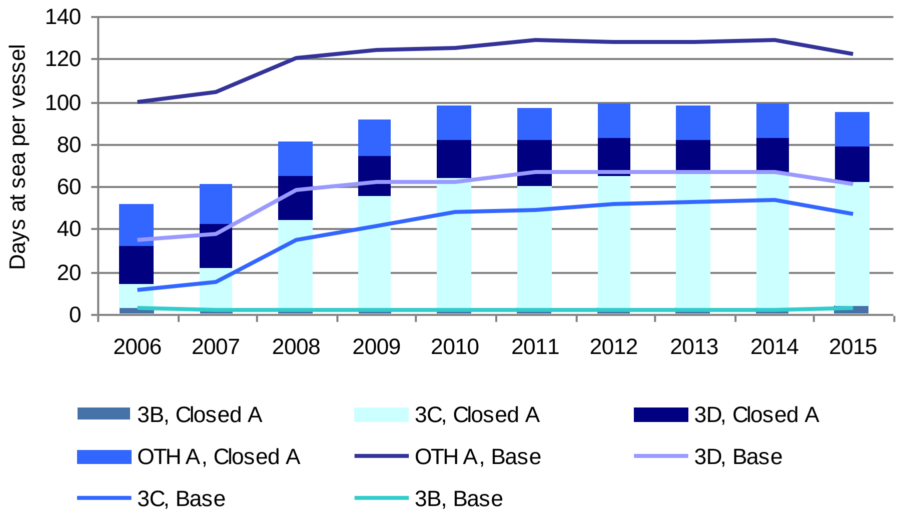
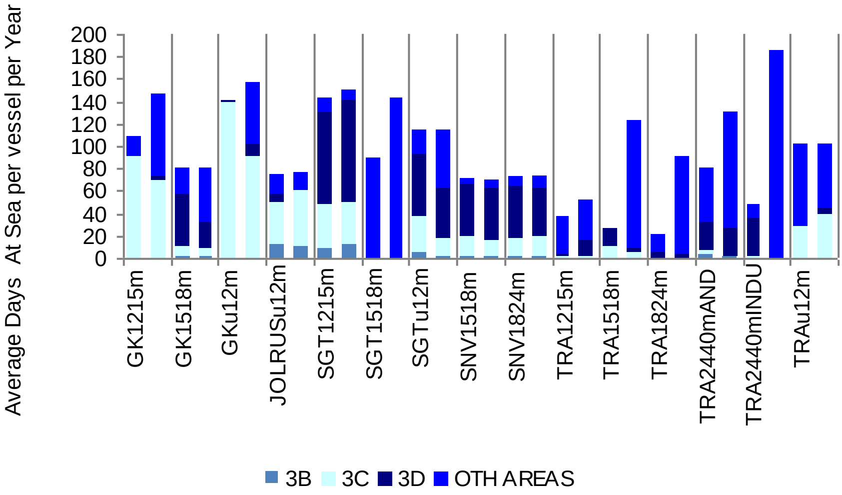


Figure 4.26 shows the average number of days at sea per vessel per year in each of the vessel groups in scenario 1 and in the base scenario. The base case results are the columns on the right for each vessel group. It is seen that most vessel segments reduce their average yearly fishing time in other areas in scenario 1 compared to the base scenario, which may be caused by the increasing fishing possibilities for cod in 3D when the stock increases. Especially the large industrial trawlers (TRA2440mINDU) and the liners and gillnetters between 15 and 18 (GK1518m) m increase their effort in 3D in scenario 1, while the remaining segments keep approximately the same effort in 3D in the two scenarios. The effort increase in 3C is caused mostly by liners and gillnetters 0-15m (GKu12m and GK1215m).

Figure 4.26. Average days at sea per vessel per year over the simulation period, scenario 1 (left hand columns) and Base case (right hand columns)

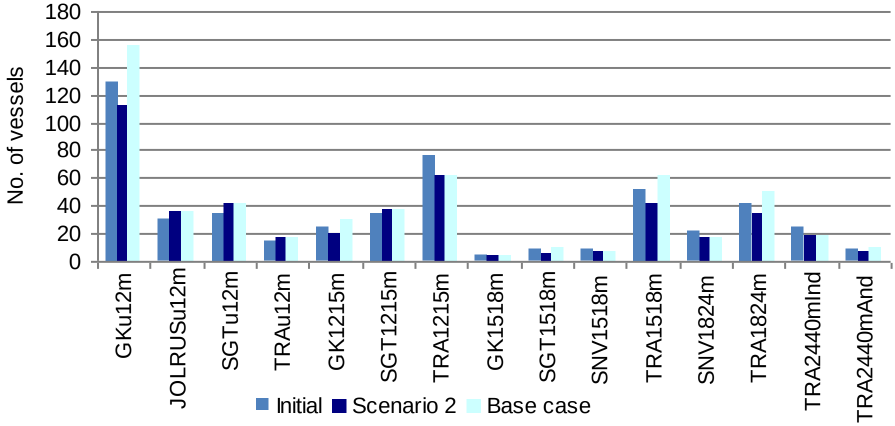


4.4.3. Extended closure of the Bornholm Deep (Scenario 2)

As mentioned above this scenario has kept the extended closures of scenario 1, but extend the closure around the Bornholm Deep even further, such that most of ICES area 25 is now closed to cod fishery. In all 13 out of the 58 squares in the eastern Baltic (3D) is now closed throughout the year. As in scenario 1 it is assumed that the total cod catches taken by the other nations in 3D are scaled down with a factor 45/58, i.e. that these catches are distributed homogeneously over the eastern Baltic and are therefore proportionally reduced by the closure of 13 ICES squares.

Figure 4.27 shows the average number of vessels per year over the simulation period for each vessel group in scenario 2, together with the initial number of vessels in 2005 (table 2.3) and the number of vessels in the base scenario. As in scenario 1, the average number of vessels in scenario 2 is either equal to or lower than the average number of vessels in the base scenario. Thus again the optimal capacity of the Danish fleet decreases with the increased closures in the eastern Baltic.

Figure 4.27. Average number of vessels over the simulation period in Scenario 2 and in the base scenario, together with the Initial (2005) number of vessels.



The total maximum profit in scenario 2 summarised over the optimisation period of the included vessels is DKK 3,689 millions (€ 495 millions) for the total fleet, i.e. approximately the same as in scenario 1. Figure 4.28 shows the average profits per vessel in scenario 1 and 2, and in the base scenario, measured in present values and summarised over the optimisation period. It is seen that the aggregated profitability of most of the larger vessel segments (>12m) is lower in both scenarios when compared with the base case. The exception is the multipurpose vessels 12-15m (SGT1215m) that have a higher total profitability with the extended closure of the Bornholm Deep compared to both the base case and to scenario 1. For the small vessels the picture is more mixed. All of these, except the multipurpose vessels below 12 m (SGTu12m) have a small increase in profitability in scenario 2 compared to scenario 1. The small dinghys (JOLRUSu12m) and the small trawlers (TRAu12m) moreover also have a small increase in profitability when compared to the base case.

Figure 4.28. Average present value profit per vessel summed over the optimization period (Million DKK) in the scenario 2, scenario 1, and in the base scenario.

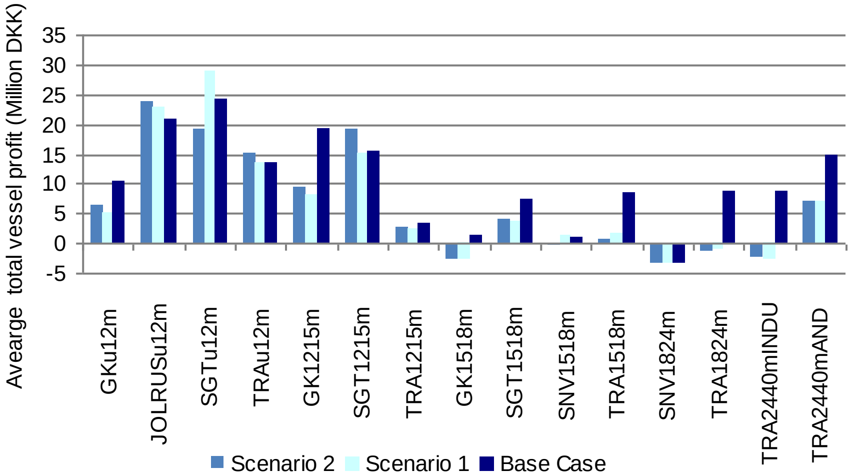


Table 4.10 shows the catch value per vessel distributed over the species groups and areas in the Baltic, summed over the optimisation period. It is interesting to notice that the catch value distribution in scenario 2 is closer to the base case than to scenario 1 i.e. that while the extended closures in scenario 1 resulted in a significant increase in cod catch value in 3D, extending these closures even further around the Bornholm Deep leads to decrease of this catch value again. Cod is still the most important species in 3C and 3D while herring and cod are equally important in 3B. The catch value of cod has increased in 3D compared to the base case, but not as much as in scenario 1. And contrary to scenario 1, the catch value of cod in 3C is the same in scenario 2 as in the base case.

