FISHERIES ECOSYSTEM PLAN:
NORTH SEA

WORK PACKAGE 7 REPORT
EC FP7 PROJECT # 212881

“....we need to make sustainability our primary goal; we need to base our management decisions strictly on science; we need to adopt an ecosystem approach that is geographically specified, adaptive and capable of balancing diverse social objectives....forgive me for borrowing a somewhat trite old saying: when the wind of change is blowing, some build walls, others build windmills.”

Maria Damanaki

European Commissioner for Maritime Affairs and Fisheries
Brussels, 16th November 2010

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EXECUTIVE SUMMARY

Science based fisheries management developed late in the 19th century with a narrow focus on the dynamics of fish stocks. Now, early in the 21st century fisheries management is becoming integrated into wider environmental management. The July 2011 Green Paper on the Reform of the Common Fisheries Policy (CFP) identified the need reform European fisheries management and advocated the application of an Ecosystem Based Fisheries Management (EBFM) approach to deliver ecological, social and economic sustainability, stated an intention to move towards a longer term approach to fisheries management, and made commitments to greater stakeholder involvement in management. The Marine Strategy Framework Directive (MSFD) defines environmental objectives for European seas, based on sustainable utilisation of healthy marine ecosystems in support of sustainable development, and the Integrated Maritime Policy requires that individual sectors (e.g. fisheries) need to support MSFD objectives.

The Making the European Fisheries Ecosystem Plan Operational (MEFEPO) project was conceived to further the development of a framework, and the supporting evidence base (natural and social science), required to integrate the MSFD objectives within a reformed CFP in the context of sustainable ecosystem based fisheries management (EBFM). Fisheries Ecosystem Plans (FEPs) have been developed as a tool to assist managers and stakeholders simultaneously consider the ecological, social and economic implications of management decisions within a framework supporting EBFM. The aim of FEPs is to provide managers with a strategic rather than prescriptive plan for the adoption of EBFM. Through structured interaction with stakeholders, the MEFEPO project developed this FEP for the North Sea (NS) Regional Advisory Council area.

Ecosystem impacts of fishing activities on the North Sea

As a first step towards the development of a FEP for the North Sea we assessed to what extent the ecological policy objectives for this region were compromised by fishing. For this we focussed on the four MSFD descriptors that were considered to be affected by fishing: (1) biodiversity, (3) commercial fish and shellfish, (4) foodweb and (6) seafloor integrity and attempted to assess their current status using the most appropriate available indicators.

The Biodiversity descriptor was assessed using (two variations of) the indicator "Conservation Status of Fish" where slight modifications were required to how it was initially described in order to resolve some of the issues that were identified when applying this indicator to the North Sea. Three out of four configurations of the indicator we considered showed that biodiversity was not compromised but as the 4th configuration did show an approximately 20% decline in the average biomass of large vulnerable fish species the best method to calculate the indicator should probably be resolved before a final conclusion can be drawn.

The Commercial fish and shellfish descriptor was assessed using two variations of the indicator reflecting the proportion of stocks that are within Safe Biological Limits (SBL): based on the number of stocks and based on the landings. Both indicators demonstrated that the majority of the stocks are outside SBL and for this descriptor the policy objectives are therefore clearly not achieved.

The Foodweb descriptor was assessed using the Large Fish Indicator (LFI). This showed that even though it has greatly improved in the past year, the indicator is still below its target for GES and thus this policy objective is not achieved.

The Seafloor Integrity descriptor was assessed using the indicator reflecting the proportion of the seabed not impacted by mobile bottom gears. Problems existing with this indicator: (1) there is currently no target level for GES; and (2) acceptable levels of impacts from mobile bottom gear will depend on the resilience and susceptibility of the habitat (and its key functions) to damage therefore a single unified reference level for application across all habitat types may not be appropriate. Whilst this limits our assessment of whether or not the GES objective for seafloor integrity is being compromised by fishing, the presence of fishing activities in more than half of the habitats assessed (based on sediment and depth) means that it is likely that current levels of fishing will be considered to compromise seafloor integrity.

Thus, irrespective of whether attainment of GES is based on an ‘average’ of descriptors or on the basis that GES needs to be achieved across the board, the current assessment indicates that fishing negatively impacts GES in the North Sea RAC region. Thus there is a clear requirement for Fisheries Ecosystem Plans (FEPs) in order to achieve GES in this region.

Supporting governance structure

The transition to EBFM requires appropriate institutional structures. Through structured interaction with stakeholders, the MEFEPO project developed a proposed institutional framework based on a decentralised management structure with decision-making power devolved to regional cooperating groups of Member States (MS), supported by enhanced (Regional) Advisory Councils (ACs) with appropriate scientific support, and a more collaborative approach between MS, ACs and scientists to develop management plans. Whilst the institutional structure and formal distribution of powers remains largely unchanged, this model would: enhance stakeholders’ participation in management at the regional scale; facilitate stakeholder involvement in the development of management objectives and appropriate descriptors for all three pillars, and in the evaluation of management strategies; and thus give greater credibility to the management process and foster stakeholder support for management decisions.

Management strategy evaluation approach

Central to the development of the FEP is a management strategy evaluation matrix, a management support tool that allows simultaneous consideration of the potential impacts of different combinations of management measures on the ecological, social and economic status of the system. ‘Descriptors’ for the ecological, social and economic status of the fisheries were developed and utilised within the matrix.

Ecological descriptors were drawn directly from the MSFD and were selected at a MEFEPO stakeholder workshop as those most impacted by fishing activities (biodiversity, commercial fish, food-webs and seafloor integrity). Social and economic descriptors were defined to monitor the main aspects of fishing contributing to the economic and social wellbeing of society, in particular coastal communities. Economic descriptors focus on fishers’ ability to maximise economic efficiency of fishing operations (efficiency) and minimising fluctuations in harvesting possibilities over time (stability). Social descriptors monitor employment opportunities within the catching sector (community viability) and securing catch potential for human consumption (food security).

The potential performance of a limited suite of case-study specific management strategies was evaluated against these descriptors; management strategies comprised of "business as usual" (BAU) and alternative strategies, applying different management tools. Four cases study fisheries were used as examples of matrix application within the North Sea region: (1) a pelagic fishery on herring, (2) a beam trawl fishery on flatfish, (3) an otter trawl fishery targeting roundfish and (4) the sandeel industrial fishery. The case study fisheries examined should be seen as heuristic examples and not definitive assessments of the potential effects of different management strategies. Matrices were completed based on best available evidence (modelled, empirical and expert judgment), which for the NS case studies predominantly focussed on expert judgement and empirical data due to low accessibility/availability of quantitative data.

Case study fisheries

Overall the alternative management strategies showed there was scope to improve the ecological descriptors compared to BAU. Each case study had at least one management strategy that was considered to lead to an improvement of one or more ecological descriptors without any of the other ecological descriptors deteriorating. The management strategies that before best commonly included input restrictions (e.g. effort control or mesh size increase for the beam trawl fishery and MPAs to protect vulnerable species for the otter trawl fishery), but also output control (i.e. the adoption of MSY to set the TAC for the beam trawl fishery).

In some cases, management strategies that had the potential to perform best from an ecological perspective required a major trade-off in terms of the socio-economic objectives. For example, in the herring case study, the management strategy with the objectives to provide prey for the top predators was considered to lead to a deterioration of both of the economic descriptors (efficiency and stability) and to compromise the food security. However, for each case study there was at least one management strategy that was considered to show improvements across all pillars. For the beam trawl case study, this was a technical measure (increase in mesh size) and a revision of the target exploitation rate (F) to levels consistent with F_{MSY}. For the otter trawl fishery, this was a discard ban combined with a multi-species TAC. Several management strategies were considered to afford this for the herring fishery, but the most promising was the strategy to protect the spawning habitats. For the Sandeel fishery only few management measures were considered but the introduction of multi-annual right-based fishing should result in an improved economic efficiency and stability which in turn leads to an increased food security without affecting the ecological descriptors. Only community viability is expected to decrease through the loss of jobs in the fishery.

The outcomes of these management strategy evaluations for the North Sea case studies show that there is scope for EBFM in order to achieve (or at least progress towards achieving) the ecological policy objectives as stated in the MSFD. Crucially, application of the matrix approach demonstrated the complexity of interconnections among descriptors, and highlighted that trade-offs among objectives are required. Due to the nature of the trade-offs, it may not be possible to satisfy all stakeholder groups or objectives simultaneously.

Steps required for implementation of EBFM

The MEFEPO project has demonstrated the application of a management strategy evaluation matrix approach to the development of regional Fisheries Ecosystem Plans (FEPs) to help decision-makers to simultaneously consider ecological, social and economic implications of decisions, and to inform the development of ecosystem based fisheries management (EBFM) for European fisheries. Five key steps make ecosystem based fisheries management a reality for European fisheries have been identified:

- Develop long-term management plans (LTMPs) for each of the region's fisheries considering the ecological, economic and social implications for ecosystem components. LTMPS should be integrated into regional FEPs.
- Develop closer integration among stakeholders, fisheries scientists, ecologists, social scientists and economists to develop effective management advice for LTMPs. Social and economic descriptors, and appropriate (region specific) indicators, require further scrutiny and development.
- Develop qualitative assessments and expert judgement to supplement analytical modelling to meet the increased data requirements of LTMP development and make them operational in the short term.
- Ensure that the management framework is adaptive and able to respond to new information and understanding to allow decisions based on the best available evidence.
- Implement appropriate governance mechanisms that facilitate true stakeholder engagement to generate credibility in the management process and foster stakeholder support, this includes both in definition of objectives and indicators as well as the development and evaluation of LTMPs.

Fisheries Ecosystem Plans and non-technical summary documents

This report is one a series of 3 Fisheries Ecosystem Plans (FEPs) produced by the MEFEPO project; the FEPs cover the North Western Waters and South Western Waters RAC regions.

Stakeholder summary documents have been produced for each FEP to accompany this technical report and can be accessed via the project website at http://www.liv.ac.uk/mefepo/reports-and-outputs/wp7/

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GLOSSARY and ACRONYMS

BAU	Business as usual
CFP	Common Fisheries Policy
EBFM	Ecosystem based fisheries management
EC	European Commission
EU	European Union
FEP	Fisheries Ecosystem Plan
GES	Good Ecological Status (defined by the MSFD)
LFI	Large Fish Indicator
Management objectives	Overarching objectives (would be set/decided by managers/society)
Management scenario	Possible (sets of) operational targets for management
Management strategies	Management tool(s) proposed to meet management scenarios
Management tools	Input/output/technical measures
MS	Member State
MSFD	Marine Strategy Framework Directive
MSY	Maximum Sustainable Yield
SBL	Safe biological limits

1. INTRODUCTION

1.1. European fisheries

The EU fishing industry is the fourth largest producer (fisheries and aquaculture) in the world, accounting for 4.6% (6.4 million tonnes live weight) of the global production in 2007 (EC 2010). The EU currently consists of 27 Members States (Fig. 1.1.1), and fishing and associated activities (e.g. processing) provide jobs for more than 400,000 people[1]. The number of (full-time equivalent) people employed in the fish catching sector was estimated at 141,110 in 2007 (< 0.1% of total employment in the EU[2]), with a further 126,000 (full-time equivalent) employed in the processing industry (EC 2010). The total income generated by EU fisheries sector in 2005 was EUR 10.9 billion(EC 2009a), approximately 0.1% of EU GDP; the majority of this income was concentrated in a small number of coastal areas. The overall value of the outputs of the processing industry in 2007 was estimated at EUR 23 billion (~US$ 32.5 billion), approximately 3 times the value of the catch. Spain (1.0m tonnes), France (0.8m tonnes) and the UK (0.8m tonnes) are the top 3 producers, together accounting for ~40.5% of total production (EC 2010). Spain, Denmark and the UK dominated the catches (Fig. 1.1.1; EC 2010) and Spain is by far the greatest recipient of fisheries funds, receiving almost half of EU subsidies[2].

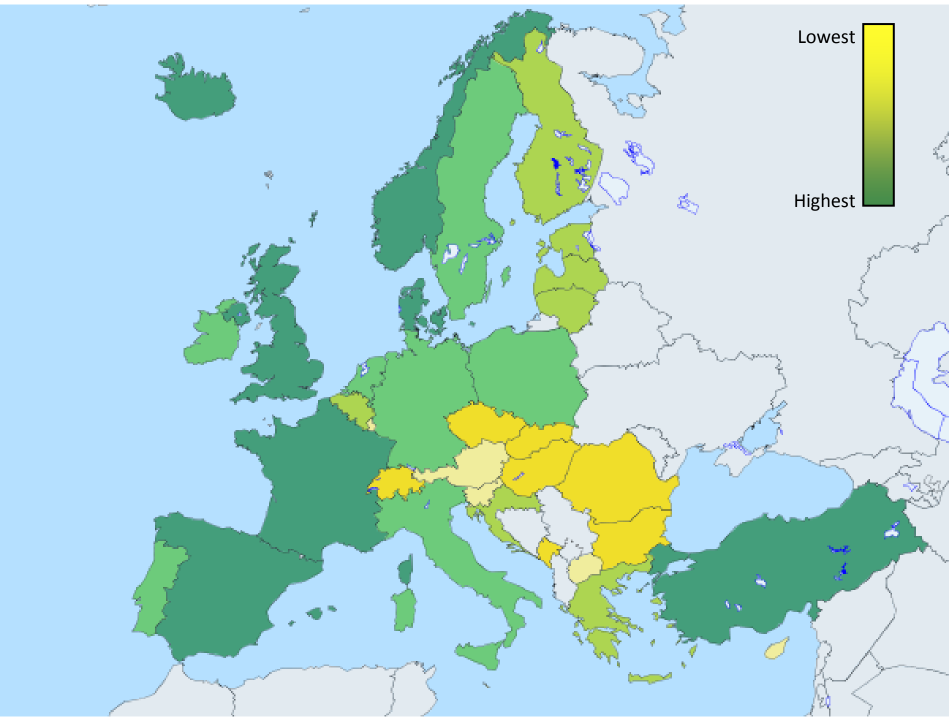

Fig. 1.1.1 Relative annual catches (based on live weight equivalent of landings) of fishery products by EU Members States, Iceland and Norway and other major fishing nations, in 2009. Data excludes any products which, for a variety of reasons, are not landed (Source: Eurostat[3]).

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[1] http://europa.eu/pol/fish/index_en.htm (accessed 07/08/11)

[2] http://www.cfp-reformwatch.eu/category/top-menu/sea-facts-and-figures/ (acccessed 07/08/11)

[3] http://epp.eurostat.ec.europa.eu/guip/mapAction.do?mapMode=dynamic&indicator=tag00076#tag00076 (accessed 02/08/11)

Employment in marine fisheries is concentrated in a handful of countries in the EU. In 2007, Spain accounted for ~25% of the total employment in the fish catching sector (35,274 full-time equivalent) and the top 3 EU countries (Spain, Greece and Italy) accounted for 60% of EU employment in this sector. Spain, the UK and Italy lead in terms of processing value, and employment numbers in the processing sector by Member State broadly reflect processing value (EC 2010). Spain, Greece and Italy also account for ~50% of the vessels in the European fleet (EC 2010), which range from small artisanal boats focussed on activities in inshore waters to large factory ships operating in international waters.

Fleet capacity has decreased over the last 2 decades, at an annual average rate of just below 2% (tonnes and engine power) and in 2009 was estimated at 85,000 vessels (EC 2010). However, the reduction in fleet size has potentially been compensated by technological advances and increased efficiency ("technology creep") estimated at 2-4% per annum (Sissenwine & Symes 2007). Fleet overcapacity remains a fundamental problem in EU waters, with the number of vessels (and associated effort) considered to be too high for the resources available (EC 2009b; EC 2011).