Table 4.10. Total catch value per vessel (millions DKK present values), distributed over species groups and summed over the optimisation period, Scenario 2

	COD	HER	SPR	OTH
3B	6.90	7.19	0.00	0.00
3C	29.81	12.71	6.37	0.09
3D	42.59	11.33	0.43	0.39

Figure 4.29 shows the distribution of the catch value of cod per vessel in the Baltic areas for the different vessel groups, summed over the optimisation period. This is shown both for Scenario 2, Scenario 1 and for the Base case. The total catch value of cod decreases for most vessel groups in scenario 2 when compared to scenario 1, with the exception of multi-purpose vessels 12-15m (SGT1215m) and small trawlers (TRAu12m). Both these groups have increasing catch value of cod in the eastern Baltic when compared to scenario 1 and the base case, which is also true for the dinghys (JOLRUSu12m). But generally it can be concluded that the catch value of cod in the Baltic areas will, with few exceptions, decrease for a vessel in the Danish fleet with the extended closure of the Bornholm Deep.

Figure 4.29. Total cod catch value (million DKK, present values) per vessel in the Baltic areas summed over the optimisation period, scenario 2 (left hand columns), Scenario 1 (middle columns) and base case (right hand columns).

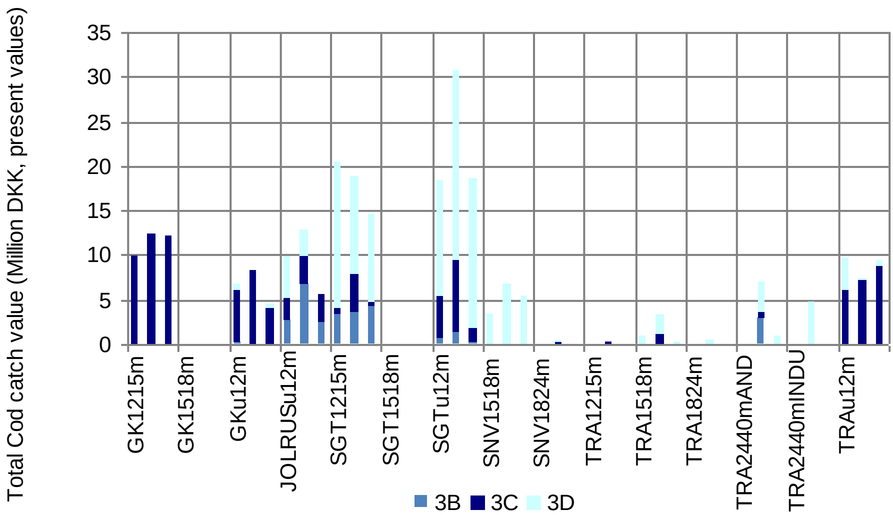


Figure 4.30 shows the development in cod spawning stock biomass (SSB) in the eastern (3D) and western (3B+3C) Baltic during the modelling period in scenario 2. Figure 4.30 shows SSB in scenario 2 relative to the SSB in the base case. As in scenario 1 the cod stock in the eastern Baltic reaches the precautionary level within 4 years, but the stock generally increases faster and to a higher final level in scenario 2 when

compared to scenario 1. This is seen by comparing figure 4.30 and 4.23. The development of the cod stock in 3C in scenario 2 resembles the pattern seen in scenario 1.

Figure 4.30. Development in cod spawning stock biomass (SSB), scenario 2 (1000 tonnes)

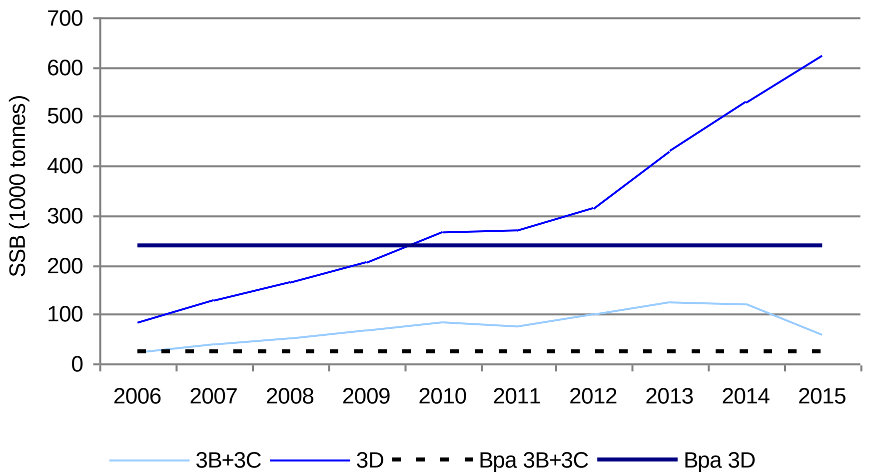


Figure 4.31. Cod spawning stock biomass (SSB) in scenario 2 relative to SSB in base scenario

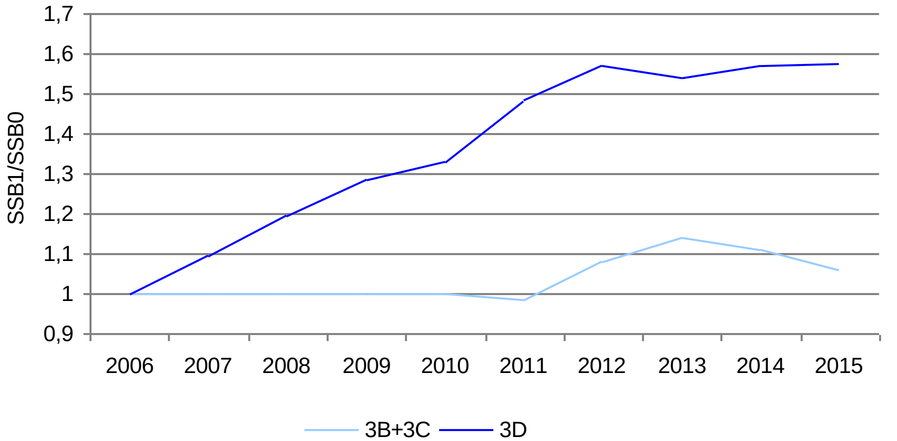


Figure 4.32 shows the average number of days per sea per vessel in the total Danish fleet in each of the simulation years in scenario 2 and in the base scenario. As in scenario 1, the average number of days at sea used by a vessel in the fleet is lower relative to the base case throughout the simulation period. Again, this is mostly caused by a decrease in effort in Other Areas, while the effort in both the eastern and western Baltic increases some in scenario 2 compared to the base case. Comparison with figure 4.25 shows that the effort used in the eastern Baltic increases compared with scenario 1 while the effort in 3C stays more or less unchanged. This additional increase of effort in 3D is again believed to be caused by the increased stock and thus catches in 3D in the later years of the simulation period.

Figure 4.32. Development in number of days at sea, scenario 2 and base scenario

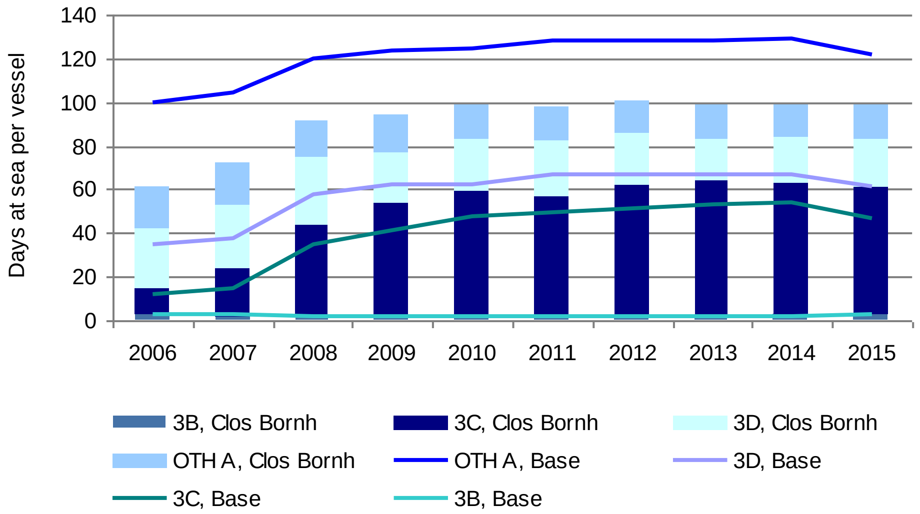
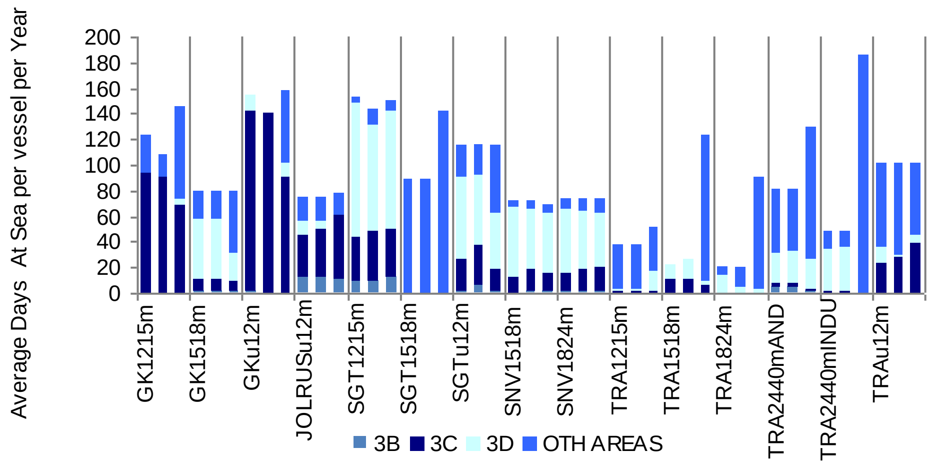


Figure 4.33 shows the average number of days at sea per vessel per year in each of the vessel groups in scenario 2, scenario 1 and in the base scenario. The scenario 2 and scenario 1 distribution of sea days does not differ much but for most fleet segments significantly from the base scenario.

Figure 4.33. Average days at sea per vessel per year over the simulation period, scenario 2 (left hand columns), Scenario 1 (middle columns) and base case (right hand columns)



4.5. Summary and conclusion

The fishery in the Baltic Sea is characterised by several things: 1) it is mainly focused on three species cod, herring and sprat; 2) many different types of gear is used: trawl, Danish seine, nets; and 3) fishermen comes from all nations around the Baltic Sea. These complexities of course influence how to analyse the economic consequences of marine protected areas in the Baltic Sea. Therefore, a bioeconomic model is required for the analysis. In bioeconomic models, functional relationships are thus established between the specific biological characteristics of the fish resource and the economic behaviour of the fishermen using the resource.

A bioeconomic model has been setup in order to analyse the consequences of marine protected areas in the Baltic Sea. The acronym of the model is BEMCOM (Bio-Economic Model to evaluate the COnsequences of Marine protected areas). BEM-COM is a flexible modelling framework, which is programmed in a generic way and can handle different case studies through the utilised dataset and parameter values. It is an optimisation model and it is programmed in GAMS (General Algebraic Modelling System).

In order to quantify BEMCOM to the Baltic Sea case study, data has been collected from ICES, The Danish Directorate of Fisheries and the Institute of Food and Resource Economics. It has unfortunately not been possible to obtain detailed data from other countries besides Denmark in order to reach the necessary level of detail required in BEMCOM. Only Danish vessels are therefore currently included, but as more data becomes available in the future, vessels from other nations can be included as well. At present total cod catches in the Baltic Sea is approximated by adding a constant catch amount for the other countries surrounding the Baltic Sea.

Because the recovery of cod has primarily been in focus, when discussing use of closed areas in the Baltic Sea, stock development of Baltic cod (eastern and western stock) has been evaluated in the present context. Catches of the remaining species both in- and outside the Baltic Sea have however been included in order to evaluate total profit of the fleets in question.

Three scenarios have been investigated, both run over a ten year time period. The first scenario is considered to be a status quo situation, where it is assumed that the current regulation in the Baltic Sea continues, thus the current closed areas in the Baltic Sea continues to be in place. Secondly, because fishing continues around the borders of the status-quo closures, thus taking any spill over of cod, the second scenario considers extended closures around the Bornholm and the Gotland Deep. Finally, seeing that the Bornholm Deep is the most important spawning ground for eastern Baltic cod, a third scenario has been considered, that assumes an even more extended closure around the Bornholm Deep.

To assess the economic efficiency of the Danish fishing fleet in the three scenarios, the net present value of total profits, defined as discounted catch revenue minus variable and fixed costs summed over the 10 year period, has been maximised for the Danish fleet in each scenario. The maximisation is done under a range of restrictions including maximum and minimum number of days at sea per vessel and expected quotas.

In the base status-quo scenario the total net present profit for the Danish fleet is DKK 6,331 millions (€ 850 millions). In scenario 1 (extended closures around the Bornholm and the Gotland Deep) and scenario 2 (further extension of the closed area around the Bornholm Deep) the values are DKK 3,640 and 3,689 millions (€ 489 millions and € 495 millions) respectively. As such the scenario evaluations indicate that extending the marine protected areas in the Baltic Sea will decrease the economic efficiency of the Danish fishing fleet. This is not a surprising result, because vessels are excluded from fishing areas with high catch and CPUE levels around the deeps, and are thus forced to fish in areas that are less attractive.

On the other hand the model evaluations also show the desired recovery of the eastern Baltic cod stock, and it can therefore be concluded that extending the marine protected areas will be good for the fish, but economically bad for the fishermen. However, it must be noted that this conclusion depends on the assumptions and restrictions made.

5. Participatory governance in the western shelf northern hake fishery

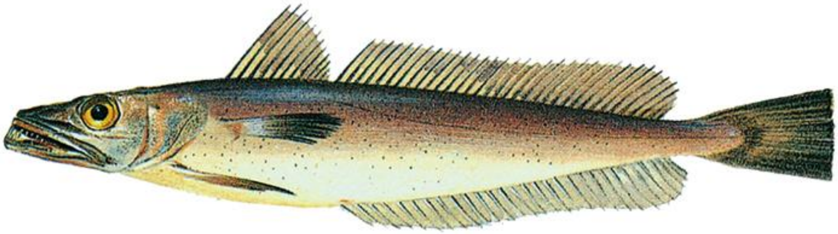
5.1. Introduction

Underreporting and discards are two of the main problems in the assessment of Northern stock of hake. The catch of younger ages is completely discarded and there is no reliable data to obtain reliable estimates of discard time series. So discards are not taken into account in the assessment and management of this stock. There is no data to quantify the underreporting but it is believed that it would be around 30% of the total catch. These two facts introduce bias in the assessment of the stock and would lead to the failure of the management. Participatory governance and effort management regimes would contribute to obtain reliable discards estimates and to reduce the underreporting. Improvement in data quality and reduction of underreporting would improve the management of the stock, obtaining in the long term a healthy stock. In turn a healthy stock would lead to a more economically efficient fleet. In this work we analyze, by means of simulation, the economic efficiency of Basque fleets targeting hake under TAC and effort based management regimes combined with participatory governance.

5.2. The stock

European hake (*Merluccius merluccius*) see figure5.1, is a commercially exploited top predator gadoid species. It is widely distributed from Norway to Mauritania and from the Mediterranean to the Black Sea (Svetovidov, 1986). ICES assumes two different stock units: the so-called Northern stock, in division IIIa, Subareas II, IV, VI and VII and divisions VIIIa,b,d, and the Southern stock in divisions VIIIc and IXa, along the Spanish and Portuguese coasts. The main argument for this choice was that the Cap Breton canyon (close to the border between the Southern part of division VIIIb and the more eastern part of division VIIIc, i.e. approximately between the French and Spanish borders) could be considered as a geographical border limiting exchanges between the two populations. See map about the ICES fishing areas (figure 5.2).

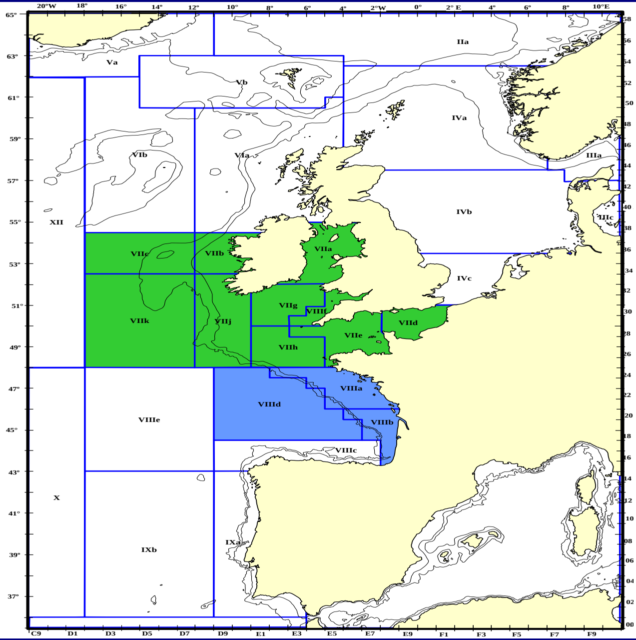
Figure 5.1. European hake (Merlucius merlucius)



Northern hake has been commercially exploited since the 18th century (Casey & Pereiro, 1995), with annual catches ranging from 40 000 to 96 000 tones during the period 1961-2007. Hake fishery is, economically, a very important fishery to Spain and France which account for the 60% and 27% of the total landings respectively. Hake is caught together with other species such as monkfish, megrim, *Nephrops* and sole. The fleet is mainly composed by trawlers, gillnetters and longliners. Hake discarding in youngest ages is high for some fleets, but due to lack of data, reliable estimates of discard time series are not available. (ICES, 2008).