The EU fleet operates worldwide but catches are predominantly taken in the Eastern Atlantic and the Mediterranean. In terms of tonnage, catches are dominated by the Atlantic herring and sprat which accounted for almost a quarter of the total landed catch (Fig. 1.1.2). However, catches vary considerably among Member States and fishing regions in terms of quantities and species caught (EC 2010; Table.1 1.1).

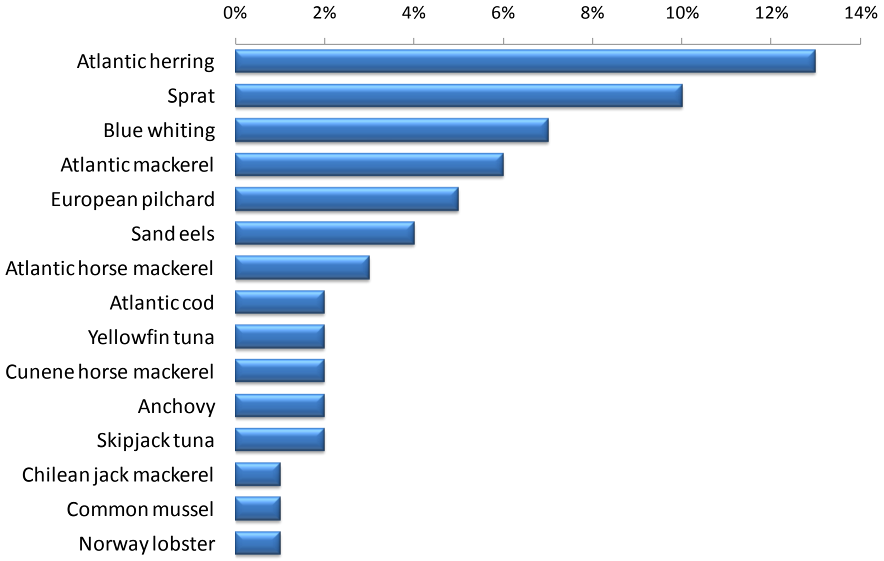

Fig. 1.1.2 The 15 main species caught and their contribution to the total EU production (6.4m tonnes based on live weight) in 2009 (EC 2010; Source: Eurostat).

Table 1.1.1 Examples of the diversity of catches by Member States based on the three main species caught by the fleet of each nation (% of tonnes (live weight) based on total catch of that species across the EU; EC 2010).

Denmark Sand eel *Ammodytes* sp. (26%) Sprat *Sprattus sprattus* (22%) Atlantic herring *Clupea harengus* (18%)	**France** Yellowfin tuna *Thunnus albacares* (8%) European pilchard *Sardina pilchardus* (7%) Skipjack tuna *Katsuwonus pelamis* (7%)
UK Atlantic mackerel, *Scomber scombrus* (22%) Atlantic herring *Clupea harengus* (15%) Blue whiting *Micromesistius poutassou* (9%)	**Portugal** European pilchard *Sardina pilchardus* (36%) Chub mackerel *Scomber japonicus* (11%) Atlantic horse mackerel *Trachurus trachurus* (5%)
Netherlands Atlantic herring *Clupea harengus* (25%) Blue whiting *Micromesistius poutassou* (20%) Atlantic horse mackerel *Trachurus trachurus* (15%)	**Spain** Yellowfin tuna *Thunnus albacares* (10%) Mackerel *Scomberomorus* sp. (8%) European pilchard *Sardina pilchardus* (8%)

1.2. Management of European Fisheries: the Common Fisheries Policy

The Common Fisheries Policy was established in 1983 (Regulation (EEC) No 170/83) to provide an integrated framework for the management of European fisheries *“....which enshrined commitment to EEZs, formulated the concept of relative stability and provided for conservatory management measures based on total allowable catches (TACs) and quotas”* (Olivert-Amado 2008). The CFP is subject to review every 10 years (Box 1), and in 1992 was reformed (Regulation (EEC) No 3760/92) with the intention of remedying the serious imbalance between fleet capacities and catch potential through fleet reduction and associated structural measures to alleviate social and economic impacts. The *“...concept of ‘fishing effort' was introduced with a view to restoring and maintaining the balance between available resources and fishing activities in response to changes in EU membership and associated fleet structure”.*

Box 1 Summary of the development of the Common Fisheries Policy

1970	First common measures for EU waters agreed which allowed EU fishers equal rights to exploit Member States’ waters, with the exception that local fishers had exclusive fishing rights to 6 miles.
1976	MS rights were extended from 12 – 200 miles in line with international agreements in 1976; 6 to 12 miles was restricted to local vessels and vessels from MS with historic entitlements (Styring 2010)..
1983	Common Fisheries Policy (CFP) established with stated overarching aim to “*...the protection of fishing grounds, the conservation of biological resources of the sea and their balanced exploitation on a lasting basis and in appropriate economic conditions.*” (Regulation (EEC) No 170/83)
1992	First reform of the CFP stated an overarching objective to *“...protect and conserve available and accessible living marine aquatic resources, and to provide rational and responsible exploitation on a sustainable basis, in appropriate appropriate economic and social conditions for the secgtor, taking account of its implications for the marine ecosystem, and in particular taking account of the needs of both producer and consumer.”* (Regulation (EEC) No 3760/92)
2002	Second reform of the CFP stated an overarching objective to *“...provide for sustainable exploitation of living aquatic resources and of aquaculture in the context of sustainable development, taking account of environmental, economic and social aspects in a balanced manner*.” (Council Regulation (EC) No 2371/2002)

However, these measures were not effective; they failed to prevent overfishing and further depletion of many fish stocks accelerated. In response, the major challenge of the 2002 reform (Council Regulation (EC) No 2371/2002) was *"....tackling simultaneously the risk of collapse of certain stocks, the impact on marine ecosystems, significant economic losses for the industry, the fish supply to EU markets and the loss of jobs."* These reforms also sought to address the increasingly acrimonious and polarised positions of managers and the fishing industry. Governance reforms included the provision of greater industry scrutiny of the advisor process and the establishment of Regional Advisory Committees consisting of representatives from the commercial fishing industry and non-governmental organisations. The 2009 Green Paper on the Reform of the CFP identified key failures of the 2002 reforms in relation to overfishing and stock depletion, fleet overcapacity, continued heavy subsidies, low economic resilience and decline in the volume of fish (EC COM(2009)163 final).

Most EU fish stocks have been fished down to below levels considered sustainable, with 88% being fished beyond MSY and 30% considered to be outside safe biological limits (EC COM(2009)163 final). The 2002 Reform has also been criticised due to the absence of guidance in terms of scaling and trade-offs between ecological, social and economic objectives, and for failing to specify what timeframe should be used when considering these objectives (Sissenwine and Symes 2007). For example, long term sustainability of fish stocks has the potential to deliver long-term ecological, social and economic benefits but may have short term economic and social costs which potentially jeopardize economic and social sustainability (Sissenwine and Symes 2007).

Box 2 Five key structural failings of the CFP identified in the Green Paper on the Reform of the CFP (EC COM(2009)163 final)

1. Deep-rooted problem of fleet overcapacity;
2. Imprecise policy objectives resulting in insufficient guidance for decisions and implementation;
3. Decision-making system that encourages a short-term focus;
4. Framework that does not give sufficient responsibility to the industry; and
5. Lack of political will to ensure compliance and poor compliance by the industry.

The recently published Communication on the 2012 Reform of the CFP (COM(2011) 417 final) states an overarching objective,

> "*By bringing fish stocks back to sustainable levels, the new Common Fisheries Policy (CFP) aims to provide EU citizens with a stable, secure and healthy food supply for the long term. It seeks to bring new prosperity to the fishing sector, end dependence on subsidies and create new opportunities for jobs and growth in coastal areas. At the same time, it fosters the industry's accountability for good stewardship of the seas.*"

1.3. Ecosystem based management and integration of the CFP with other marine policies

The concept of Ecosystem Based Management (EBM) has been recognised in a number of international agreements, and derives from the 1992 Convention on Biological Diversity and the subsequent 2002 World Summit on Sustainable Development. EBM is also central tenant of the FAO (UN) Code of Conduct for Responsible Fisheries (FAO 1995), and new policies are being developed in response to these drivers to integrate management across sectors (e.g. Canada's Oceans Act 1997; Australia's Oceans Policy 1998; DEFRA 2002; EC COM(2008) 187) rather than focussing on a particular sector (Pascoe 2006). Fisheries management can no longer be seen in isolation and the 2008 (COM(2008) 187) and 2011 (COM(2011) 417 final) Communications on the Reform of the CFP acknowledge the interaction between fisheries and other maritime sectors, highlighting the importance of ecosystem based approach to marine management, covering all sectors, and states:

> "*The future CFP must be set up to provide the right instruments to support this ecosystem approach.*" (COM(2008) 187)

Within the EU, the cross-sectoral approach is being pursued under the Integrated Maritime Policy (IMP; COM(2007) 575 final) which has been implemented to take account of the multiple pressures from the different sectors and address interactions between European policies and maritime affairs (EC 2007). The Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) forms the environmental pillar of the IMP and is the thematic strategy for the protection and conservation of the marine environment "*with the overall aim of promoting sustainable use of the seas and conserving marine ecosystems*" (EC 2008). Economic and social sustainability are acknowledged as dependent on productive fish stocks and healthy marine ecosystems, and the Green Paper sets out a commitment to manage European fisheries within the constraints of the MSFD to achieve good environmental status (GES), defined as,

> "*environmental status of marine waters where these provide ecologically diverse and dynamic oceans which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations…*" (Article 3(5); EC 2009b).

The EU is a signatory to 2002 World Summit on Sustainable Development target for fish stocks to be exploited at maximum sustainable yield (MSY), and achievement of this objective would also enable the reformed CFP to contribute to achieving GES in the marine environment, in line with the provisions of the MSFD (EC 2011).

Commitments through OSPAR and the 2002 World Summit on Sustainable Development call for the establishment of a representative network of marine protected areas (MPAs) by 2012 to help restore degraded marine ecosystems and fish stocks to sustainable levels (WSSD 2002; Pita *et al.* 2011), and there is growing support for zoning of marine activities in the context of ecosystem based marine management (Charles 2001).

1.4. Developing Ecosystem Based Fisheries Management: Fisheries Ecosystem Plans

The 2009 Green Paper on the Reform of the Common Fisheries Policy (EC 2009):

- identified the need for ecosystem based fisheries management (EBFM);
- stated an intention to move towards a longer-term approach to fisheries management;
- made commitments to greater stakeholder involvement and management to support the three pillars of sustainability: ecological, social and economic.

Understanding of the links between ecological, social and economic systems is essential in order to ensure that management decisions are appropriately informed. One of the greatest challenges of management, and to managers, is finding ways to achieve objectives simultaneously; in practice achieving multiple objectives is difficult and trade-offs have to be considered.

In the US, Fisheries Ecosystem Plans (FEPs) were developed to further the development of the ecosystem approach in fisheries management as a tool to assist managers to consider the ecological, social and economic implications of their management decisions (Fluharty *et al.* 1999). The core concept of the Making European Fisheries Ecosystem Plans Operational (MEFEPO) project is the development of operational Fisheries Ecosystem Plans (FEPs) for three regional seas (North Sea, North West Waters and South West Waters) to support the transition to EBFM, building upon lessons learned from previous EU project (e.g. European Fisheries Ecosystem Plan, EFEP, completed in 2005) and international experience (e.g. Fisheries Ecosystem Planning for Chesapeake Bay[4]).

The aim of FEPs is to provide managers with a strategic rather than prescriptive plan for the adoption of EBFM. FEPs are thus a guide for use in FM planning and development (or amendment of fisheries management plans), and should realistic, focussing on critical features and processes of ecosystem vital in managing fisheries resources (Link 2002).

1.5. Making the European Fisheries Ecosystem Plan Operational

The Making the European Fisheries Ecosystem Plan Operational (MEFEPO) project team has been supported by an Advisory Committee, consisting of senior figures from the industry and management organisations, engagement with 4 Regional Advisory Councils and stakeholder interviews and workshops. Through structured interaction with stakeholders, the project has developed Fisheries Ecosystem Plans (FEPs) for three regional seas (North Sea, North West Waters and South West Waters) to support the transition to EBFM. These regions were selected as they represent a range of challenges in terms of: knowledge; data availability; the number of national interests; spatial extent; and a broad range of physical and biological characteristics.

Central to the FEPs is a management strategy evaluation matrix, developed with stakeholders (see van Hoof *et al.* 2011), which can be used to explore the potential impacts of different combinations of management measures on ecological, social and economic descriptors, and assist managers to understand the ecological, social and economic implications of their decisions. This management support tool is demonstrated using case study fisheries within each region (Table 1.5.1) and gaps in

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[4] February 2004 the FEP was published [provide details].

knowledge (ecological, social and economic) which may limit the ability to successfully implement EBFM are identified.

Table 1.5.1 Regional Advisory Councils and associated case study fisheries

North Sea	**North Western Waters**	**South Western Waters**
Mixed flatfish beam trawl	North East Atlantic mackerel	Purse seine fishery
Sandeel industrial fisheries	Dublin Bay prawn (*Nephrops*)	Mixed demersal trawl fishery
Herring pelagic fisheries	Northern hake	Mixed demersal line fishery
Cod-otter trawl fishery	Scallops	*Nephrops*

This report focuses on the North Sea and case study fisheries and is one a series of 3 Fisheries Ecosystem Plans (FEPs) produced by the MEFEPO project; the other FEPs focussing on the North Western Waters and South Western Waters RAC regions. Stakeholder summary documents have been produced for each FEP to accompany this technical report and can be accessed via the MEFEPO project website at http://www.liv.ac.uk/mefepo/reports-and-outputs/wp7/

Whilst the geographical focus of the FEPs is different, the structure remains the same and draws upon the wealth of information and outputs from the MEFEPO project, consisting of:

- Section 3 provides an overview of the critical ecological, economic and social ecosystem components of the North Sea;
- Section 4 provides a summary of the ecological state of the North Sea ecosystem;
- Section 5 examines the regional case studies and provides an introduction to the fisheries and state of the stock, current management tools and performance, evaluation of alternative management strategies against ecological, social and economic descriptors, and management guidance; and
- Section 5 considers the next steps required for implementation of EBFM.

The MEFEPO project has also examined stakeholder views on the governance and institutional frameworks in European Fisheries (Raakjaer *et al.* 2010) and, with stakeholders, developed an operational model for a regionalised CFP to support successful implementation of an EBFM in Europe (van Hoof et al. 2011). The proposed model is common to all of the FEPs and is presented in Section 2.