According to the ICES assessment of this stock, the population size of Northern European hake showed a steep decline during the beginning of the 1990s and the present level is considered to be only 60% of the maximum historical estimate. The stock is managed by a TAC and quotas system with some technical measures associated. A minimum landing size at 27 cm was set in 1998 for all areas, except for the Skagerrak/Kattegat area in which it was set at 30 cm (Council reg. 850/98). Due to the critical state of the population an Emergency Plan was introduced in June 2001 (Council reg. 1162/2001). The aim of the plan was to protect juveniles, limitations of minimum mesh sizes for some gears were imposed; these limitations were dependent on the geographical area, the amount of hake landed and the technical characteristics of the vessel. Since 2004, a recovery plan is in force which objective is to obtain, in two consecutive years, levels of mature fish above B_{pa} at 140 000 tonnes, (Council reg. 811/2004). According to last ICES assessment (ICES, 2008) the objective of the plan has already been achieved, so it is foreseen to be replaced by a long term management plan by 2009 (STECF 2007a, STECF 2007b). The long term management plan proposed are focused in achieving a fishing mortality level in accordance with maximum sustainable yield by 2015, in agreement with Johannesburg Plan of Implementation (2002).

Figure 5.2. Map of the ICES statistical fishing areas of the Northeast Atlantic.



5.3. The Basque fleet

Two different fleets exploit northern hake in the Basque Country, “Baka” trawlers and pair trawlers. “Baka” trawlers can be defined as a single vessel which trawls a bottom net operating in contact with the seabed. In this case trips last on average 6 days depending on the area being fished, and the haul duration is between 4 and 5 hours. Catches are generally landed in Basque ports (Ondarroa and Pasaia) and in French, Scottish and Irish ports from where the catch is transported by trucks to be sold on local Basque markets.

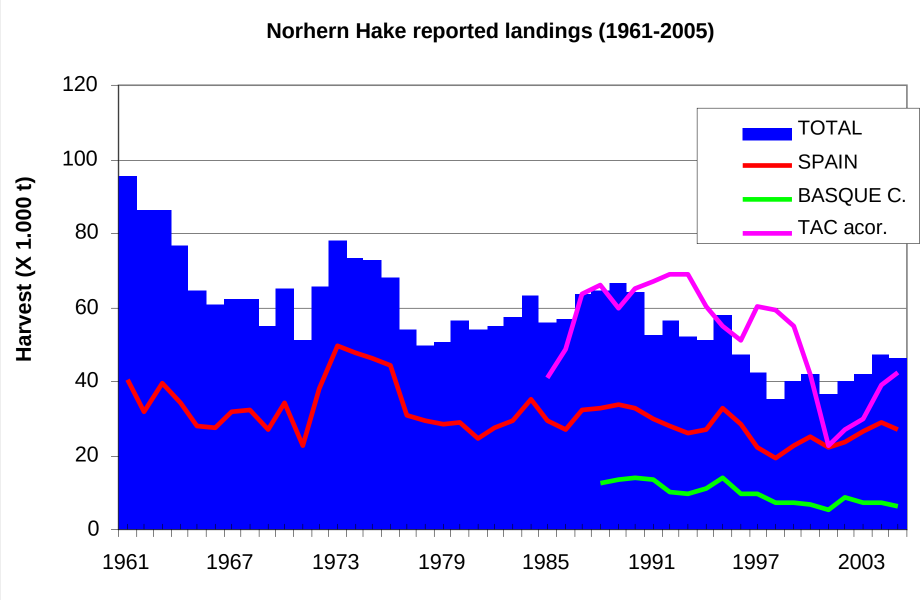
On the other hand, bottom pair trawlers are composed by two vessels trawling a single VHVO net between 25-35 meters high and 75 to 90 meters wide. The average number of days for a trip is 5 or 6. The duration of the haul is longer than that of the otter trawls taking 7-8 hours on average for each haul.

The main differences between the two fleets, in terms of the fishing, are given by the catch profile and the cost structure.

The main characteristic of the Basque fisheries together with the biological status of the stock have conditioned their historical economic performance. Beginning with the technical characteristics the Baka otter trawlers are vessels with a mean length at 32 m, mean power at 812 HP, mean GT at 224 and a mean age at 17 years employing 10 to 12 crewmembers. The VHVO pair trawlers are vessels with a mean length at 32 m, mean power at 907 HP, mean GT at 247 and mean age at 22.4 years.

The annual catches for Basque fisheries related to the international catches are around a 20% of the TAC (Figure 5.3), being higher for Pair than for Baka trawler which determines the different economic performance between both fleets. However, for both of them the assigned quota and so the total catches put in evidence the great importance of both fleets given the small number of fleets composing the fishery table 5.1.

Figure 5.3. Basque landings of northern hake.



Economic performance also depends on the landing composition, and in this sense Baka trawlers could be considered to be executing a mixed fishery given that only 8-9% of their catches are due to the hake stock. This percentage goes up to more than the half of the catches for the pair trawlers, which is then considered as a single fishery.

Table 5.1.	Economic indicators per vessel for the Basque fleets targeting northern hake					
	2000	2001	2002	2003	2004	2005
Baka						
Value of hake landings (1000 €)	130	97	144	97	123	89
Revenue (1000 €)	725	532	565	615	580	635
Crew share (1000€)	392	323	323	335	375	425
Gross Cash flow (1000 €)	7	-126	-92	-39	-184	----
Net Profit (1000 €)	-123	-245	-211	-404	-594	----
Volume of hake landings (tonnes)	37	24	31	22	32	38
Number of vessels	28	27	24	21	21	17
Pair trawlers						
Value of hake landings (1000 €)	664	697	961	893	772	924
Revenue (1000 €)	809	818	1094	1027	838	949
Crew share (1000€)	311	332	332	361	361	----
Gross Cash flow (1000 €)	184	193	468	329	127	----
Net Profit (1000 €)	-15	23	298	70	-243	----
Volume of hake landings (tonnes)	214	219	317	276	253	304
Number of vessels	25	19	21	20	20	18

5.4. Actual management regime

It must be stressed that several management tools are combined under the northern hake management. These tools are:

- Northern hake stock is managed by a TAC and quotas.
- Technical measures associated such as minimum mesh size in some areas for some gears and minimum length in landings (Council reg. 850/98). The minimum legal sizes for fish caught in Sub areas IV-VI-VII and VIII is set at 27 cm total length (30 cm in division IIIa). First, a 100 mm minimum mesh size has been implemented for otter-trawlers when hake comprises more than 20% of the total amount of marine organisms retained onboard. This measure did not apply to vessels less than 12 m in length and which return to port within 24 hours of their most recent departure. Second, two areas have been defined, one in subarea VII and the other in subarea VIII, where a 100 mm minimum mesh size is required for all otter-trawlers, whatever the amount of hake caught.
- Furthermore, in November 2000, ICES announced that the northern hake stock was in serious danger of collapse and from 14th of June 2001 an emergency plan was implemented by the Commission for the recovery of the northern hake stock (Council reg. 1162/2001, 2602/2001 and 494/2002). The objective of the northern hake stock recovery plan is to increase the level of spawning biomass of this stock. Once the target level has been achieved the

Commission will introduce follow-up management measures replacing the recovery plan.

- A TAE (total allowable effort) system, which is introduced previous to the TAC regulation, is being used. It works as follows: In 1981 it was decided to list all the Spanish vessels operating in divisions VIIIabd and sub-areas VI and VII in order to create access rights to these fisheries (a single fishing right per vessel). The idea was to maintain the level and fix these rights even if the number of vessels decreased. When Spain joined the EU in 1986 the number of vessels in that list was close to 300 and the so-called “300 list” or the “300 fleet” was created. These fishing rights became transferable by area, and the system continued nowadays. Currently, there are several negotiations going on to decide whether this system will continue or not.

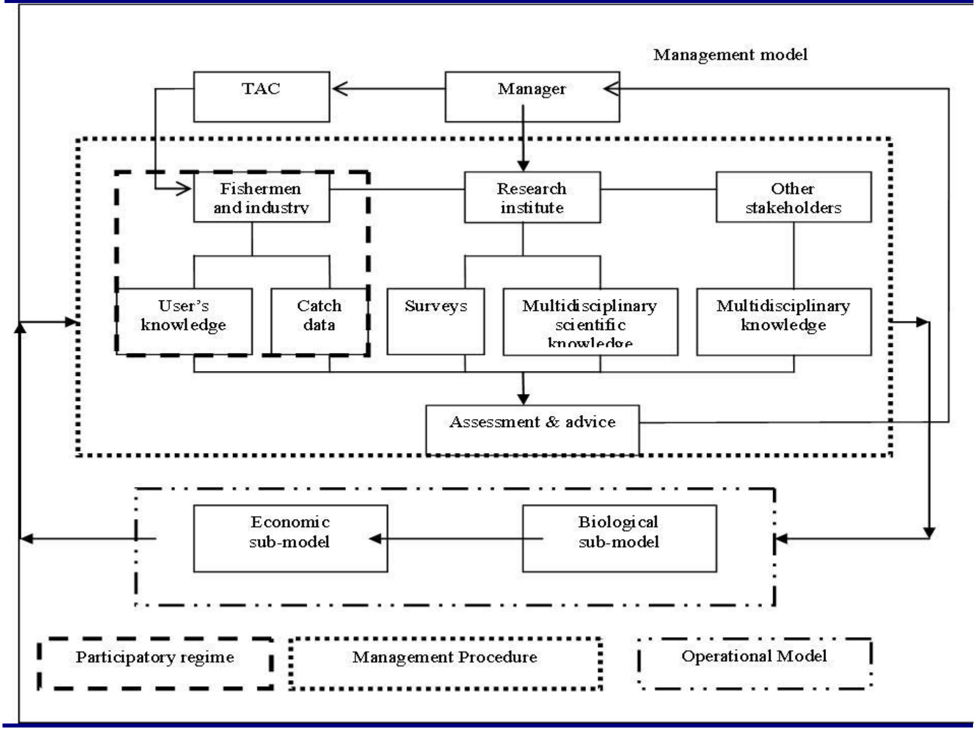
5.5. The simulation model

The main reason to focus on the particular fishery of the northern hake fishery exploited by Basque trawlers from Spain, among several fleets from other countries i.e. France, Ireland, and United Kingdom, is due to the fact that the process for managing the northern hake stock by the measures in section 5.4 has been modified recently by adapting to a new innovative participatory regime, through the two Regional Advisory Councils (RACs). With the creation of the North Western Waters Regional Advisory Council (NWW RAC), established in September 2005 and the South Western Waters Regional Advisory Council (SWW RAC), created in April 2007, this innovative participatory system was introduced and began to develop for the management of the northern hake.

Taking into account the specific characteristics of the northern hake, the effect of the management strategy of introducing a participatory regime on the economic efficiency of the Baka and pair trawler fleets is tested. With this aim, a management procedure is considered together with an operational bio-economic model that has been implemented to allow for simulating the real world, that is, real stock population and other key variables in the past and in the future. This framework has been developed by the work package five of the CEVIS project. The management procedure evaluation framework has been represented by figure 5.4 based on Aranda et al. 2006.

Following Kell et. al, (2006): *Management Strategy*: refers to the combination of specific management objectives and associate implementation measures. *Management Strategy Evaluation (MSE)*: refers to the simulation of some or all elements of a management strategy. *Management Procedure (MP)*: assess status of stock and set management options depending upon perceived status of the stocks. *Operational Management Procedure (OMP):* developed through an Operating Model which represents the "real/true" dynamics of the stocks and fisheries. *Management Procedure Evaluation Framework (MPEF):* simulation framework.

Figure 5.4. The Evaluation Framework for TAC setting.



The operational model consists of two sub-models: 1) a biological sub-model based on an age structured population and three different fleets harvesting the resource: Baka, pair trawler and a third category that covers other fleets, and 2) an economic sub-model. The economic sub-model considers the fishing mortality function specified within the biological sub-model which is linearly dependent on effort (fisher behaviour is not considered within the model).

The management procedure allows for simulating data sample for the assessment which permits estimating the population (using XSA). Finally, management advice is produced: a harvest control rule based on a fishing mortality target setting the objective.

The economic sub-model includes price functions for the target species: hake, megrim and anglerfish according to the EIAA model (STECF 2007b). For the rest of the species the price is taken as a constant. The multi-species nature of the fishery is not covered by the objective of this study, and so the economic effect of the innovative regime is only analysed for the northern hake stock within the context of the mix-fishery.

Additionally, cost indicators (variable and fixed) are used to evaluate historical economic performance of the fishery from 1992 to 2006 and to develop future economic performance projections from 2007 to 2040. In particular, economic performance has been measured for the fleets in the short term and in the long term by means of the following indicators: hake revenue, total catch revenue, gross cash flow, gross surplus, net surplus, financial profitability, full equity profit, net present value, and the break even revenue.

Finally, it should be mentioned that fleet behaviour is included in the sense that the collapse of some iteration can cause a tactical reaction of the fleet.

5.6. The management scenarios tested

Hypothesis:

- The management through participatory governance is just starting recently with the establishment of the South Western Regional Advisory Council (RAC) in which the fishing industry groups are being organised to participate from the beginning in the assessment and decision process. We assume that the participatory governance will improve the quality of the input data to the assessment both in terms of reduced bias and reduced uncertainty. This improvement will, principally, be reflected in the reduction of the unreported landings and inclusion of discard data.
- Controls on fishing effort, as an innovative management measure, appear to be more likely to succeed than the TAC and quota system when managing mixed fisheries as northern hake. All vessels involved in hake fishery are currently monitored by satellite vessel monitoring system (VMS) and it would be relatively easy to use this system for control purposes. They have the ad-

vantage that they address an input to the fishery, i.e. fishing effort. They also address fisheries rather than individual stocks.

- Four different management scenarios have been analysed depending on the different hypothesis related to the introduction of the participatory TAC and/or effort regime.
- A base case *(bc)* is evaluated under which the fishery is managed by traditional tools; that is by means of TAC without considering a participatory governance. The historic levels of underreporting are maintained and discards estimates are not available.
- A second scenario *(tac.pgov1)* is evaluated by assuming the introduction of participatory innovation which will permit 100% observation of the discard data at ages 0, 1 and 2 which is not included in the traditional assessment base for fixing the TAC.
- A third scenario *(tac.pgov2)* is evaluated by assuming that the introduction of the participatory regime implies not only that the discards are observed, but also that the fishermen's engagement in the management process for setting TAC (see figure 5.1) implies a reduction in the underreporting level.
- A fourth scenario *(eff.bc)* is analysed to evaluate the effect of effort management without participatory governance. The underreporting is reduced due to the effort management but discards estimates are not available.
- A fifth scenario *(eff.pgov2)* is analysed to evaluate the effect of the participatory regime by means of discard observations based on effort management, which will allow for comparison with respect to the introduction of the innovative regime based on the more traditional TAC system.

In general, reduction in discards and underreporting will contribute to decrease the differences between the real world and the observed one in terms of the economic performance of the involved fleets in the medium and long run. Notice that, under the observed world the catches are equal to the TAC while within the real one the catches could be above the TAC given the underreporting.

5.7. Results

Economic performance is analysed both in the short-run by means of the revenues, gross cash flow, gross surplus and gross added value and in the long-run by means of the financial profitability and the full equity profit. The following results are obtained:

I. *pgov1* (discard observation) and *pgov2* (discard and unreported landings observation) produce better economic performance than the base case (*bc*) TAC scenario, both in the short-run and in the long-run.
II. However, the *pgov2* system produces better economic performance than the *pgov1* but only in the long-run.
III. Introducing co-management regime based on an effort system the *eff.pgov2* is similar or little higher than *eff.bc* in the short run, while *eff.pgov2* is lower than *eff.bc* in the long run.
IV. *eff.bc* is the regime that assures the best economic performance in the long run for Baka, while *eff.bc* and *pgov2* provide the best result for pair trawlers, although *pgov2* is a little higher than *eff.bc* for several years.

Economic performance is also analysed through reference points as the net present value (NPV) among others:

I. For pair trawlers, the NPV is positive under the five scenarios, but higher within the *pgov2* than within the *pgov1* and the *bc*; and higher in the *eff.bc* than the *eff.pgov*.
II. For Baka trawlers the NPV related to the *bc* is negative while being positive for other scenarios, being higher for *pgov2* than *pgov1*, and higher for *eff.bc* than *eff.pgov2*.
III. NPV under *eff.bc* produces better result than NPV under any TAC based scenario for Baka, and better result than NPV under TAC *bc* for pair trawlers.

In general, for both fleets effort management produces better economic performance than TAC management in the base case. Participatory governance (observed discards) improves economic performance in the TAC scenario; being even stronger when the underreporting level is reduced. Moreover, in the long run this improvement is higher the more profitable the fleet is (pair trawlers). Finally, participatory governance has a slightly negative effect on economic result in an effort scenario, see table 5.2.

Table 5.2. Traffic light system for the NPV (millions €)

Regime\ Year	2008-2028	2008-2032	2008-2034	2008-2040	2008-2010	2008-2014	2008-2028	2008-2040
TAC bc (base case)	-32	-34	-37	-39	128	54	196	359
TAC pgov1	-1.3	-0.8	-0.4	0.1	247	104	384	717
TAC pgov2	15	18	20	23	236	98	391	822
Effort bc	15	18	21	25	224	91	374	796
Effort pgov2	10	12	14	16	221	86	367	748

6. Economic consequences of effort management in the Faroese fisheries

6.1. Introduction

In order to assess the effect of effort control on the economic performance of fisheries, the case of the Faroe Islands fisheries has been considered. This case study investigates how the economic performance of Faroese long liners and pair trawlers is affected by the varying degrees of the innovative effort control systems introduced in the Faroese fisheries management in 1996. This is compared with the situation in which the Faroese fishery is assumed to be managed by a more traditional quota control. Two kinds of effort scenarios are considered. The first is a feed-forward simulation system, where the effort in a year is based on the situation for the stocks in previous years plus policy decisions regarding the proposed effort measure. The second effort scenario is an economic optimum scenario, where the effort each year is set to maximise the total net present value of the Faroese fishing fleets over the considered period.