2. GOVERNANCE AND INSITUTIONAL FRAMEWORKS

2.1. Governance challenges

Although the extent of the failure of the Common Fisheries Policy (CFP), the fisheries policy framework of the EU, can be debated, it is clear that the policy has not delivered satisfactory results. Recent reflections on the CFP (Sissenwine & Symes 2007), the Green Paper (EC 2009b) and Raakjaer (2009) paint a rather depressing picture of the performance of the CFP. Many fish stocks are fished to the limits and some stocks are overfished and on the brink of collapse, although it should be noted that there is evidence of improvements in some small pelagic stocks following implementation of long-term management plans (LMPs). The EU fisheries sectors are characterised by poor profitability with sector employment steadily declining according to the Commission (EC 2009b) . In addition, the EU fishing sector is facing intensive competition from freshwater and marine aquaculture production, making the market extremely competitive. The lack of success of the CFP is primarily caused by a lack of political will and ability among Member States to reduce fishing efforts and alter the present management path (Hegland & Raakjaer 2008). Further shortcomings of the present CFP that need to be considered when reforming the governance system by the end of 2012 include:

- Lack of clear principles and long-term objectives
- Mismatch between the scale of the governance and the ecological systems
- A tendency to apply one-size-fits all-solutions
- Micro-management trap
- Low legitimacy among fishermen
- The type of co-management introduced has not led to responsible behaviour among fishermen
- Problems of 'implementation drift' and inconsistent enforcement exist in the member states
- Discrepancies in the ways administrators and fishermen view the goals and means of the management regime

Over the last couple of years, *the governance option of regionalising the Common Fisheries Policy* (CFP) has become one of the hot topics in the debate about the content of the upcoming reform of the CFP. The recent Green Paper from the Commission has been instrumental in putting regionalisation firmly on the reform agenda. Spurring from the nature of the shortcomings facing the CFP and the focus of public discussions on introducing new modes of governance generally to the EU, discussions of further regionalisation of the CFP (in line with the principles of subsidiarity) have increased considerably over the years. Stakeholders, researchers, administrators, and politicians still struggle to find long-lasting and innovative solutions to put the CFP on a sustainable track and create a governance structure that facilitates the move towards ecosystem-based fisheries and marine management in accordance to the Johannesburg Declaration (United Nations 2002).

2.2. Meeting the governance shortcomings of the CFP

Understanding the structural failures of the CFP is closely related to the mismatch in scales of governance, particularly the lack of ability to find the 'right fit' of scales for governance intervention. Additionally, allocating power and responsibility to the best-suited scale of governance in line with the principle of subsidiarity has become an increasingly challenging task in the light of adopting ecosystem-based management in EU fisheries. Regionalisation has been seen as one answer to solve this problem.

Regionalisation of the CFP has been discussed at varying intensities beginning in the mid-1990s (e.g. Symes 1997) through the 2002 CFP reform, which made the first move in this direction by establishing Regional Advisory Councils (RACs). Since 2004, seven RACs have been established, organised along either specific sea areas roughly corresponding to large marine ecosystems (Baltic Sea RAC, North Sea RAC, South Western Waters RAC, North Western Waters RAC and Mediterranean RAC) or specific types of fisheries (Pelagic RAC and Distant Waters RAC). The RACs were introduced to provide a forum for stakeholders to discuss particular issues in their region and bring attention to those issues and convey advice to managers and decision-makers in the central EU institutions as well as the member states.

The discussions on regionalisation of the CFP are complex and compound. In Raakjær *et al.* (2010), we focused attention on the issue of regionalisation of the CFP by identifying and organising explanations for why particular actors with an interest in EU fisheries management would want to (or not want to) regionalise the governance system. Strikingly, the discussions of regionalisation in relation to the CFP have shown that the concept has been employed in both a multi-faceted manner—in the sense that it subsumes several discussions under one heading—and in an ambiguous manner—in the sense that as a description of a way of governing, it means different things to different people. In short the concept of regionalisation subsumes three interrelated discussions pertaining to who, where, and what—although achieving this separation can be difficult in practice.

The discussion of where to regionalise is related to the relative importance of different geographical levels in a perceived politico-administrative hierarchy of the CFP. The governance system of the CFP operates across three politico-administrative levels: the member state level, the intermediary level of regional EU seas (or the RAC areas), and the EU central level. One of the present challenges is that the scale of the governance system often does not correspond to the ecological system being managed. Matching the scale of the natural system with the scale of the governance system is essential and this supports calls for regionalisation in the shape of strengthening the intermediary (generally sea basin) level between the EU central level and the member state level.

The discussion whom to regionalise to has primarily focussed on the extent to which stakeholders should be involved in the fisheries management process of the CFP or merely subject to it. In the EU it is commonly accepted that those dependent on fishing for their livelihood ought to be well-represented in the management process. In scientific fisheries management literature, many different setups for devolution of management exist. Hegland *et al.* (2012) describes five different setups: 1) Top-down hierarchical management by the state where mechanisms for dialogue with users and stakeholders might exist, but only minimal exchange of information takes place and EU/National governments decide what information to share. 2) Co-management by consultation where extensive formal mechanisms for consultation (and feedback on use of recommendations) with users and stakeholders exist, but all decisions are taken by EU/National governments. 3) Co-management by partnership where EU/national governments, users, and stakeholders cooperate as decision-making partners in various aspects of management. 4) Co-management by delegation where EU/national governments have devolved de facto decision-making power to users and stakeholders in relation to various aspects of fisheries management. And 5) industry self-management with reversal of the burden of proof where government has devolved wide-ranging management authority to users and stakeholders, who must demonstrate to EU/national governments that management decisions are in accordance with the given mandate.

The question of what to regionalize has mainly evolved around what tasks need to be kept at a central level and which can be devolved. Many different kinds of decisions have to be made in European fisheries management. The decisions can be ordered in a system starting at the top layer, which covers the general conditions and frameworks (e.g. the Basic Regulation of the CFP), going down to a layer that contains policymaking and management plans (e.g. stock recovery plans), and finally down to a layer of formulation of the national obligations (e.g. distribution of quotas or days-at-sea). In reality the layers interact and are difficult to separate (there may even be more layers). However, the layers help to visualise the management; as you go down the layers, the number of details in the regulation increases but the span of influence decreases. Currently the CFP suffers from an approach to governance that requires the upper levels to take decisions on detailed issues (e.g. mesh sizes) with little span of influence in specific sea areas.

Given the complexity and multidimensionality of regionalisation of the CFP, there are a number of different ways in which the political aim of regionalisation could be made operational. We initially focused on five different models of regionalisation; 2 of the models (Regional Fisheries Management Organisation and Regional Fisheries Co-Management Organisation) were identified as having the greatest stakeholder support following interviews with RAC participants (Raakjaer *et al.* 2010). Each of these 2 models has advantages and disadvantages, but implemented in the right way any of these models could be put into practice and deliver many of the benefits that people are seeking in relation to regionalisation. It is notable that both models build on the matching of ecosystem scale and governance levels and therefore, in contrast to the current system, could facilitate the adoption and implementation of regionally distinct, tailor-made management approaches.

It is important that the chosen model can work as a common framework for all regions but also that the model incorporates flexibility to accommodate regions who develop their own regional governance approach. Based on our findings it seems likely that for some time it will be necessary to retain the ‘default option’ of the present system to allow regions who do not current have the capabilities/resources to take on extra authorities presented by a more ambitious model freedom to mature and develop at their own pace.

2.3. Operational challenges – and their regional differences

2.3.1. Legal challenges

It is important to note that some models for regionalisation may pose legal challenges due to the Lisbon Treaty. Long (2010) describes the uncertainty about the legal limitations imposed by the overall policy framework of the Lisbon Treaty in relation to increasing the regional scope of the governance system of the CFP.

However, the legal challenge is also considered one of the defining elements of the regionalisation debate; the question of the level of de facto authority that the regional level should have. There are differences in opinion on this, one position being that the member states cooperating at the regional level should be in a position—although subject to approval at the central level—to decide on vital issues such as whether and how to use quotas and/or effort regulation to reach long-term management targets. At the other end of the spectrum, it has been argued that the regional structure should basically be restricted to something that can facilitate member states cooperation on issues of implementation.

2.3.2. *Challenges of increasing administration costs*

Regionalisation of the CFP is likely to increase the administrative costs of the management system and the costs for stakeholders participating in the management processes. Both stakeholders from the fishing industry and managers from the national administrations have expressed concerns in this regard (van Hoof *et al.* 2011).

These costs could be mitigated by shifting towards a management approach where the industry carries a larger share of the burden of management by introducing result-based management, possibly combined with reversal of the burden of proof. In general this approach entails that the industry is presented with certain targets or limits that they have to comply with and—as long as respecting those limits—the industry itself may decide on how it wants to do management. If this is combined with a reversal of the burden of proof, the industry itself would have to cover the costs of documenting that they are within the limits. This way of perceiving regionalisation also links it to the issue of financial efficiency by giving the industry more manoeuvrability and self-determination with the caveat that the industry takes over (some of) the costs associated with fisheries management.

2.3.3. *How can the institutional set-up foster ownership and facilitate compliance of management measures?*

It is not only the direct, goal-achieving value of more tailor-made management from regionalisation that is important; the value of regionalisation also responds directly to another key problem of low legitimacy of the CFP, which has contributed to the failure to cultivate a culture of compliance. It is important to distinguish between two kinds of legitimacy when discussing fisheries management: process (or procedural) legitimacy refers to the legitimacy that fisheries management measures derive from being the product of a governance process perceived as fair and just (Jentoft 1989; Jentoft 1993; Jentoft & McCay 1995; Raakjaer Nielsen & Mathiesen 2003); and content legitimacy broadly refers to the legitimacy that a measure can derive from being perceived as reasonable and appropriate by those subjected to it or with an interest in it. Many stakeholders perceived that a regionalised governance process has the potential to strengthen the process legitimacy of the CFP and the improved outputs capable of strengthening the content legitimacy—at best this could break the cycle of failed management, low legitimacy, and non-compliance that the CFP has for long found itself in.

2.3.4. Challenges of differences in the organisational capabilities of various stakeholders

Major differences exist among EU member states on many levels, e.g. culture, framework conditions, organisational structures. Regionalisation of the CFP poses a new set of institutional and structural challenges for the stakeholders involved as well as for the governments of member states. In the southern part of Europe, the fishing fleets are composed of many small scale actors and their capacity is considered to be relatively weak. In contrast, in northern Europe the traditions and mechanisms for decentralised decision making are much stronger. These differences have to be considered when making an operational model for a regionalised CFP and the incentives for tailor-made management to suit regional needs minimising one-size-fits-all solutions.

2.3.5. Experiences from the RACs

A key focus of the MEFEPO project is how best to make current institutional frameworks responsive to an ecosystem approach to fisheries management at regional and pan-European levels in accordance with the principles of good governance. The principles of fisheries policies and management (CFP) should be consistent with and complement other EU legislation (e.g the Marine Strategy Framework Directive (MSFD), Habitats Directive etc.) rather than additive or contradictory. However, for the development of Fisheries Ecosystem Plans one does not necessarily have to involve all the other industries in the marine environment.

The RACs are relatively new bodies created by the 2002 CFP reform. The RACs consist of fisheries stakeholders mainly the fishing industry and eNGOs. As such the RACs are naturally oriented towards fisheries and are maturing as fisheries advisory bodies. This process presents a number of internal challenges (see below), however, this process is under pressure as fisheries is just one of the many sectors exploiting the marine environment and environmental Non-Governmental Organisation (eNGOs) are pushing for more restrictive regulations o protect the marine environment. Thus questions are being asked as to whether the RACs can continue to operate as a stand-alone advisory body or will be ‘forced’ to merge into more integrated marine co-management bodies with broader representation. If so, how could or should this be achieved? Unfortunately, these questions are outside of the remit of the MEFEPO project due to our focus on fisheries management; however it is clear that the RACs will play a key role in the future for wider marine ecosystem based management.

Various stakeholders (e.g. industry representatives and eNGOs) and both EU and national managers participated in an email survey on regionalisation and the work of the RACs. In the questionnaire, the respondents were asked for their views on a number of challenges for the RACs including: ‘reaching consensuses’, ‘communicating in different languages and across cultures’, ‘balancing small-scale vs. large-scale fishing priorities’, ‘addressing different national catching sector priorities’, ‘responding to specific advice requests’ and, ‘cultivating better cooperation between industry and non-industry interests’. The survey totals 138 observations, of which 100 participants completed an online questionnaire, 30 completed a paper version, and eight partially responded online providing enough answers to merit inclusion. The response rate for the survey stands at 41.9 % (138/329). The respondents were asked different questions in the survey: basic questions about their background and their way of working, questions on their views on different models of regionalisation, questions on their view on the RACs work and the challenges of the RACs. It is the answers from the last group of questions that are synthesizes below focusing on the regional differences between the RACs (Table 2.3.5.1).

Table 2.3.5.1 The table shows the averages of the rankings of the challenges for each of the RACs and the overall average. Respondents are asked to state how challenging they find various aspects of the RACs from one (very easy) to five (very difficult); hence the average is three. The table shows the averages in the answers from each RAC – green marks that the average is 'below 3' (easy or very easy) and red marks that the average is above three (difficult or very difficult).

	Reaching consensuses	Balancing small-scale vs. large-scale fishing priorities	Addressing different national catching sector priorities	Responding to specific advice requests	Communicating in different languages and across cultures	Cultivating better cooperation between industry and non-industry interests
NWW RAC	4.00	3.45	3.63	3.44	3.00	3.60
SWW RAC	3.78	3.77	3.27	2.91	2.60	3.52
NS RAC	3.60	3.38	2.83	3.45	2.67	3.67
Pelagic RAC	3.38	3.36	3.32	2.95	2.76	3.16
All RACs	3.72	3.52	3.29	3.19	2.76	3.51

2.3.6. The experiences on reaching consensuses

RACs were put in place as advisory bodies as an initial step toward more stakeholder participation in developing EU fisheries policy. The idea being that the stakeholders on a RAC will seek consensus on issues to do with fisheries management and policy, and thereby allow DG MARE to weigh the political advantages of following the RAC's consensus against any differences between the consensus and other preferences of DG MARE (Hegland & Wilson 2009). Hegland (2009, p. 13) argues '*…the main tool of the RACs in relation to gaining an impact on the decision-making process remains the alternative instrument of consensus-building: in the first instance the RAC needs to build consensus among the various stakeholder groups within it; at the same time, however, the RAC needs to anticipate the Commission's position so that the RAC's consensus does not fall too far from that. If a consensus or a 'close-to-consensus' can be found between the RAC and the Commission, it could be argued that the member states (or smaller groups of member states) in the Council would find it politically too costly to overrule that consensus. It could be argued that this represents a dispersion of power from the central state governments to other actors, i.e. the Commission and the RACs, which are in turn becoming increasingly interdependent (vertical and horizontal interdependence)*'. Indicating the RACs can gain political impact if they could reach consensus or at least establish a situation of 'close-to-consensus'.

Despite the potential for increased political impact – or perhaps because of it – respondents in all four RACs ranked 'reaching consensus' as one of the two most difficult challenges; this challenge was ranked most difficult by respondents in the NWW RAC and least difficult for respondents in the Pelagic RAC.

2.3.7. The experiences on balancing small-scale vs. large-scale fishing priorities

Along with fostering consensus, the SWW RAC has the greatest difficulty with 'balancing small-scale versus large-scale fishing priorities'. A majority of the SWW respondents rank the measure somewhat difficult to 'very difficult'; while in the other RACs such answers less than half of responses. In addition to the difficulty, a quarter of the SWW participants select this challenge as the most critical to the RAC's success. Notwithstanding, geographic affiliation highlights a starker contrast for the difficulty associated with the proposed obstacle. A third of the survey participants from the North rate the challenge as more difficult than neutral; in comparison two thirds of those from the South rank it as more difficult than neutral. Like in the case of the SWW RAC, more than a quarter of the 52 South category participants believe the issue of scale is the most critical to the RAC's success while none in the North category regard scale as the most important challenge.

This challenge demonstrated one of the more pronounced cleavages between northern (e.g. NS and NWW RACs) and southern (SWW) perspectives among our results.

2.3.8. The experiences on addressing different national catching sector priorities

'Addressing different national catching sector priorities' was identified as a key challenge within the NWW RAC while the NS RAC stands apart from the other three RACs on this measure because of the below average. Two thirds of the NWW respondents rank the challenge as somewhat 'difficult' to 'very difficult' compared to approximately one quarter of the NS RAC respondents. Nearly half of the Pelagic RAC respondents ranked this challenge as neutral. Half of the NS RAC respondents found the challenge of addressing different national catching sector priorities 'somewhat easy' or 'very easy'; whereas few respondents from the other RACs (NWW, SWW and Pelagic) selected these responses.

2.3.9. The experiences on responding to specific advice requests

There was disagreement among RACs on the difficulty of "*responding to specific advice requests ('fire fighting')*". Respondents from both the NS and NWW RACs experienced greater difficulty with this challenge compared to those from the Pelagic and SWW RACs. It could be speculated that this divide is due to the precarious situation of several stocks in the NS, and to a lesser extent the NWW, has led to more demands on providing advice to specific requests, often referred to as 'fire fighting', compared to the Pelagic and SWW RACs. However, few participants from each of the RACs selected this challenge as the most critical; highlighting that is in any case not one of the most salient issues to RAC participants

2.3.10. The challenge of communicating in different languages and across cultures

The survey included a question on the difficulty of '*communicating in different languages and across cultures*' to examine whether RACs with more diverse composition of countries and languages, such as the NWW RAC, struggle with this factor more than a RAC that is able to communicate almost entirely in one language, for example, the NS RAC where English is the dominant language. To a degree this question also gauges the North-South divide without explicitly naming the ostensible phenomenon. The mean score for the NWW RAC as higher, indicating that communication was perceived as more of a challenge for this RAC than the NS, Pelagic and SWW RACs. However, the NWW RAC mean score reflected a neutral rating overall. Therefore, communicating in different languages and across cultures does not seem to pose a major challenge in the perception of participants for any of the RACs. Somewhat surprisingly the SWW RAC averages the lowest in terms of difficulty, but is in close proximity to the North Sea RAC and the Pelagic RAC averages; moreover, there is little difference in the frequency distribution of answers along North-South lines. Communicating in different languages and across cultures does not seem to pose a major challenge in the perception of participants for any of the RACs.

2.3.11. The experiences on cultivating better cooperation between industry and non-industry interests

Survey responses indicated that all RACs struggle with the challenge of “cultivating better cooperation between industry and non-industry interests”. This challenge is closely related to the challenge of ‘reaching consensus’ as it is – most frequently – the industry and non-industry stakeholders’ positions that are hard to combine. Respondents from the NS RAC ranked this challenge the most difficult challenge of all challenges presented but the NWW RAC and SWW RAC fall close to the overall mean. These results from these three RACs are fairly close; however the Pelagic RAC averages the lowest of the RACs on the industry and non-industry challenge. Probably the main explanation for this situation is that the industry stakeholders pre-dominate the composition of Pelagic RAC respondents with few other stakeholders counterbalancing. The Pelagic RAC’s small size and relative stakeholder homogeneity may also contribute to the tightness of the range in difficulty for the presented challenges.

2.3.12. Differences in experiences between the RACs

There is no significant association between the choice of most critical challenge and the RAC membership; however, the North-South divides proved a strong relationship. Overall, respondents from NS, NWW, and Pelagic RAC ranked the consensus measure and the cooperation between industry and non-industry members as the first or second most critical challenge to the RAC’s success (approximately one third of respondents within each RAC). While SWW participants recognise reaching consensus as a critical challenge, a higher proportion of respondents from this RAC (25%) selected ‘balancing small- versus large-scale priorities’ as the most critical challenge. The North-South divide demonstrated division over scale; none of the respondents the north (NS, NWW, and Pelagic RAC) viewed scale as the most critical issue, compared to more than a quarter of the respondents from the south (SWW). There was also significant association between geographic affiliation and the most critical challenge, with respondents from the north more concerned about consensus and cooperation between industry and non-industry members, and respondents from the south more concerned about scale issues (82% of respondents in this region ranked this as the most critical issue). The challenges of ‘reaching consensus’ and ‘addressing different national catching sector priorities’ were also considered to be critical by respondents from the south.

2.4. Operational model for a regionalised CFP[5]

The suggested model for regionalisation by establishing Decentralized Fisheries Management Boards (DFMBs) is drawing closely on the model Raakjaer *et al.* (2010) labelled “Cooperative Member State Council” and what Symes (2009) labelled “Standing Conference of member states administrators”. The DFMB model this was developed with stakeholders from a range of backgrounds and regions as part of WP6 (van Hoof *et al.* 2011). This model will largely keep the institutional structure and formal distribution of powers unchanged. The model is based on voluntary agreements, soft law and de facto authorities based on quality of input rather than de jure authority to take decisions. Thus, regionalisation will have to be seen in the light of implementation, where the Council and the Parliament will take all essential decisions and set the high level objectives.

The aim of Fig. 2.4.1 is to illustrate how regionalisation of the CFP could be institutionalised. Regionalisation is considered a vehicle to overcome the present shortcomings of the CFP and not a mean in itself. It is acknowledged that the move to ecosystem approaches in fisheries management requires appropriate geographical scale, both in terms of the eco-system per se and the governance system responsible for management. Regionalisation, as outlined here, would be a step towards introducing tailor-made regulations based on an understanding of the dynamics of specific fisheries and ecosystems and creation of an institutional framework wherein the CFP becomes a suite of de facto eco-region fisheries policies to address many of the political challenges the CFP is currently facing.

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[5] In MEFEPO WP 4 (Raakjaer *et al.* 2010) a set of models for regionalisation of the CFP developed and tested by stakeholders in four RACs (NWW, SWW and NS and Pelagic) and two/three models emerged to have potentials. These were presented and discussed at a workshop with broad stakeholder representation a part of WP 6 (van Hoof *et al.* 2011) and that lead to shared agreement among stakeholders and project scientists for proposing one model. It is important to remember that in the drafting this document we have no knowledge about how proposal from the Commission on the CFP reform will deal with regionalisation.

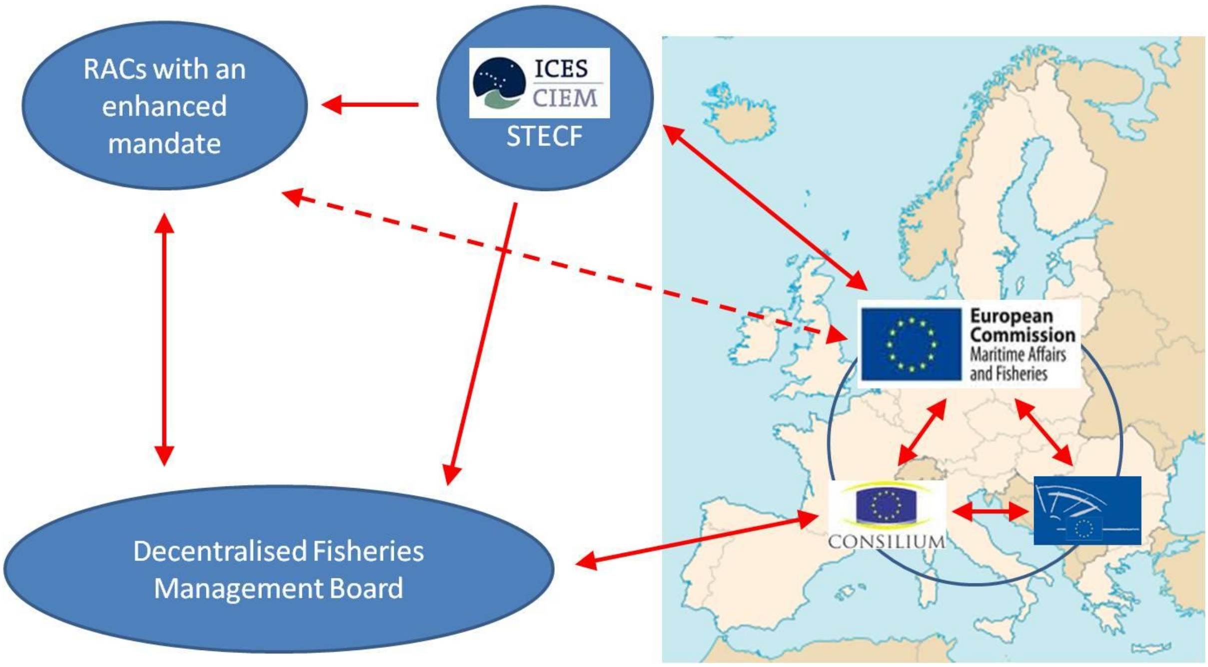


Fig. 2.4.1 Governance model for regionalisation of the Common Fisheries Policy developed by stakeholders at the MEFEPO workshop in Haarlem, April 2011. Decentralised Fisheries Management Board (FMB) similar to the 'Cooperative Member State Council' model put forward by Raakjaer *et al.* (2010) but supported by RACs with an enhanced mandate.

Based on development with stakeholders, the MEFEPO project recommends that Decentralised Fisheries management Bodies (DFMBs) are established for each of the existing 5 geographical RACs (Baltic Sea, North Sea, North Western Waters, South Western Waters and Mediterranean Sea) and for the two RACs (Long Distance Waters and Pelagic) dealing migratory stocks covering more than one of the present geographical RAC areas (Long Distance Waters and Pelagic). DFMB would address fisheries management issues specific to their geographic area or stock, and member states with fishing interests in a regional sea or migratory stocks would become members of the respective DFMB. The mandate of the DFMBs would be to draft long term management plans (LTMPs) and establish implementation strategies and thus become de facto involved in drafting proposals. This setup is close to what has previously been described as co-management by informal partnership (Raakjær *et al.* 2010), and would provide RACs with an enhanced mandate to be involved in the decision-making process and create incentives for tailor-made management to suit regional needs reducing off-the-peg and one-size-fits-all solutions in European waters. This framework between the EU institutions and the member states would enable the model to meet the shortcoming of 'implementation drift' and lack of enforcement that exists in the member states.

The DFMB provides proposals to the Commission on LTMPs and their implementation. The DFMBs will consist of members from fishing member states and observers from enhanced RACs. The exact numbers depend on member states having fishing interests in the management area. The DFMBs would forward their recommendations for LTMPs and implementation to the overall EU Fisheries Council for formal approval. RACs with enhanced mandate make recommendations to the DFMBs and the Commission.

RACs would become a working group for DFMB, and indirectly to the Commission, and provide input to and suggestions for LTMPs and their implementation. RACs would also identify and put forward requests for provision and improvement of scientific advice. In most cases, the enhanced RAC would advise the DFMBs rather than the central EU institutions. The exact extent to which stakeholders' input is given weight in the recommendations of the mini-council is up to that mini-council on a case-by-case basis. Representatives of the RACs will be granted 3 observer seats at DFMBs: the RAC chair and two others from the RAC maintaining the 2-1 balance between industries and NGOs as presently used to determine representation in RACs. If effectively implemented, this structure should serve to increase the legitimacy of the CFP and associated regulations among stakeholders (which presently is low) and reduced conflict between administrators and the industry due to differences in how these groups view the goals and means of the management regime. It is envisaged/hoped that this may lead to more responsible behaviour among fishermen. The DFMB model would allow each region to calibrate the model to their situation, providing a high degree of flexibility within the present structures despite based on de facto delegation of authority.

The approval of LTMPs would remain with the Commission which is responsible for auditing that existing, proposed and future plans are implemented in accordance to the principles and long-term objectives that have been decided by the EU.

2.4.1. Migratory Stock RACs

For the majority of migratory stocks, the EU needs to collaborate with other (non-EU) countries and mechanisms to address how these stocks and countries should be dealt has to be considered in a regionalized CFP. One solution could be that the North East Atlantic Fisheries Commission (NEAFC) is transformed into an equivalent to the Decentralised Fisheries Management Board and a management set-up with an advisory structure covering all relevant countries in a similar way to that proposed above for the regional RACs. These different options have not been fully explored and we therefore recommend that that more attention is directed to the issue of migratory stocks and third countries.

3. NORTH SEA CRITICAL ECOSYSTEM COMPONENTS

3.1. Introduction to the region

The North Sea is a marginal, shallow sea on the European continental shelf. It is more than 970 km long and 580 k, wide, with an area of around 750,000 square km. The North Sea RAC area is larger, because it includes the Skagerrak and Kattegat. The North Sea is surrounded by England, Scotland, Norway, Denmark, Germany, the Netherlands, Belgium and France. In the southwest, beyond the Straits of Dover, the North Sea becomes the English Channel connecting to the Atlantic Ocean. The basin of the North Sea is shallow and becomes deeper to the north.

The dominant seabed feature of the North Sea is the Doggerbank, a large sandbank in the middle of the North Sea. It extends over approximately 17,600 km^2, about 260 km long and 97km broad. It is clearly shallower than the surrounding water, ranging from 15 to 36 meters. Another dominant feature is the Norwegian Trench in the northern part of the North Sea along the coast of Norway, with a wide of 20 to 30 km and a maximum depth of about 725m.

The North Sea substrate is formed by sedimentary deposits several kilometres thick, which originate from the surrounding land masses. Some of their strata contain large amounts of liquid and gaseous hydrocarbons, which are intensively exploited. The sediment distribution pattern shows sand and gravel deposits occurring in the shallower areas, whereas grained muddy sediments have accumulated in many of the depressions (e.g. Oyster Grounds, Elbe valley, NW of the Dogger Bank, Devils hole and the Fladen Grounds. Tidal flats like the Wadden Sea (NL) and the Wash (UK) receive their sediments directly or indirectly from rivers and from adjacent North Sea areas. The suspended particulate matter settles to form either sandy or muddy sediments according to its composition and the predominant local hydrodynamic conditions.

The water masses in the North Sea are continuously moving under the influence of tides, winds and storms. The overall current is however anti-clockwise, bringing Atlantic water in from the north along the English coast and water from the English Channel along the coast of Belgium and the Netherlands. These currents cause among others frontal areas as the Frisian Front on the Dutch part of the North Sea and the Flamborough front on the English part. Along the Dutch coast, circulation is affected by the inflow of rivers resulting in a northerly orientated residual flow (OSPAR 2000). Yearly, 300 – 350 km^3 of freshwater flows into the North Sea via rivers, most of which originates from Scandinavia. The water of the shallow North Sea consists of a varying mixture of North Atlantic water and freshwater run-off, whereas the deeper waters of the North Sea consist of relatively pure water of Atlantic origin. Along the continental coast, a coastal river with lower salinity and increased turbidity, strongly influenced by river discharges and freshwater run-off, extends several tens of kilometres offshore. The salinity and temperature characteristics of shallow areas are strongly influenced by heat exchange with the atmosphere and local freshwater supply. Deeper areas are also partly influenced by surface heat exchange (especially winter cooling) and, in certain areas, are slightly modified through mixing with less saline surface water. The inflow of Atlantic water, both from the north and through the Channel, shows large seasonal and inter-annual variability, driven by the North Atlantic Oscillation (NAO) (Pingree 2005). The NAO winter index, a measure of the atmospheric pressure gradient between the Azores and Iceland, has undergone long term and short term fluctuations. High (positive) NAO index values are associated with strong inflow and transport of Atlantic water through the North Sea (Reid *et al.* 2003). The NAO index shifted to high values from the late 1980s through the first part of the 1990s, followed by a marked drop to a strong negative anomaly in the winter of 1995/96. These were very marked climatic events that have been associated with changes in plankton composition (Planque & Batten 2000; Beaugrand *et al.* 2002; Beaugrand 2003; Reid *et al.* 2003), fish populations and other biota in the North Sea (Reid *et al.* 2001; Reid & Edwards 2001; Edwards *et al.* 2002).