In the simulation framework, the analysis of economic performance is carried out in two steps. In the first step, a simulation model developed by Baudron (Baudron, 2007) for evaluation of the biological effects of effort-based management in the Faroe Plateau cod fishery is run to obtain catch and effort distribution for the two fleet segments. These outputs are then used as inputs in the second step to evaluate economic performance given the evaluated effort or TAC-based management system. In the optimisation framework the Baudron-model, combined with the economic model, are run together over the modelling period, and optimised with respect to total net present value, by varying the yearly efforts of the two fishing fleets.

Within the 200 nautical miles economic zone (EEZ) for which the effort management applies the Faroese fishery is mainly focused on cod, haddock and saithe. Faroese pair trawlers, longliners and small trawlers/netters/jiggers dominate this fishery. The latter group is not covered by the cost and earnings statistics and is therefore the vessel segments considered in the present study are the pair trawlers and the longliners.

6.2. Management of the Faroese Fishery

Until 1959, all nationalities were allowed to fish in the Faroese waters outside a limit of 3 nautical miles. Throughout the 1960s, this zone was gradually expanded, ending at a 200 nautical miles EEZ in 1977 (ICES NWWG, 2007). In 1987, fisheries licenses were introduced. From 1994 to 1996, the fishery was regulated through individual transferable quotas with the aim to increase the stocks of Faroe Plateau cod and haddock to safe biological limits. The quota system was, however, met with considerable criticism and resulted in substantial discarding and in misreporting. Thus the Faroese Parliament abandoned the system in May 1996 and a new system was developed based on individual transferable effort (days) quotas within fleet categories. The new system was introduced in June 1996. It may be expected that such a system of effort control may increase economic performance compared to a quota system. The effect of the new system is, however, mixed, as the Faroe Plateau cod was still under safe biological limits in 2005 while the haddock stock had risen to a sustainable level.

The individual transferable effort quotas apply to (i) longliners < 110 GRT, jiggers, and single trawlers < 400 HP, (ii) pair trawlers, and (iii) longliners > 110 GRT. Of these pair trawlers > 400 HP and longliners dominate the fishery, and are therefore the fleet segments considered in the present work. Table 6.1 shows average (per vessel) economic performance and capacity indicators for the pair trawlers and longliners during the period 1999-2004.

Table 6.1. Economic and capacity indicators for the important Faroese pair trawlers and longliners. Per vessel

	1998	1999	2000	2001	2002	2003	2004	2005
Pair trawlers								
Value of landings (1000 €)	1168	1159	1359	1427	1483	1190	1140	1343
Crew share (1000 €)	512	530	578	632	641	468	464	501
Gross cash flow (1000 €)	273	260	262	251	302	129	146	146
Net profit (1000 €)	172	171	176	169	211	-32	-58	20
Effort (days at sea)	249	264	264	246	257	242	281	266
Volume of landings (tonnes)	1113	1192	1338	1497	1699	1683	1761	2057
Fleet - number of vessels	28	28	30	30	28	28	26	26
Long liners								
Value of landings (1000 €)	1731	1604	1410	1674	1949	1953	1642	1566
Crew share (1000 €)	996	935	818	937	1077	1060	821	764
Gross cash flow (1000 €)	217	197	146	220	223	268	127	126
Net profit (1000 €)	136	112	56	108	118	124	-28	-23
Effort (days at sea)	234	233	219	241	227	216	248	239
Volume of landings (tonnes)	1151	895	696	823	1061	1112	1084	892
Fleet - number of vessels	15	16	18	21	21	22	21	23

Source: Rasmussen and Weihe, auditing company

Table 6.1 shows that the capacity (number of vessels) is approximately constant for the pair trawlers while it has increased a bit for the longliners from 1999 to 2006. The net profit of the pair trawlers has decreased steadily during the period while it has stayed approximately constant for longliners until 2003, and then drops suddenly in 2004. The gross cash flow is positive for both segments throughout the period but decreases for the pair trawlers.

6.3. Model framework

The basis of the effort-based management scenarios considered in the present case study is the model developed by Baudron (Baudron, 2007) for evaluating biological effects of various effort-based management scenarios for the Faroese Pair Trawlers and Long liners. On top of this an economic module has been build to be able to evaluate the economic consequences as well. The biological model is described in detail in Baudron (2007), therefore only a short description of this will be given below, followed by an outline of the economic equations used to evaluate the economic performance.

6.3.1. Biological framework

The biological model consists of an operating model (OM) and a Management Procedure (MP). The OM simulates stock dynamics, including natural and fishing mortality. The MP simulates the observed, or perceived, world, i.e. what scientists can conclude about the true stock via catches, sampling and stock assessments based on these. The MP further includes the management decisions based on these perceptions. It should be clear that the management decisions taken in year *y* in the MP will influence the stock status in year *y+1* in the OM, i.e. that there is feedback between the two modules. The advantage of including both the OM and MP in the final simulation model is that this ‘allows testing of alternative management strategies before implementing with respect to both the intrinsic properties of natural systems and our ability to understand and monitor them’ (Kell et al., 2006).

In the present context, the OM model covers eight years of observed data (the historical period running from 1998 to 2005) and a ten years simulation period (2006-2015). In the historical period, the effort applied by the fleets (and the corresponding fishing mortality) is set equal to the historical reported measures, i.e. stock development and catches are evaluated based on the historical effort (and fishing mortalities), which gives the possibility to assess how well the model predicts the historical catches and assessed stocks. In the simulation period the effort is set based on the effort management-rules. The fishing mortality used in the historic period is based on data reported by ICES North-Western Working Group (NWWG) during this period. Likewise the stocks in the start year are set equal the stocks reported by NWWG in 1998. Finally natural mortality, maturity, and catch and stock-weights are equal to values reported by the NWWG. The OM assumes that discards are equal to zero as there are no historical discard data available.

The OM model runs in the following steps:

- Recruitment in year *y* is evaluated based on historical relationships between spawning stock biomass and recruitment, using a Ricker recruitment function.
- The stocks in year *y* are evaluated using the well-known biological projection equation based on stock, natural mortality and fishing mortality in the previous year.
- Fleet fishing mortalities in year *y* is set equal to stock selectivity times fleet catchability times fleet effort. The effort has been deduced by the MP based on previous years stocks, as will be outlined below.
- Total species fishing mortality is set equal to the sum of the fleet fishing mortalities.
- Fleet catch of each species in year *y* is evaluated using the well-known biological projection formula also used to determine the stock, together with the fleet fishing mortality.
- Total species catch in year *y* is set equal to the sum of the fleet catches.

The MP model is a simulation of the real management system based on observed catches and samplings. When management decisions are performed by working groups in the real world, there will always be a two year lag between data used for the decision and the TAC/effort decided upon. This time lag occurs because when the working groups meet in year *y* they have observed catch and sampling data available for year *y-1* only, and they use this to set the TAC/effort for year *y+1*. Thus the MP model runs in the following steps:

Based on the catches in year *y-1* XSA (virtual population) analysis is used to assess the stocks up until year *y-1*. This opposed to the ‘true’ stock set by the OM as described above. The decision makers can only get a ‘best guess’ of the OM stock based on the observed catches.

Given the perceived stocks in year *y-1*, the MP sets the effort (fishing mortality) for each species in year *y+1* based the harvest control rule (HCR) for this species. For all three species the HCR aims at keeping the stocks above safe biological limits using a target fishing mortality of 0.45 for all three species. On top of this an upper limit is set on how much the effort must vary from one year to the next. Thus the model ends up with three possible efforts for year *y+1*, one each for cod, haddock and saithe respectively.

Based on the efforts determined for each species in year *y+1* the MP model sets a final effort aim for the Faroese fleet in year *y+1* depending on the final management objective. This effort can be the minimum of the three efforts, thus protecting the most endangered stock (the one with the lowest fishing mortality). Or it can be the maximum effort, thus overfishing two stocks. Or some third measure, e.g. the effort giving the highest net present value for the total fishery in the period considered. The latter is the approach used in the optimisation scenario considered in the present context.

The final effort decided upon for year *y+1* is then divided between the fishing fleets according to an effort distribution key based on historical effort data for the Faroese fleet.

The biological model thus provides the catches of cod, haddock and saithe taken by pair trawlers and longliners during the simulation period, together with the effort used by each fleet in each year, and 'true' and perceived stock estimates. These are used in the economic module described below to evaluate economic performance of the fleets given the simulated management system.

6.3.2. Economic framework

In the economic framework landing value (revenue), crew share, other variable costs and cash flow is evaluated for each fleet each year of the simulation period. This is used to evaluate the total net present value (NPV) for each fleet in the simulation period including 2005, i.e. for the period 2005-2015.

The revenue for each fleet *Fl* in year *y* is given by:

(6.1) $$R_{Fl,y} = \sum_{sp} p_{sp} \cdot C_{Fl,sp,y}$$

I.e. the sum over the species (*sp*) of the price of that species times the fleet catch of the species in year *y*.

The crew share is assumed to be given by a constant share of the revenue, i.e. by:

(6.2) $$CS_{Fl,y} = cs_{Fl} \cdot R_{Fl,y}$$

where cs_{Fl} is the fraction that the crew on fleet *Fl* get of the total fleet revenue.