3.2. Ecological

In temperate waters, a phytoplankton bloom occurs every spring, generally followed by a smaller peak in autumn. The production of phytoplankton depends on light and nutrients. The depth on which the production occurs varies from 10cm in turbulent areas to 30m in offshore areas. Due to the limited depth of the North Sea and the inflow of nutrients, phytoplankton grows lavish and the North Sea is highly productive. Phytoplankton abundance has increased generally in the north-western and eastern North Sea whilst diatoms and dinoflagellates have decreased in these regions and increased in the north-eastern North Sea.

The main benthic organisms are various species of marine bristle worms (Polychaetes), burrowing clams (bivalve molluscs), sand shrimps (amphipods), sea urchins and brittlestars. Various species of mobile scavengers, such as crabs, starfish and fish, range across the various habitats.

Over 230 species of fish species occur in the north Sea, 11 of these species are main targets of fisheries for human consumption, three other species are target species of industrial fisheries. The fish community is under pressure of these fisheries and climate change. Thou, there are changes in distribution due to climate change and some species are at risk due to fishing, no extinctions have occurred in latest years. The diversity even increased by species form southern or Atlantic waters.

Over ten species of whales and dolphins are regularly sighted in the North Sea. Although they were once subject to extensive commercial hunting, only a few countries, including Norway and Iceland, still hunt whales. In most regions these species have become the subject of a growing eco-tourism industry. The harbour seal and the grey seal both breed within the North Sea. Harbour seals occur throughout the North Sea, whereas grey seals almost exclusively occur around northern Britain.

Approximately 2.5 million pairs of sea birds, made up of 28 different species, breed on coasts in the region. Several years of the poorest breeding success on record have occurred since 2003. It is thought that climate change could cause long term effects on the distribution and abundance of seabirds around the North Sea through impacts on seabird ecology and in particular effects on the food resources of seabirds. Increases in large scavenging seabirds due to increased availability of fisheries discards sometimes cause reductions in smaller seabirds breeding in the same area through competition for nesting sites or direct predation.

3.3. Social

The area is important for marine shipping, it is in use as fishing and military ground, minerals, oil and gas are extracted, and it is a place for tourism. Lately it becomes more important for renewable energy, e.g. wind farms.

The North Sea is one of the most intensively exploited seas of the world. In addition to the exploitation of living resources (like shrimp trawling, demersal and pelagic fisheries) the area is used for several other human activities. The area is used for shipping to and from several large ports in Belgium, the Netherlands, Germany and England, and busy shipping lanes to the Atlantic and the Baltic cross the area. Other human activities are oil and gas exploitation, tourism and recreation, cables and pipelines, sand and gravel extraction, coastal nourishments, dredging and relocation of dredged materials, military activities, and the construction and use of wind farms for renewable energy. Several areas have been assigned as protected areas under the Birds and Habitat Directives. These human activities exert biological, physical and chemical pressures on the marine ecosystem.

In addition to the activities at sea, there are also land-based activities with impacts on the marine environment. Emissions from point and diffuse sources on land can reach the sea, either through the inland water system resulting in river discharges of substances, or through the atmosphere resulting in atmospheric deposition at sea.

Within the EU, the majority of fishing communities have been getting smaller as quotas and fleets have been progressively reduced, and thus jobs in fishing and associated industries have become less common. Many coastal communities are dependent on the fishing industry and in some areas of the European coast there are few employment opportunities outside of fishing. Certainly in the past 20 years, few new job opportunities have been created at the coast, although some enterprising ex-fishers and fishing industry support workers have found ways of making a living.

Small-scale, or in certain cases even large-scale, aquaculture has developed and in some cases outstripped the income from wild fisheries in areas that are suitable for such activity, for example those that are less exposed to the elements but where local conditions (e.g. plankton productivity for shellfish; flushing capacity for both finfish and shellfish culture) are appropriate. Some processing plants of large national and multinational companies have retained or even expanded their presence in coastal communities, processing vegetables and meats on lines previously utilised for fish or shellfish, and/or bringing in fish and shellfish from other landing areas to supplement their processing activities as local supplies of marine produce were interrupted or halted. In some areas, immigration from new EU states has produced a coastal workforce more willing to handle the menial tasks of fish and shellfish processing, and farming than long-resident locals, many of whom have moved elsewhere to seek work which they find more acceptable, changing the cultural make-up of some coastal communities and sometimes causing the coastal population to burgeon.

The coastlines of many European countries have long been favoured holiday and tourist destinations, particularly in summer, and jobs have also been created to support tourism, for example in the accommodation, entertainment and catering industries. Although these employment opportunities tend to be seasonal, they are often lucrative. Ports have historically been crucial to the economies and populations/consumers of European states and of the region as a whole, with shipping and small-boat recreation in many areas being highly visible.

3.4. Economic

The following paragraphs of national fleets and economic indicators for the North Sea were sourced from the STECF Annual Economic Report, 2010 (STECF 2010).

In 2008, European fishing fleets landed 1,164 thousand tons of seafood from the North Sea, worth around €1,250 million. These fleets spent around 521 thousand days in the North Sea in 2008. The UK accounted for about half of days, with Denmark, the Netherlands, Sweden and Germany accounting for the majority of the remaining days. The volume of landings in the area remained fairly stable from 2003 to 2007 and decreased sharply in 2008. However, it must be acknowledged that due to lack of information for some countries in some years, the outcome of a time series analysis might be not be very precise. Therefore, the decrease in total volume of landings of about 47% from 2003 to 2008 must be considered with care. Although subjected to the same data collection problem reported above, the time-series for value of landings shows a slight increase from 2004 to 2007 followed by a large fall in 2008. The time-series of days at sea shows that while effort has been quite stable from 2003 to 2007 it decreased by almost 20% from 2002 to 2008.

A wide variety of UK vessels and segments are active in the North Sea. However, the key UK fleet segments in the North sea are the demersal trawl and seine 12-24m and 24-40m. These vessels target a range of whitefish species and also large volumes of nephrops across the North Sea. In 2008, these vessels made an average profit of €39,028 and €93,423 respectively. Key issues affecting the UK fleets operations in the North Sea include reductions in quotas of key species in particular cod and haddock, days at sea restrictions and discards as a result of the management regime. Specifically, one concern about the cod recovery plan is that it imposes an effort limitation on top of the existing quota limitations, and the effort allowance is generally more limiting than the quota.

The main Dutch fleet segments fishing in the North Sea are beam trawlers over 40m, beam trawlers 18-24m including shrimp fishery and pelagic trawls and seines over 40m. The larger beam trawlers mainly target sole and plaice, the smaller beam trawlers target shrimp. The pelagic fisheries mainly target whiting and mackerel. The larger beam trawlers were struggling in 2008 with high fuel prices and low prices for sole and plaice. Although the fuel price has decreased in 2009, the prices for sole and plaice are still low resulting in either a (small) loss in 2009 or a small profit. The shrimp fisheries made a profit in 2008, however in 2009 due to low prices for shrimp it is expected to make a loss. The pelagic fleet faced lower quota in 2008, this trend in continuing in 2009 and 2010. Because the prices for frozen fish increased in 2008 the overall value of landings still increased. However costs increased faster than income resulting in a net loss

In 2008, the main species caught by German vessels in the North Sea area were brown shrimps, herring, saithe, cod, blue mussels, Greenland halibut, mackerel, sandeels and plaice. The segments mainly involved in fishing activities in this area are demersal trawlers and seiners 18-24m and 24-40m, beam trawlers 12- 18m, 18-24m and 24-40m, and dredgers 24-40m. In the case of Germany, overall, quota were limiting activities. Saithe remained stable, cod stocks developed satisfactorily, herring quota dropped and limited activity of trawlers. Flatfish quotas were lowered. In general, fishing activities were affected by a debatable effort day restriction, allowing demersal gear with mesh opening 100-119mm only half of the number of days as 80-99mm, thanks to quota exchange options, the fishery on nephrops could be used as an alternative for decreased flatfish quota.

Moreover, the brown shrimp fishery developed favourably as both catches and prices increased and blue mussels developed satisfactorily.

For Denmark, the most important segment economically in the North Sea consists of large pelagic trawlers, catching sandeel, sprat and mackerel. Furthermore, the Danish demersal trawlers are a large segment, targeting plaice, cod and nephrops.

4. ECOLOGICAL STATE OF THE NORTH SEA ECOSYSTEM

4.1. Introduction

The goal of the Marine Strategy Framework Directive (MSFD) is to achieve or maintain good ecological status (GES) across all European waters by 2020. GES is defined as "*the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations*." The MSFD identifies eleven qualitative ecosystem descriptors with which to measure GES, which range from marine biodiversity to underwater noise levels. MEFEPO (WP 2 Technical Report) identified four of these descriptors as being directly affected by fishing activity and attempted to assess their current status using the most appropriate available indicators. The following sections provide a summary of the methods and results of each assessment.

4.2. Biodiversity

MSFD GES Descriptor 1: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

The indicators chosen to assess this descriptor were two variations of the "Conservation Status of Fish" (CSF). Slight modifications to the method described in COM(2008) 187 were made to each indicator calculation (see WP 2 Tech. Report Le Quesne *et al* 2010 for details). Calculation of the CSF indicators is based upon fishery independent trawl survey data that reports CPUE of species by length. This data is available from surveys conducted under the DCR. The North Sea IBTS survey provides coverage of the whole North Sea area as a single co-ordinated survey and can provide the information required to calculate the CSF indicators (Le Quesne *et al.* 2010).

CSFa (Fig. 4.2.1) and CSFb (Fig. 4.2.2) show some variation in behaviour between the full list and 5 year list, which was attributed to two species, *Anarhichas lupus* and *Squalus acanthias*, that were incorporated in the 5 year list but not included in the full list. Both these species started at low abundance and declined further over time. Whereas five species were included in the full list that were not included in the five year list. In each case these were species that were increasing over the survey time period. Their abundance over the first 5 years was insufficient to allow the species to be included on the basis of abundance, but their increased numbers over time meant that they do achieve the abundance threshold over the full time series.

The result that the CSFa indicator has remained below the provisional threshold level of 1 over the full time period for which unified data across the whole North Sea is available suggests that the effect of fishing on the marine biodiversity with respect to GES descriptor 1 is well within acceptable limits. Using the selection criteria specified in COM(2008) 187 the CSFb indicator also indicates that effect of fishing on biodiversity is within acceptable levels. When the full species list is used the CSFb indicator reports a greater than 80% increase in the average biomass of large vulnerable fish compared to the reference period, whereas when the 5 year species list is used the indicator reports an approximately 20% decline in the average biomass of large vulnerable fish compared to the reference period and then it could be considered that the conservation status of fish is not being maintained. When interpreting the CSF indicators it is important to note that this indicator only considers a selected portion of the fish community. There are 29 species and 10 habitats listed on the OSPAR list of threatened and declining habitats and species that are considered under threat or in decline in the greater North Sea (OSPAR area II). Of the 29 species listed as threatened or declining in the North Sea 10 are fish species, and of these 10 fish species only one (*Gadus morhua*) is considered in the indicator based on the full list and two (*G. morhua* and *S. acanthias*) are included in the 5 year list. This indicates the limitations of the CSF indicators as indicators of the effect of fishing on biodiversity (Le Quesne *et al.* 2010).

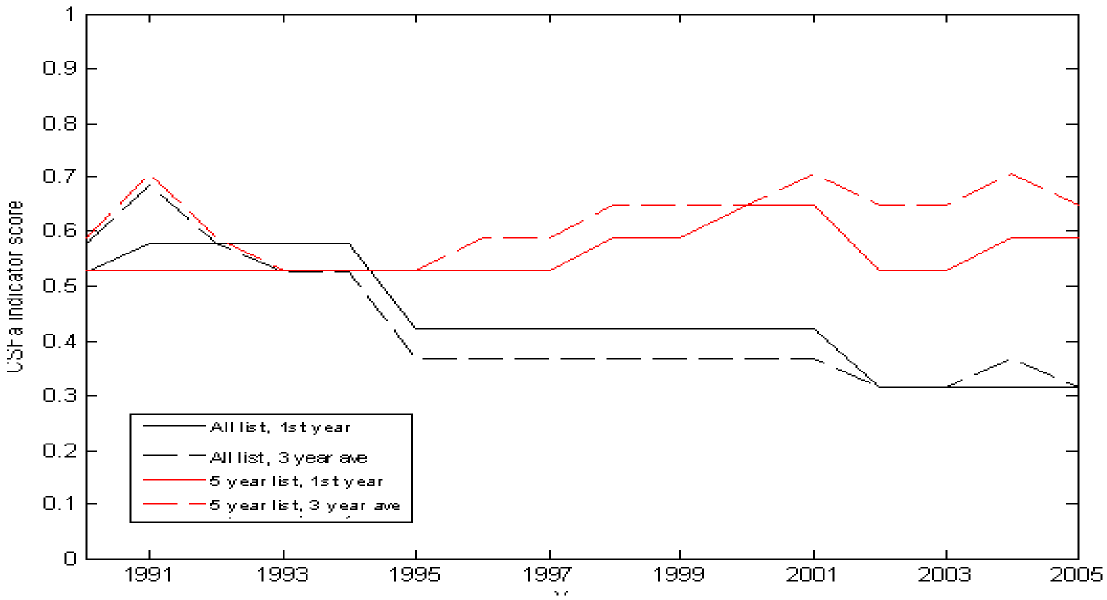


Fig. 4.2.1 CSFa indicator values calculated with the full and 5 year species lists, and using either the first year or average of the first three years as the reference period (Le Quesne *et al.* 2010).

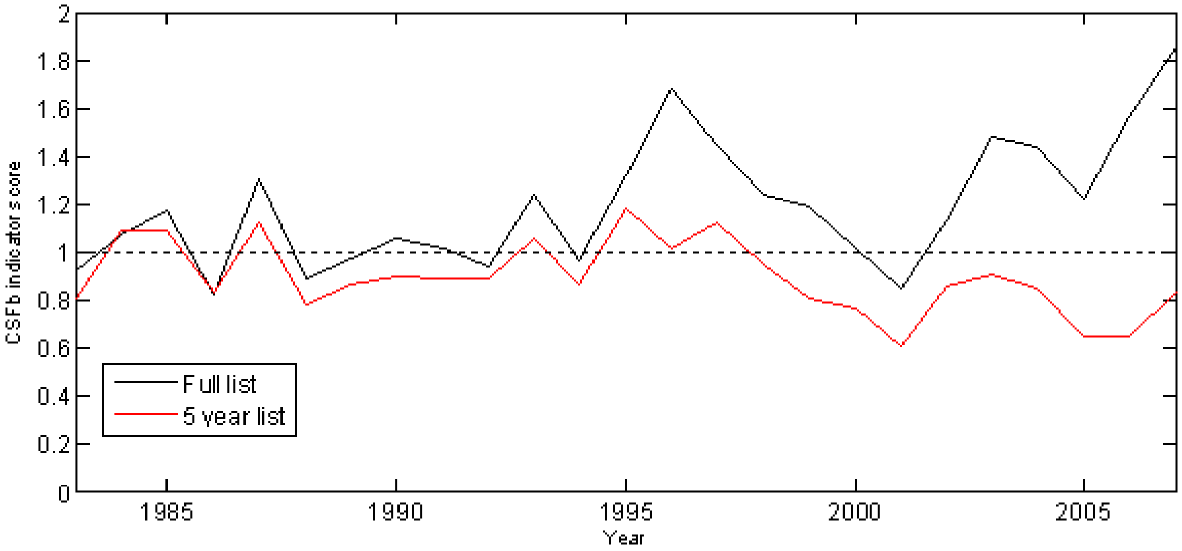


Fig. 4.2.2: CSFb indicator values calculated with the full and 5 year species lists. The dashed line is a reference line with a value of 1 (Le Quesne *et al.* 2010).

4.3. Commercial stocks

GES Descriptor 3: Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

The data required to calculate the commercial species indicator are yearly assessment values of SSB and F for a stock and the reference values for SSBpa and Fpa for the same stock. Ideally this would be known for all stocks, as this is practically unfeasible a target coverage of including stocks that made up 75% of the value of the landings was identified as desirable, albeit this level of representativity is currently unavailable (Le Quesne *et al.* 2010). Among the stocks used to calculate the indicator, are also the target stocks of the case study fisheries. For the full description of the data used and the calculations performed, see Le Quesne et al. (2010).

The time-series of the proportion of stocks within “Safe Biological Limits” (SBL) indicator show a strong decrease from 100% at the start in 1957 when only based on two stocks (plaice and sole) to about 20% in the early 1970s to about 10% in the 1990s (Fig. 4.3.1). In recent years there appears to be a slight increase to about 30%. A comparable trend is observed for the linked indicator, “proportion of landings within SBL” which also decreases strongly over the 1960s remaining mostly below 20% and showing a slight increase in recent years (Fig.). The decrease at the beginning of the time-series may be caused by the change in the composition of the suite of stocks on which the indicator is based. As the indicator was based on a consistent suite of stocks from 1995 onwards the increase in recent years appears to be genuine. The target reference point to achieve GES for the commercial species descriptor is 100% of stocks are within SBL. The 2008 indicator value of just over 40% is well below the target level.

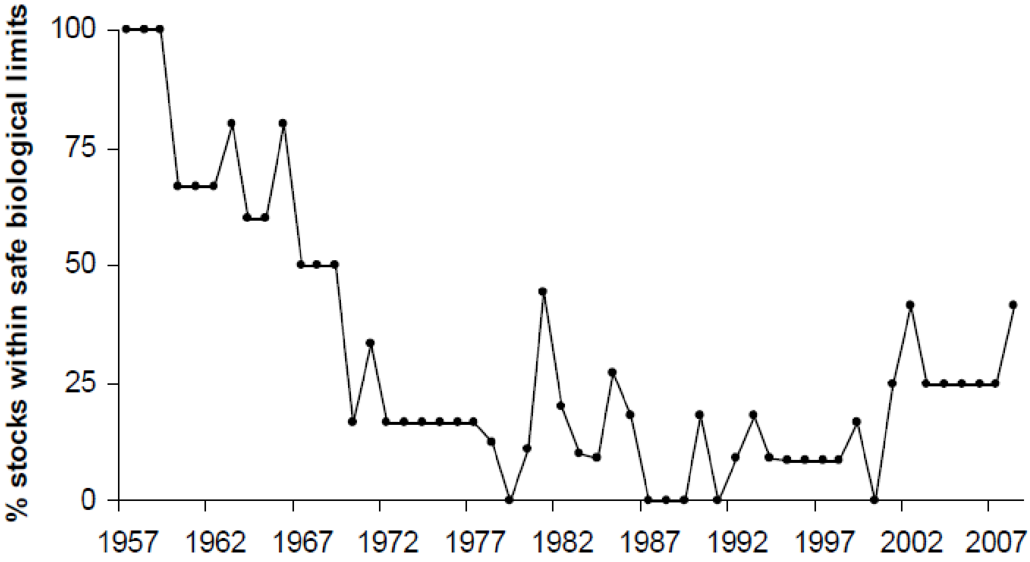


Fig. 4.3.1 Proportion of North Sea stocks within safe biological limits (Le Quesne *et al.* 2010).

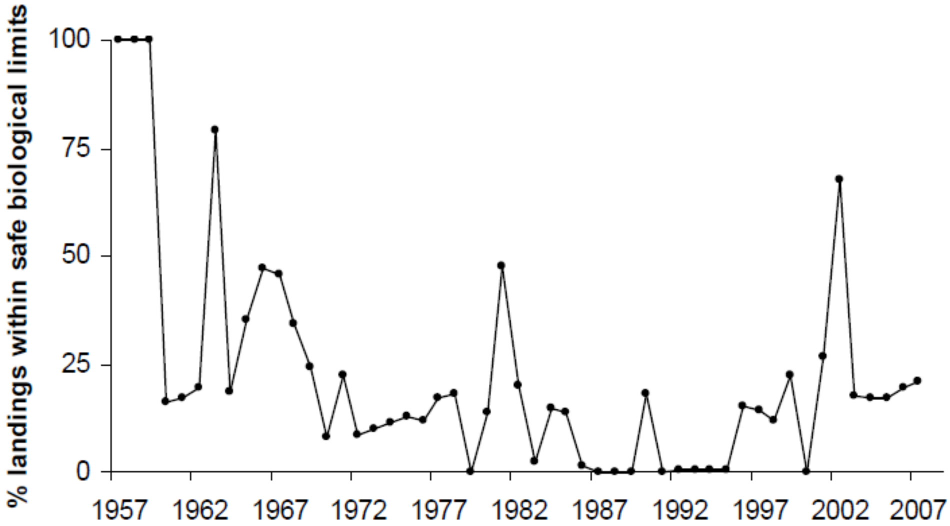


Fig. 4.3.2 Proportion of landings from assessed North Sea stocks that are within safe biological limits (Le Quesne *et al.* 2010).

4.4. Food webs

GES Descriptor 4: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

The indicator chosen for the assessment of this descriptor was the large fish indicator (LFI), this indicator only considers a selected portion of the fish community. Calculation of the LFI is based upon fishery independent trawl survey data that reports catch per unit effort of species by length. The surveys and data used for this indicator are the same as those described in *Biodiversity*. The formula used to calculate the LFI for each year was:

LFI = Weight of fish ≥ 40cm in length / Total weight of fish

The limit reference level for the LFI, as implement by OSPAR, is for the LFI to be 0.3 or greater. The LFI calculated for the North Sea IBTS has been below the OSPAR target value of 0.3 since the early 1980s (Fig. 4.4.1). Although the indicator is still below the target value of 0.3 it has risen considerably from its low point in the early 2000's. The North Sea is not considered to be attaining GES in relation to qualitative descriptor 4 as monitored by the LFI indicator with a target value set at 0.3.

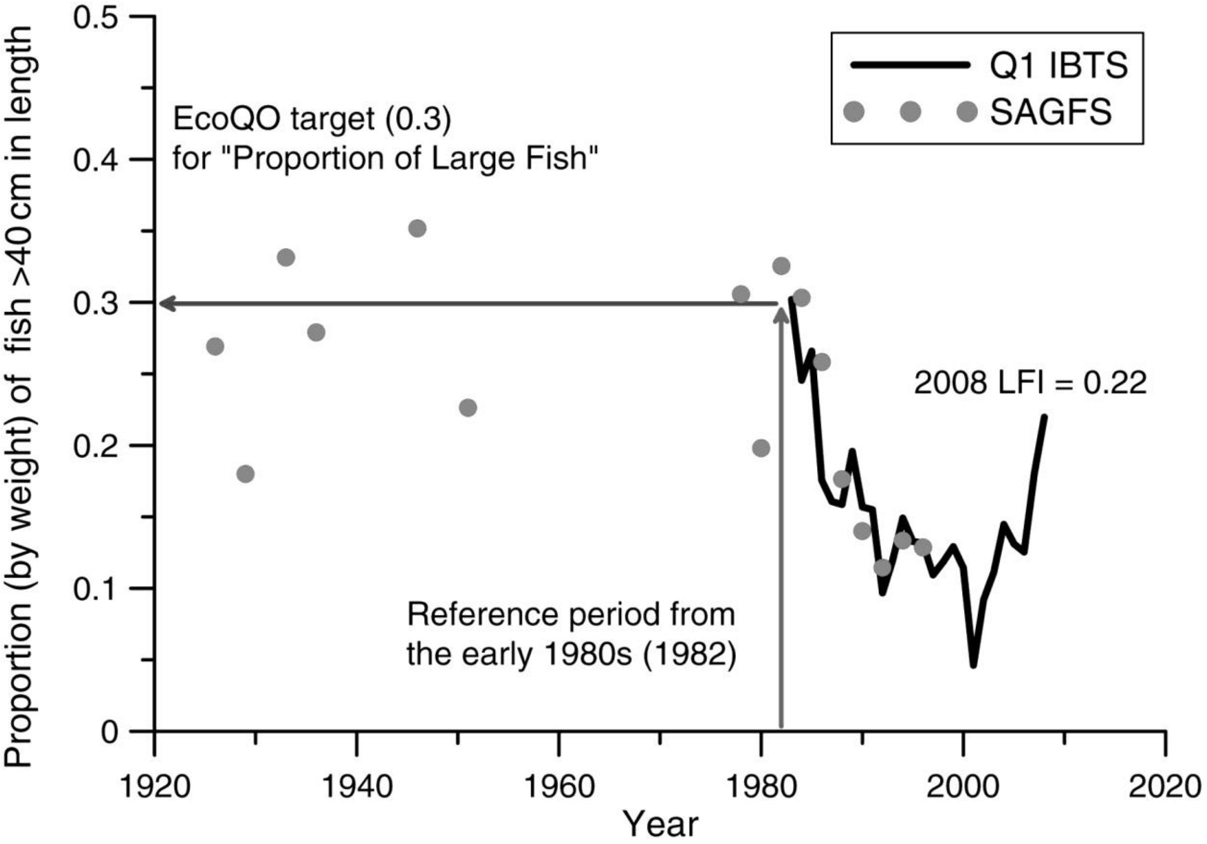


Fig. 4.4.1 LFI calculated for the North Sea IBTS shown alongside historic data from the Scottish August Groundfish Survey (SAGFS). The dashed line indicates the value of 0.3 which is the target level for the OSPAR EcoQo for large fish (Greenstreet *et al.* 2011).

Although the LFI is not the perfect indicator to report on the effects of fishing on food web integrity, the LFI has strong pragmatic merits as an operationally indicator that could be applied over large regions of EU waters on a rapid basis with limited further development. Given the debates surrounding the question of defining acceptable food web structure the LFI is grounded on a solid theoretical basis and achieving the target for the LFI could well lead to a general improvement in food web integrity with regards to elements of marine ecosystems that are not explicitly considered by the indicator.

4.5. Seafloor integrity

GES Descriptor 4: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

The indicator used to assess this descriptor was the proportion of area not impacted by mobile bottom gears. This is calculated using vessel monitoring systems (VMS) and provides a direct measure of the main pressure on benthic systems. However, it provides no indication of the actual state of the benthic habitat. Currently there are no robustly justified reference levels as target or limit values for this indicator. The acceptable level of mobile bottom gear impact will depend on the resilience and susceptibility of the habitat (and its key functions) to damage, thus a single unified reference level to be applied across all habitat types may not be possible. Until justified reference levels are developed the target reference direction for the indicator is for the proportion of area not impacted by mobile bottom gears to remain constant or increase.

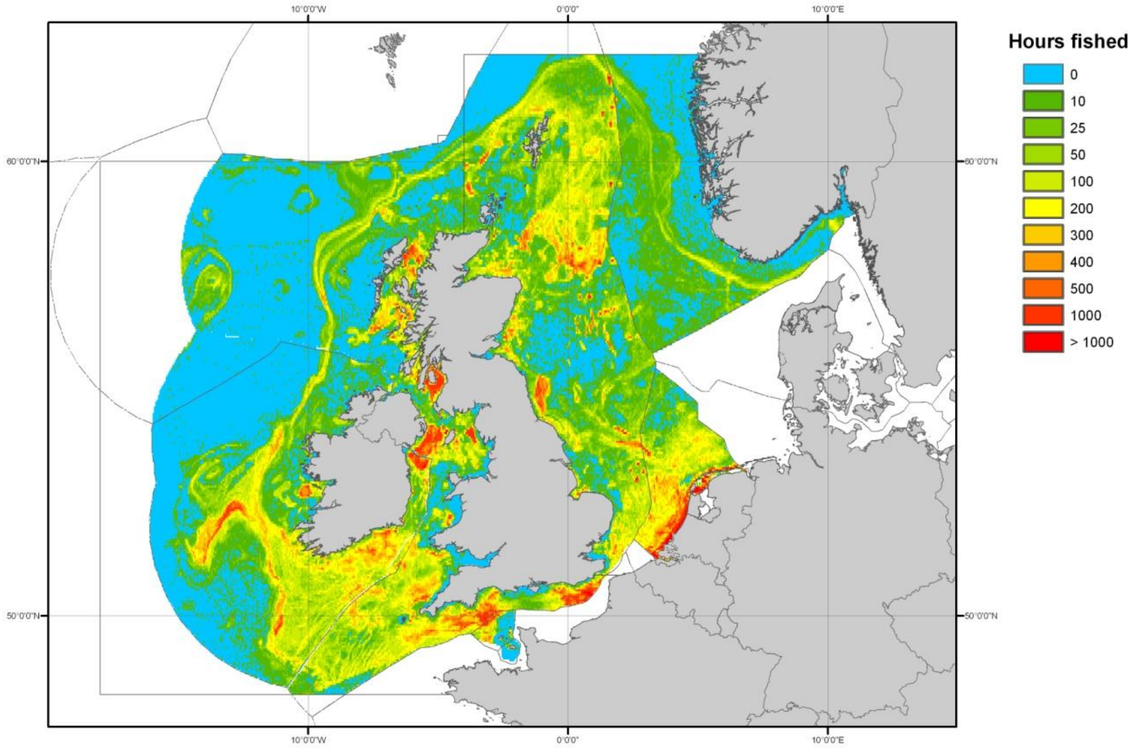
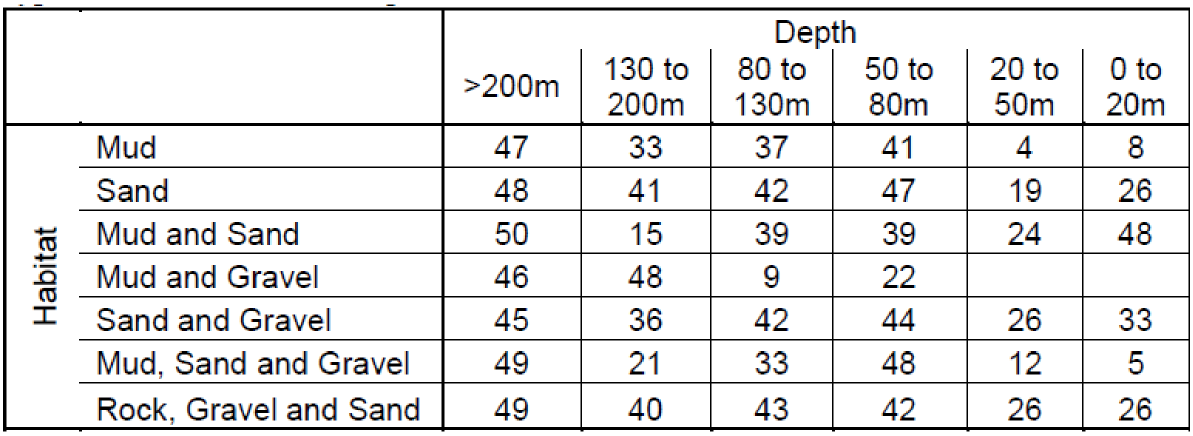


Fig. 4.5.1 Distribution of fishing effort by mobile bottom gears for 2007 by 3'x3' cells based on VMS records from submitting nations (no French data) (Le Quesne *et al.* 2010).

The combined VMS data (Fig.) reveal the bottom-fishing 'hotspots' in North Sea, particularly the trawling along the Dutch coast, shrimp fishers and eurocutters and the fisheries in the Botney Cut and on the English coast at the height of Newcastle (Fig. 4.5.1).