The other variable costs are given by:

(6.3) $$VC_{Fl,y} = vc_{Fl} \cdot E_{Fl,y}$$

where $E_{Fl,y}$ is the effort applied by fleet *Fl* in year *y* and vc_{Fl} is the variable cost per effort unit used by fleet *Fl*.

The cash flow (profit) taken by fleet *Fl* in year *y* is then given by:

(6.4) $$\Pi_{Fl,y} = R_{Fl,y} - CS_{Fl,y} - VC_{Fl,y}$$

Finally the net present value for each fleet over the simulation period plus 2005 is given by:

(6.5) $$NPV_{Fl} = \sum_{y=2005}^{2015} \frac{\Pi_{Fl,y}}{(1+r)^{y-2005}}$$

i.e. the total discounted rent over the period. In the optimisation framework, it is the sum of the NPV’s for each fleet segment that is the optimisation objective, determined by varying the fleet efforts from 2006 to 2015.

6.3.3. Biological data

The biological input to the model is based on observed data provided by the ICES North-western Working Group (NWWG). The initialisation data used for the three species are given in table 6.2, 6.3, and 6.4.

Tabel 6.2.	Initialisation data (year=1998) for Faroe plateau cod			
Age	Stock number (thousands)	Natural mortality rate	Maturity rate	Weight per fish (kg)
1	17669	0.2	0	0
2	5949	0.2	0	1.004
3	4988	0.2	0.62	1.417
4	7019	0.2	0.90	1.802
5	12021	0.2	0.99	2.280
6	2587	0.2	0.99	3.478
7	355	0.2	1	5.433
8	209	0.2	1	5.851
9	49	0.2	1	7.970

Table 6.3.	Initialisation data (year=1998) for Faroe plateau haddock			
Age	Stock number (thousands)	Natural mortality rate	Maturity rate	Weight per fish (kg)
1	18359	0.2	0.00	0.000
2	3638	0.2	0.01	0.622
3	7656	0.2	0.36	0.846
4	28565	0.2	0.87	1.016
5	44557	0.2	0.99	1.283
6	1163	0.2	1.00	2.080
7	161	0.2	1.00	2.556
8	211	0.2	1.00	2.572
9	233	0.2	1.00	2.452
10	1216	0.2	1.00	2.753

Table 6.4.	Initialisation data (year=1998) for Faroe plateau saithe			
Age	Stock number (thousands)	Natural mortality rate	Maturity rate	Weight per fish (kg)
3	12391	0.2	0.01	1.39
4	26844	0.2	0.16	1.71
5	15161	0.2	0.37	1.95
6	17927	0.2	0.54	2.40
7	4118	0.2	0.79	3.30
8	1824	0.2	0.97	4.22
9	790	0.2	0.97	5.00
10	148	0.2	1.00	6.39
11	67	0.2	1.00	6.66
12	150	0.2	1.00	8.48

Note: ‘N’=Stock numbers at age (Thousand individuals), ‘M’=Natural Mortality, ‘Mat’=Maturity fraction, ‘W’=Stock weight at age (kg)

The Ricker model ($R = r \cdot SSB \cdot \exp(-s \cdot SSB)$) is used to estimate recruitment R each year based on spawning stock biomass (SSB) in the previous year. The parameters used in the equation are given in table 6.5.

Table 6.5. Ricker stock-recruitment parameters used in the biological simulations

	r	s
Cod	0.7756	$1.529 \cdot 10^{-5}$
Haddock	2.558	$2.708 \cdot 10^{-5}$
Saithe	2.393	$2.119 \cdot 10^{-5}$

6.3.4. Economic data

In the years 1999-2005 historical fleet-specific species prices are used to calculate the yearly catch values (equation 1). From 2006 and onwards the 2005 prices are used. The prices are shown in table 6.6.

Table 6.6. Fleet-specific species prices (€/kg) used in the economic evaluations

		1999	2000	2001	2002	2003	2004	2005
Pair trawl	Cod	2.20	2.61	2.72	2.09	2.24	2.22	2.51
	Haddock	1.61	1.90	1.91	1.56	0.92	0.94	0.93
	Saithe	0.70	0.66	0.67	0.66	0.50	0.44	0.54
Long Line	Cod	2.01	2.32	2.41	1.90	2.04	2.00	2.41
	Haddock	1.75	2.11	1.93	1.47	1.07	1.08	1.38
	Saithe	0.61	0.51	0.55	0.60	0.29	0.40	0.53

Source: Hagstova (the Statistical Bureau of the Faroe Islands)

Likewise historical data has been used for crew share and other variable costs in the period 1999-2005, while the 2005 data has been used for the period 2006-2015. The crew share (% of revenue) and variable cost per sea day is shown in table 6.7.

Table 6.7. Crew share (% of revenue) and variable cost (€) per days at sea used in the economic evaluations.

		1999	2000	2001	2002	2003	2004	2005
Pair trawl	Crew share	46%	43%	44%	43%	39%	41%	38%
	Variable cost	1399	1962	2213	2095	2445	2053	2577
Long line	Crew share	58%	58%	56%	55%	54%	50%	49%
	Variable cost	2023	2039	2147	2859	2892	2790	2825

Source: Rasmussen and Weihe, auditing company

6.4. Scenarios examined

To evaluate the economic performance of the two fleet segments in an effort control management system, 6 scenarios have been considered:

1. Effort control management where the minimum of the efforts needed to take each of the three species is chosen. Moreover the fleet efforts are allowed to vary by up to 10% per year.
2. Effort control management where the maximum of the efforts needed to take each of the three species is chosen. Moreover the fleet efforts are allowed to vary by up to 10% per year.
3. Effort control management where the minimum of the efforts needed to take each of the three species is chosen. Moreover the fleet efforts are allowed to vary by up to 20% per year.
4. Effort control management where the maximum of the efforts needed to take each of the three species is chosen. Moreover the fleet efforts are allowed to vary by up to 20% per year.
5. Effort control management where the fleet efforts are chosen to optimise to total Net Present Value of the fishery over the simulation period.
6. TAC management, where the TAC is set according to the same HCR as the effort (i.e. with at target fishing mortality of 0.45). An effort corresponding to each TAC is then evaluated for each species. Again the minimum or the maximum of these efforts can be chosen but the evaluations have shown that the maximum effort scenario leads to quick extinction of especially the cod stock, so this case is left out. Thus the minimum of the three efforts is used to calculate the final TAC/landings for each species. The species TACs are allowed to vary with ±15% each year.

6.5. Results

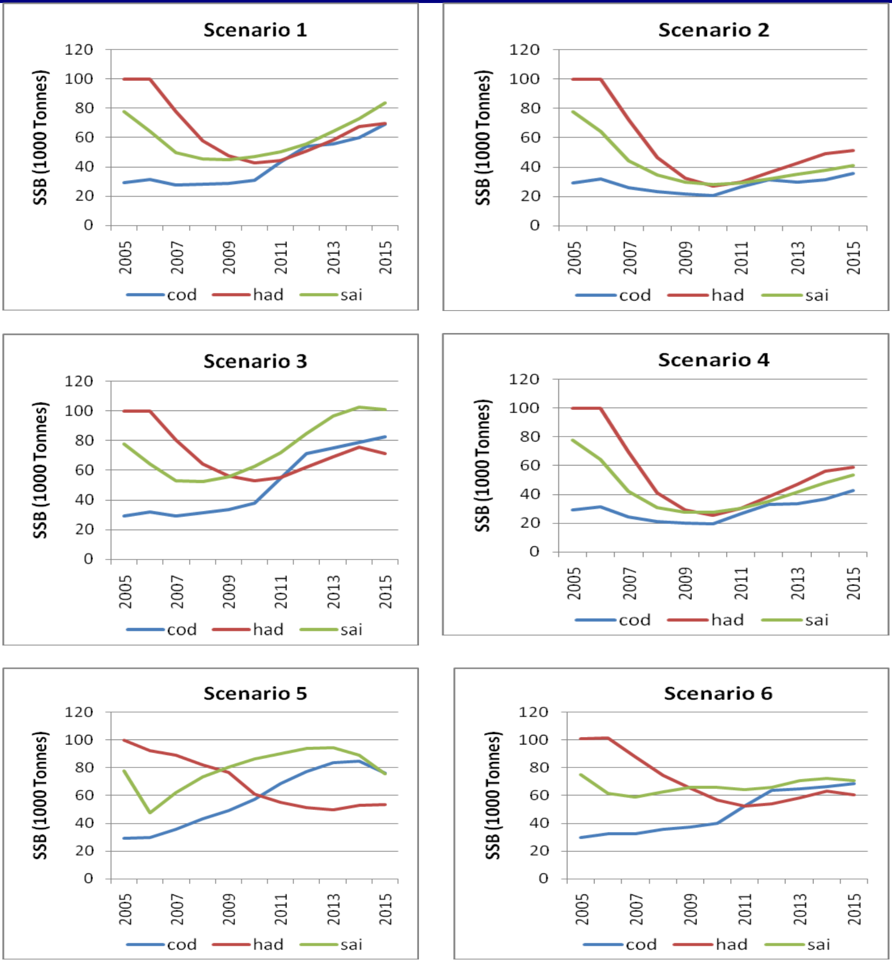
Table 6.8 shows the NPV’s over the simulation period for each fleet in each scenario. It is firstly seen that the total fleet NPV is highest in scenario 5 as expected. It is however interesting to observe that the individual NPV for the long liners is approximately equal in scenario 5 and in scenario 1, i.e. it seems that it is only the pair trawlers that profit when the total fleet NPV is optimised. Secondly it is seen that both fleets have highest NPV in scenario 1 and 3, i.e. when the minimum of the three species efforts are chosen, corresponding to complying with all species quotas. In the maximum scenarios on the other hand the NPV of both fleets are low, and negative for the pair trawlers, meaning that it does not pay off in the long run to take the least binding quota while overfishing the two other stocks. This will also be illustrated below via the stock developments in the period. Finally it is seen that the TAC scenario shows approximately the same result as the 10% effort min scenario. This is not surprising as both scenarios build on the same HCR, and as the TAC scenario complies with all three quotas. Moreover the TAC scenario allows a 15% change in TACs from year to year.