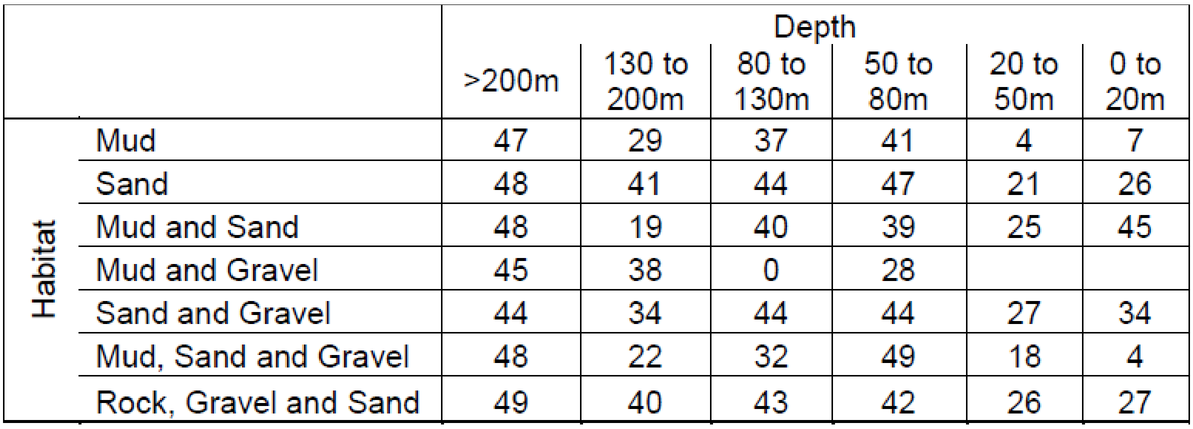
The proportion of area not trawled indicator was calculated for 2006 and 2007 by depth band and sediment type (Table 4.5.1 and Table 4.5.2). No reference limits have been set or proposed for the proportion of area not trawled indicator when used as a pressure indicator to report on the MSFD GES descriptor 6: sea-floor integrity. Some limits have been suggested for protected area coverage of rare and threatened habitats. However it is important to distinguish at this point between concern for rare and threatened benthic habitats, such as OSPAR listed habitats, and the aims of GES descriptor 6 which is concerned with benthic ecosystem processes as a whole. The focus of GES descriptor 6 on functioning of benthic ecosystems as a whole leads to a focus on the state of the widespread and dominant benthic habitats. Thus limit reference points developed for protecting habitats of conservation concern are not necessarily applicable. Concern for rare and threatened habitats falls under GES descriptor 1 (Le Quesne *et al.* 2010).

Table 4.5.1 Percentage of area not impacted by mobile bottom gears by combined depth band and sediment type For the North Sea RAC region for 2006. Blank cells for areas where the sediment type did not occur in that depth band (Le Quesne *et al.* 2010).



		Depth					
		>200m	130 to 200m	80 to 130m	50 to 80m	20 to 50m	0 to 20m
Habitat	Mud	47	33	37	41	4	8
	Sand	48	41	42	47	19	26
	Mud and Sand	50	15	39	39	24	48
	Mud and Gravel	46	48	9	22		
	Sand and Gravel	45	36	42	44	26	33
	Mud, Sand and Gravel	49	21	33	48	12	5
	Rock, Gravel and Sand	49	40	43	42	26	26

Table 4.5.2 Percentage of area not impacted by mobile bottom gears by combined depth band and sediment type For the North Sea RAC region for 2007. Blank cells for areas where the sediment type did not occur in that depth band (Le Quesne *et al.* 2010).



		Depth					
		>200m	130 to 200m	80 to 130m	50 to 80m	20 to 50m	0 to 20m
Habitat	Mud	47	29	37	41	4	7
	Sand	48	41	44	47	21	26
	Mud and Sand	48	19	40	39	25	45
	Mud and Gravel	45	38	0	28		
	Sand and Gravel	44	34	44	44	27	34
	Mud, Sand and Gravel	48	22	32	49	18	4
	Rock, Gravel and Sand	49	40	43	42	26	27

4.6. Summary/limitations

When considering the assessment of the impacts of fishing on GES in the North Sea RAC region two separate questions can be asked:

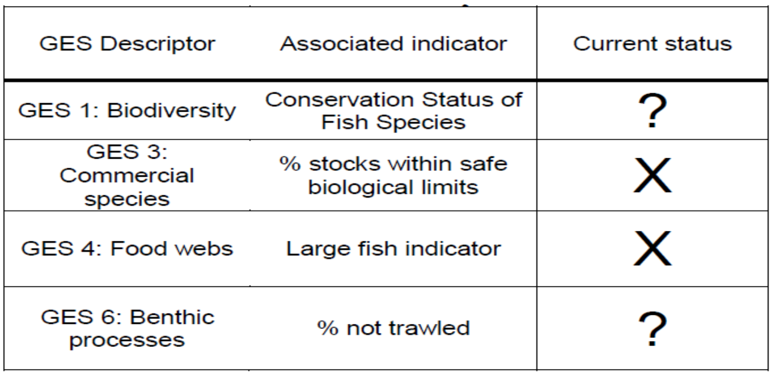
i) Does fishing compromise GES in the North Sea RAC region
with respect to individual GES descriptors?

and

ii) Does fishing compromise GES in the North Sea RAC
region with respect to a unified assessment of GES?

In response to the first question, the results of the individual GES descriptor assessments in relation to the specified reference limits are presented in (Table 4.6.1). A first order assessment shows that for the four GES descriptors identified for analysis GES is not demonstrated as achieved for any descriptor, GES is compromised for two of the descriptors (GES 3 & 4) and cannot be clearly assessed for the other two descriptors (GES 1, 6).

Table 4.6.1 Assessment of the North Sea RAC region with respect to impacts of fishing on Good Environmental Status as defined by the MSFD. A 'x' indicates that GES is not achieved, a'?' that status is uncertain or cannot be assessed, see WP2 report Le Quesne *et al* 2010.



GES Descriptor	Associated indicator	Current status
GES 1: Biodiversity	Conservation Status of Fish Species	?
GES 3: Commercial species	% stocks within safe biological limits	X
GES 4: Food webs	Large fish indicator	X
GES 6: Benthic processes	% not trawled	?

In each case limitations in indicator ecosystem component coverage has been noted, however this is of most concern in relation to GES descriptor 1, furthermore in the case of the conservation status of fish species indicator used to report against GES descriptor 1 there are notable concerns about the ability of this indicator to monitor the status of the fish species of most conservation concern.

In the case of GES descriptor 6, sea-floor processes, an assessment of the impact of fishing on GES is not currently possible. There are two related stumbling blocks. Firstly the indicator is a pressure indicator rather than a state indicator, thus the indicator does not directly provide information on the environmental status of the seafloor processes. Using a pressure indicator to inform on status can only be achieved when the link between pressure and state is well known; at present the link between pressure by mobile bottom gears and the state sea-floor functioning is not strongly developed only limited conclusions can be drawn about the impact of fishing on GES with respect to sea-floor processes. The second related stumbling block is that no reference limit has been identified by which to assess current status in relation to objective for GES. However no reference limit can be expected to be developed until the link between pressure and state has been better established.

To summarise the response to the question of whether fishing compromises GES in relation to individual GES descriptors: in the case of GES descriptors 3 and 4 there is good evidence related to a good theoretical understanding to indicate that fishing does compromise GES. Whereas in relation to GES descriptors 1 and 6 only limited conclusions can be drawn based on the indicators employed and their theoretical basis.

The second question was whether fishing compromises GES in the North Sea RAC region as part of a unified assessment of GES. In the case of the current assessment the North Sea RAC region fails to achieve GES for two of the four descriptors examined, and GES is only achieved for one descriptor (but see comments above). Therefore, irrespective of whether attainment of GES is based on an 'average' of descriptors or on the basis that GES needs to be achieved across the board, the current assessment indicates that fishing negatively impacts GES in the North Sea RAC region (Le Quesne *et al.* 2010).

5. CASE STUDIES: EVALUATING MANAGEMENT STRATEGIES

5.1. Introduction

5.1.1. Drivers of Change in European Fisheries Management

The Green Paper on the Reform of the Common Fisheries Policy (i) identified the need for EBFM taking account of the ecological, social and economic pillars of sustainability, (ii) stated an intention to move towards a longer term approach to fisheries management, and (iii) made commitments to greater stakeholder involvement in management. The Marine Strategy Framework Directive (MSFD) defines environmental objectives for European seas, based on sustainable utilisation of healthy marine ecosystems in support of sustainable development. The Integrated Maritime Policy specifies that individual sectors (e.g. fisheries) need to support MSFD objectives. These commitments have shaped the development of the MEFEPO Fisheries Ecosystem Plans (FEPs).

5.1.2. Developing the regional case studies

'Descriptors' for the ecological, social and economic status of the fisheries were developed to enable simultaneous consideration of the potential impacts of different management strategies on the three pillars of sustainability (Piet et al. 2011; Fig 5.1.2.1). Stakeholders supported the MEFEPO "three pillar" approach to explore potential impacts of different management strategies on multiple objectives for the marine environment.

Ecological descriptors, drawn directly from the MSFD, were selected at a MEFEPO stakeholder workshop as those most impacted by fishing activities (biodiversity, commercial fish, food-webs and seafloor integrity). Social and economic descriptors were defined to monitor the main aspects of fishing contributing to the economic and social wellbeing of society, in particular coastal communities. Economic descriptors focus on fishers' ability to maximise economic efficiency of fishing operations (efficiency) and minimising fluctuations in harvesting possibilities over time (stability). Social descriptors monitor employment opportunities within the catching sector (community viability) and securing catch potential for human consumption (food security).

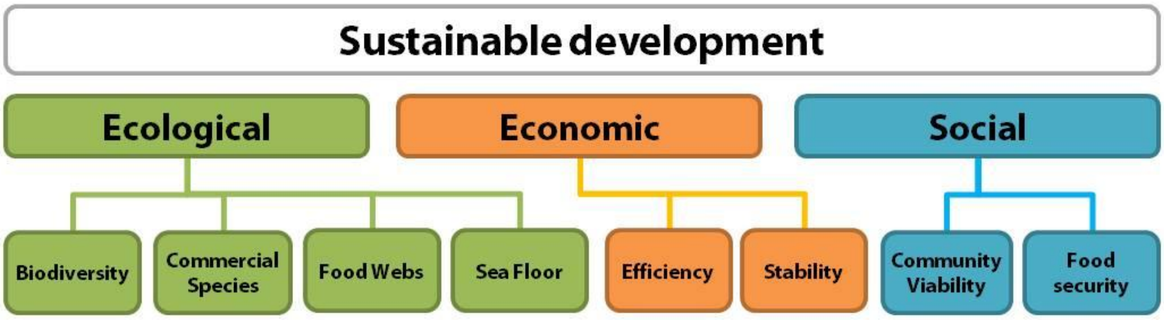


Fig. 5.1.2.1 Descriptors chosen to reflect the three pillars of sustainability (see Annex A for further details)

Preliminary case studies of selected fisheries have been developed to demonstrate practical application of the management strategies matrix approach. In each case, the potential performance of a limited number of management strategies (consisting of the application of multiple management tools) was evaluated. The efficacy of the management strategies was considered in the context of high level management objectives for European fisheries. The predicted change in the descriptor status associated with implementation of each management strategy was assessed.

🟩 Expected improvement in the status of the descriptor 🟨 Stable (i.e. no change in the status of the descriptor) 🟥 Expected deterioration in the status of the descriptor ▨ Outcome unknown

The suite of management strategies comprised of "business as usual" (BAU) and alternative strategies applying different management tools, to explore how the objectives of EBFM may be most effectively achieved. Given that it may possible to deliver the same set of objectives in more than one way or it may be impossible to fully achieve all objectives simultaneously, consideration of alternatives management strategies allowed the trade-offs associated with different management approaches to be examined.

The results of this review are reported using a common format, a management strategies matrix, developed in consultation with MEFEPO stakeholders (see Van Hoof et al. 2011). Management strategy matrices were completed based on the best available evidence (modelled, empirical and expert judgment) under the following assumptions:

- Time frame: in keeping with the principles of the ecosystem based fisheries management (EBFM), the management strategies matrix was populated based on expected medium to long-term (5-10 year) outcomes. This means that other effects may take place in the short term.
- Partial assessment: we have examined changes in one (or a few) selected management tools and assume all other measures used in the fishery are kept constant.
- Constant external environment: we have assumed that all exogenous conditions (e.g. market price on fish, fuel prices, water temperature, fish food availability, etc.) are constant.

Information on the application and success of management tools from earlier project work (Aanesen et al. 2010), scientific literature and expert opinion was used to inform the choice of management tools in the development of the management strategies. Examining the performance of management strategies was more complex for the mixed-species fisheries case studies as it may not be possible to achieve MSY for more than one species at the same time. Thus management strategies explored possible trade-offs in terms of prioritising stocks.

Ultimately the decision on which management strategy should be adopted will be based on overarching management objectives (ecological, social and environmental). The aim of this process was to demonstrate the application of the management strategy matrix approach to present the information to help decision-makers to take appropriate decisions, rather than to pass comment on the "best" management strategy. However, information on stakeholder preferences for particular management tools (e.g. from EFEP) is used to provide commentary on which strategies might receive better stakeholder support. Gaps in knowledge (ecological, social and economic), which may limit our ability to successfully implement EBFM, were identified and likely consequences of management strategy application are discussed.

5.2. Case study: Herring pelagic fishery

5.2.1. Introduction to the fishery

The North Sea herring fishery is a multinational fishery that seasonally targets herring in the North Sea. The fishery takes place in the Shetland-Orkney area and northern North Sea in the spring and summer, and in the English Channel in the late autumn and early winter (Fig. 5.2.1.1). The main fleets come from Norway, Denmark, UK, The Netherlands, France, Germany, and Sweden (in decreasing order by landings). An industrial fishery which catches juvenile herring as a by-catch in the summer and early autumn, operates in the Skagerrak, Kattegat and in the central North Sea. Most fleets that execute the fishery on adult herring target other fish at other times of the year, both within and beyond the North Sea (e.g. mackerel, horse mackerel and blue whiting). The fishery fishes against an area TAC (herring catches in the North Sea), but the assessment and fisheries advice is stock based (North Sea autumn spawning herring) to which estimates of potential catches from neighbouring stocks are added.