Table 6.8. Total NPV (mill €) over the simulation period for each segment in the Faroese Fleet, together with the sum of the segment NPVs.

Scenario	Pair trawl	Long line	Total fleet
1 (effort min, 10%)	33.2	25.7	58.9
2 (effort max, 10%)	-9.2	9.6	0.4
3 (effort min, 20%)	47.2	30.3	77.5
4 (effort max, 20%)	-5.6	10.6	5.0
5 (max NPV)	49.6	32.0	81.6
6 (TAC)	46.8	31.7	78.6

Figure 6.1 shows the development in spawning stock biomass (SSB) for each of the three species over the simulation period. It is firstly seen that the development in the two minimum effort scenarios (1 and 3) is approximately equal and that the same is true for the development in the two maximum effort scenarios (2 and 4). The difference between the minimum and maximum effort scenarios is that the stocks of cod and saithe recover more quickly in the minimum scenarios than in the maximum scenarios, while the development of the haddock stock is the same in the minimum and maximum scenarios. This indicates that the haddock TAC is the least binding of the three TACs. The quicker recovery of the cod and saithe stocks explain why the fleets have higher NPV in the minimum effort scenarios than in the maximum scenario, as their landings will increase with the stocks. Figure 6.1 secondly shows that the cod and saithe stocks seem to increase at greater speed in the optimisation scenario (5) compared to the two minimum scenarios, but also that these stocks also start decreasing again towards the end of the simulation period. The haddock stock on the contrary decreases steadily in the beginning of the simulation period but start to increase slowly towards the end.

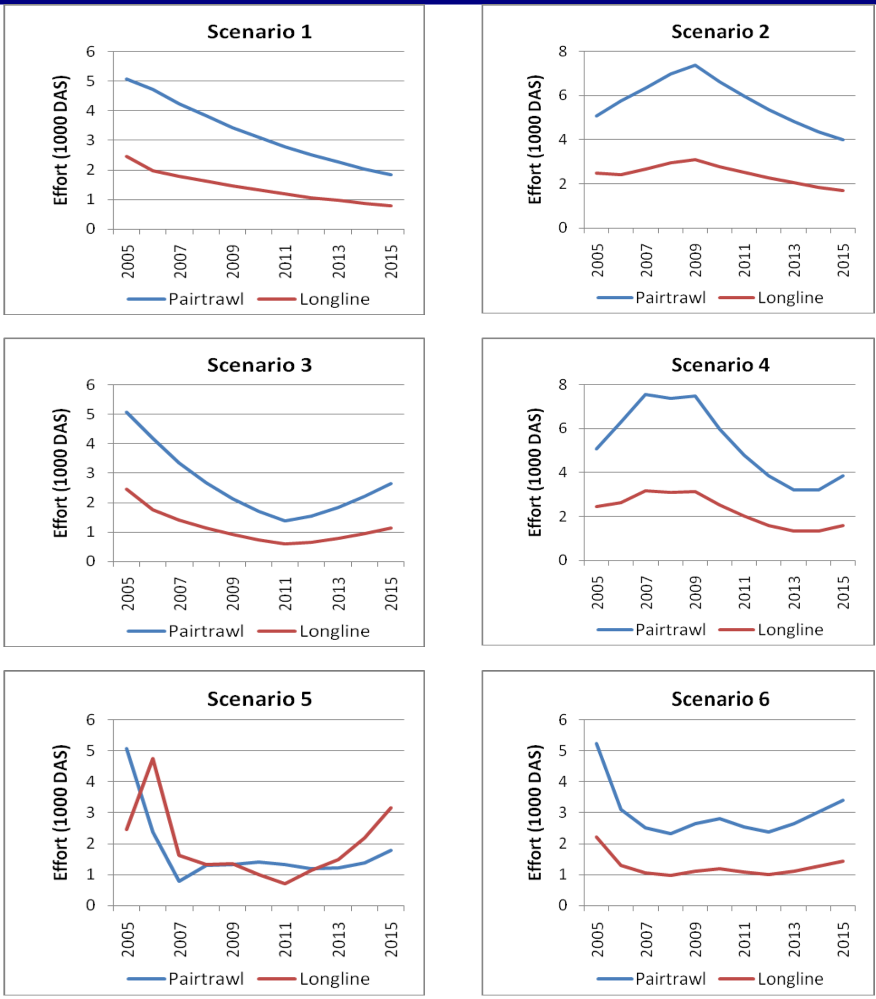
Figure 6.1. Figure 6.1. Spawning Stock Biomass (SSB) development of Faroe plateau cod, haddock and saithe in each of the six scenarios.



Thus when the effort is chosen to maximise the fleet profits the stock development will be different from both the maximum and minimum effort scenarios, but not significantly worse off. Finally it is seen that the stock oscillations in the TAC scenario is less pronounced and that the stocks develop slower in this scenario.

Figure 6.2 shows the development in fleet effort in each of the scenarios. It is not surprising to observe that the fleet efforts are generally higher in the maximum effort scenarios (2 and 4) than in the minimum effort scenarios (1 and 3).

Figure 6.2. Fleet efforts in each of the six scenarios.



It is more surprising that the effort decreases steadily in the minimum effort scenarios in most of the simulation period also when the stocks start to recover. This is observed in scenario 1 while the effort slowly starts increasing in scenario 3 at the end of the scenario. When this is compared with the NPV values shown in table 6.8 it is noticed that the fleets still manage to have high NPVs in the minimum effort scenarios even though the effort is low in these scenarios. This is caused by the increasing stocks that lead to increasing catch values. In the maximum effort scenarios it is on the contrary observed that the effort increases in the beginning of the simulation period but then starts decreasing following the decrease in SSB of all three stocks. In the NPV scenario (5) the effort is quite low for both fleet segments in most of the simulation period, reflecting that the effort in this scenario is chosen to maximise the total NPV for both fleets over the period, which is done by minimising variable costs while maximising catch values. Finally it is seen that the efforts are also quite low in the TAC scenario, reflecting the assumption that the fishermen comply with all three TACs thus utilising the lowest effort.

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Appendices to chapter 2

Regulation 1639/2001 Appendix XVII (section J)

Economic information per fleet segment as defined in Appendix III (Minimum Programme)	
General description	Minimum[1] programme First priority (annual)
Income (turnover)	Total and per species
Production costs: - crew (include social cost) - fuel - repair and maintenance - other operational costs	Total and per production cost category
Fixed costs	Average cost, calculated from investment
Financial position	Share of own/foreign capital
Investment (asset)	
Prices/species (*)	Value, tonne
Employment	Full time/part time/FTE
Fleet	- No - gt - kW - age - gear used
Effort	Relevant unit accounting for technology and time

1. There is a misprint in the regulation (says extended)
(*) Quarterly basis everywhere.

Regulation 1639/2001 Appendix XVIII (section J) cont…

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

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

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

Regulation 1639/2001 Appendix IV (section C)

Detailed disaggregation of vessels for capacities (Extended Programme)

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

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

Regulation 1639/2001 Appendix III (section C) cont…

Basic segmentation of vessels for capacities (Minimum Programme)

Vessel length	(level 1)		<12 m	12-<24 m	24- 40 m	≥40 m
	Type of gear (level 2)	Fishing technique (level 3)				
	Mobile gears	Beam trawl				
		Demersal trawl and demersal seiner				
		Pelagic trawl and seiners				
		Dredges				
		Polyvalent				
	Passive gears	Gears using hooks	(1)			
		Drift and fixed nets				
		Pots and traps				
		Polyvalent				
	Polyvalent gears	Combining mobile and passive gears				

(1) This segment is aggregated for all passive gears.
Note 1: If a gear category contains fewer than 10 vessels, then the cell can be merged with a neighbouring length category to be specified in the national programme.
Note 2: If a vessel spends more than 50% of its time using a specific type of fishing technique, it should be included in the corresponding segment.
Note 3: Length is defined as length overall (LOA).