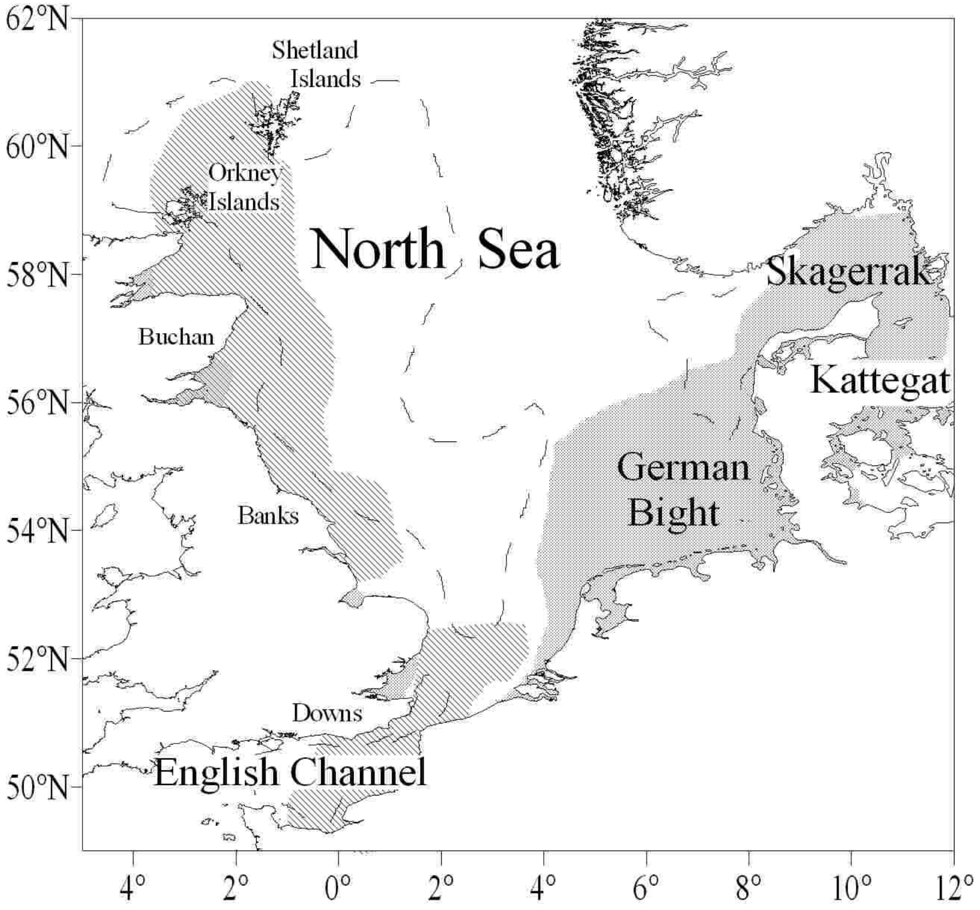


Fig. 5.2.1.1 Area of operation of the North Sea herring fishery (slashed line). ▨ denotes the main spawning grounds of North Sea herring, which are labelled Shetland, Orkney, Buchan, Banks and Downs. ░ denotes main nursery grounds.

The populations of herring constitute some of the highest biomass of forage fish in the North Sea and are thus an integral and important part of the ecosystem, particularly the pelagic components (Mackinson & Daskalov, 2007). As planktivores, they link zooplankton production with higher trophic levels (fish, sea mammals and birds) but also can act as predators on other fish species such as cod and plaice by their predation on fish eggs. Over the past century man has exerted the greatest influence on the abundance and distribution of herring in the North Sea (Dickey-Collas *et al*., 2010a). Spawning stock biomass has fluctuated from approximately 4.5 million tonnes in the 1880s and the late 1940s to less than 100 000 tonnes in the late 1970s. This large range is due to an interaction of naturally induced changes in productivity of the stock and exploitation by man. North Sea herring has demonstrated an ability to recover from low biomass, once fishing mortality is curtailed in spite of recruitment levels being adversely affected (Payne et al., 2009, Nash et al., 2009). Post-collapse populations have shown no reductions in genetic diversity or any indications of fisheries induced evolution, although recovery of the spatial diversity (e.g. recolonisation of spawning grounds) has taken longer than the recovery of biomass (Schmidt et al., 2009). The influence of the environment of herring productivity means that the biomass will always fluctuate (Dickey-Collas *et al*., 2010b).

North Sea herring have well described migration routes with spawning on gravel beds in the western North Sea (Fig. 5.2.1.1) producing larvae that are transported to the eastern North Sea and Skagerrak, i.e. the nursery grounds for the herring juveniles (Röckmann *et al*., 2011). The juveniles stay in these shallower areas until the onset of sexual maturation (generally after three summers), thereafter they head to the spawning grounds and join the existing mature population (Dickey-Collas 2010). After spawning, the adult (mature) herring migrate to a range of overwintering areas, and then return to the central and northern North Sea to feed in the spring and summer (Dickey-Collas 2010). The feeding herring can be found in the areas with highest zooplankton standing stock (Bainbridge and Forsyth, 1972; Maravelias, 2001).

North Sea herring has a complex sub-stock structure with different spawning components (see Fig. 5.2.1.1) producing offspring with different morphometric and physiological characteristics, different growth patterns and differing migration routes. A healthy North Sea herring stock is not just one where the fishing mortality on the stock is sustainable and the biomass of herring high enough to maintain successful recruitment and other ecosystem services (such as prey for top predators) but also where the phenotypic complexity and sub-stock structure is maintained thus increasing the resilience of the population (see Schmidt *et al*., 2009). Productivity of the spawning components varies. The three northern components show similar recruitment trends and differ from the Downs component, which appears to be influenced by different environmental drivers (Fässler *et al*., 2011).

Having their spawning and nursery areas near the coasts, means herring are particularly sensitive and vulnerable to anthropogenic impacts. The most serious of these is the ever increasing pressure for marine sand and gravel extraction and the development of wind farms. This has the potential to damage and destroy the spawning habitat and disturb spawning shoals if carried out (or constructed) during the spawning season. Herring naturally abandon and then recolonise spawning beds, so a recent absence of herring spawning does not mean that that spawning bed is not required to maintain a healthy population of herring in the North Sea. Climate models predict a future increase in air and water temperature and a change in wind, cloud cover and precipitation (Drinkwater, 2010). Analysis of early life stages’ habitats and trends over time suggests that the projected changes in temperature may not widely affect the potential habitats but may influence the productivity of the stock (Röckmann *et al.,* 2011; Fässler *et al.*, 2011).

5.2.1.1. Fishing gear

There are at least four techniques used to fish for herring in the North Sea:

i. Human consumption fishery using mid-water trawl by single or pair RSW (refrigerated seawater) trawlers. These are not allowed to carry sorting equipment on board and thus cannot process the catch whilst at sea (other than emptying tanks or slipping catch from the net). They either land their catch as caught or pass it on to a processing vessel. Their catching potential is limited by the size of their tanks. This fishery is operated by vessels from the UK- Scotland, Denmark and Norway.

ii. Human consumption fishery using mid-water trawl by single or paired pelagic freezer trawlers. These catch and then process on-board, offloading frozen blocks of sorted and categorised fish. Their catching potential is limited by their processing capacity, usually 200-250 tonnes per day. This fishery is operated by vessels from Germany, The Netherlands, France and UK-England.

iii. Human consumption fishery using purse seine by RSW trawlers. Purse seine nets are used to encircle the shoals of herring rather than chase them with trawls. These vessels do not carry sorting equipment. Their catching potential is limited by the size of their tanks. This fishery is operated by vessels from Norway, Sweden and Denmark.

iv. Industrial fishery as bycatch. The herring is caught when targeting sprat or Norway pout using mid-water trawls with fine mesh nets (<32mm). Their catching potential is limited by the size of their tanks and a maximum bycatch percentage of herring. This fishery is operated by Denmark.

All of these fishing methods use fishers experience and acoustic techniques to find the shoals of fish. The mid-water trawls (single and paired) and purse seines are damaged if contact is made with the seabed. The fleets are characterised by a few vessels (all >40m), with even fewer owners. For example the German, Dutch, English and biggest French vessels are all owned by three companies operating out of the Netherlands.

5.2.2. State of the stock

The stock is officially called North Sea Autumn Spawning herring, and includes the autumn and winter spawning components. The single species stock assessment for North Sea herring is relatively robust and provides useful information for stock management (Simmonds, 2007; 2009). It has been carried out by ICES since the 1960s and proved useful for preventing collapses of the stock when the productivity declined in 1995 and again in the 2000s (Simmonds, 2007; Payne *et al.*, 2009). It incorporates information from the catches by the human consumption and industrial fisheries and from 4 surveys of various life stages of herring (acoustic, trawl and ichthyoplankton). Multispecies approaches give similar impressions of stock dynamics (Dickey-Collas *et al.*, 2010a).

The stock has experienced highs and lows in productivity and biomass over the last 50 years (Fig. 5.2.2.1), but is now exploited well below MSY at approximately F= 0.1, that is similar to natural mortality. The exploitation on the juveniles is now the lowest in the last 40 years (approximately F= 0.03). ICES classifies the stock as being at full reproductive capacity and as being harvested sustainably and below management plan and FMSY targets. In the 1970s, North Sea herring provided a well-studied example of a fisheries induced stock collapse (Dickey-Collas *et al.*, 2010a). It should be also noted that extending the time series of catches back to the 1940s or using an ECOPATH model back to 1880s suggests that the spawning biomass of herring was approximately 4.5 million tonnes at the beginning of the 20th century.

The stock is currently considered to be in a low productivity phase as the recruit to spawner ration is very low (currently 1-4 recruits per spawner per year, whereas in the 1990s approximately 5-10 recruits per spawner per year). The year classes from 2002 to 2007 are estimated to be among the weakest since the late 1970s, when the stock collapsed.

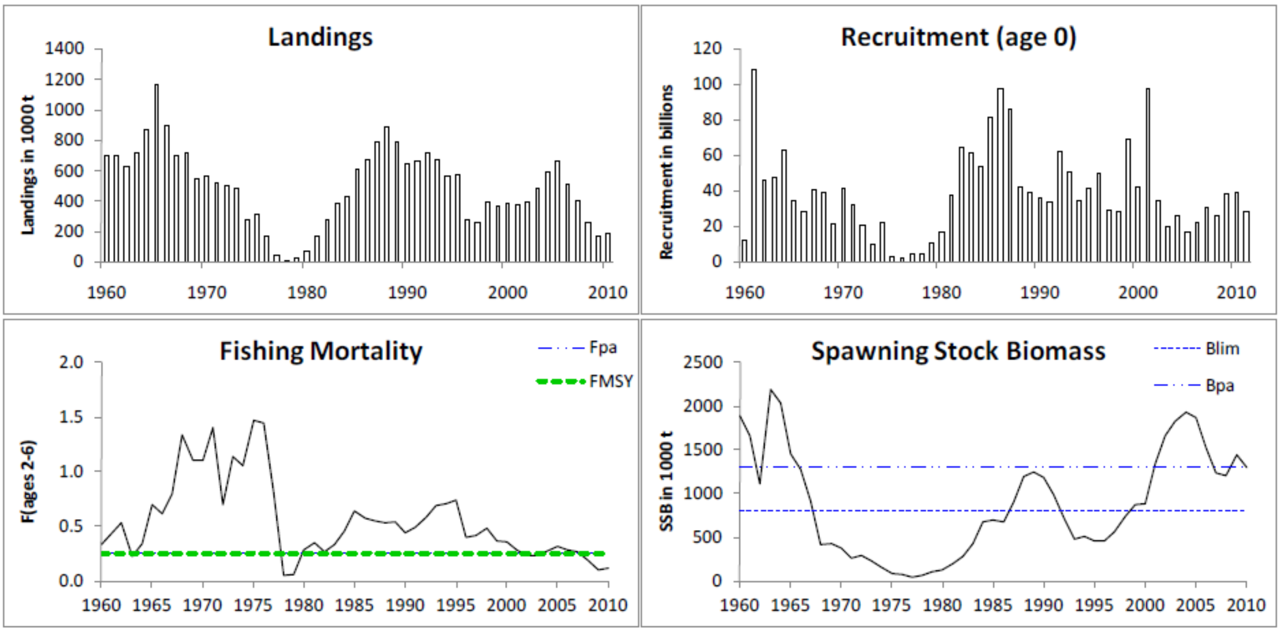


Fig. 5.2.2.1 Results of the ICES stock assessment (1960-2010) for North Sea herring, carried out in 2011 (ICES advice 2010). Top left – the landings of herring. Top right – recruitment of age 0 herring. Bottom left – average fishing mortality on herring aged 2 to 6 (showing the MSY target reference points). Bottom right – the spawning biomass (showing the biomass limit reference points B_{lim} and B_{pa}).

5.2.3. Main interactions with ecosystem components

The pelagic fisheries on herring and mackerel claim to be some of the “cleanest” fisheries in terms of bycatch, disturbance of the seabed and discarding (ICES 2010). The pelagic industry is also keen to emphasise that they are an active component of the pelagic ecosystem and should been seen as a “natural top predator”. Pelagic fish interact with other components of the ecosystem, including demersal fish, zooplankton and other predators (sea mammals, elasmobranchs and seabirds). Thus a fishery on pelagic fish may impact on these other components via second order interactions. There is a paucity of knowledge of these interactions, and the inherent complexity in the system makes quantifying the impact of fisheries very difficult.

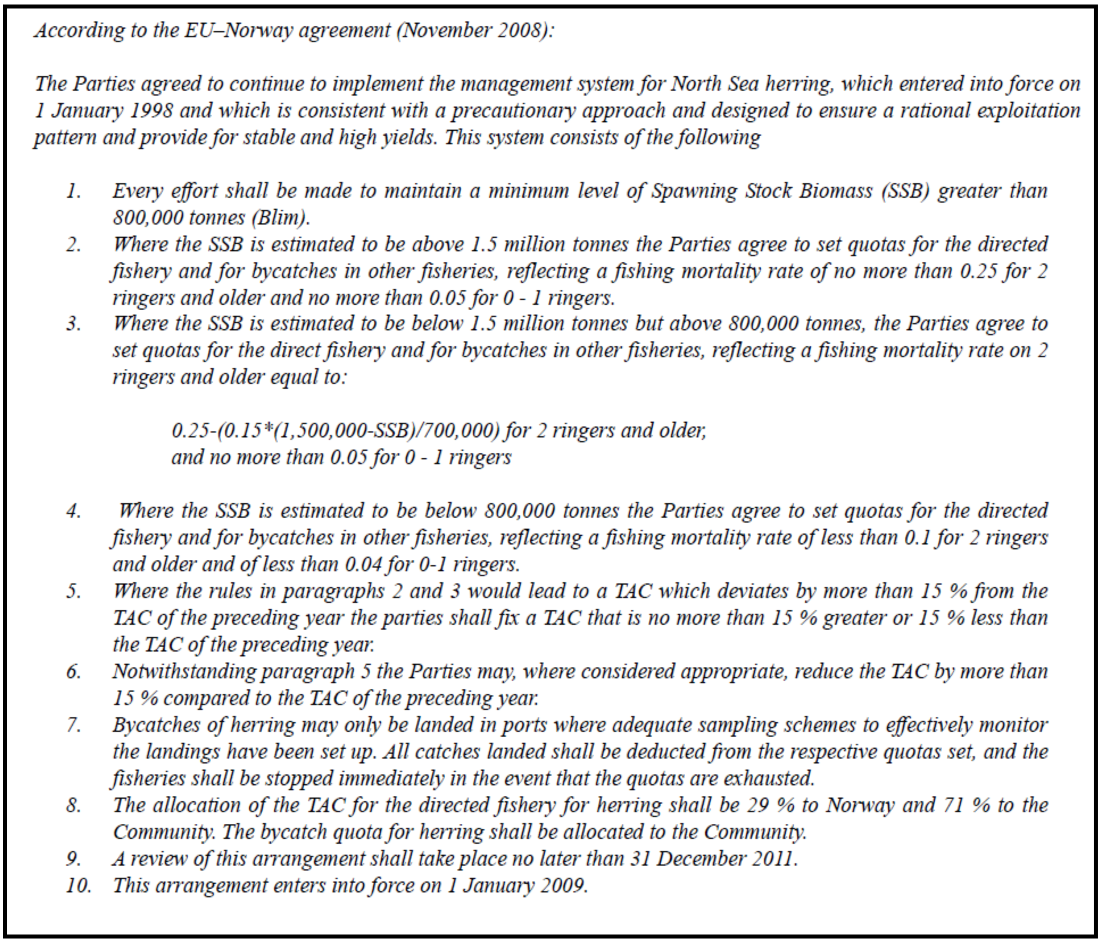
The fishery for human consumption has mostly single species catches, although some mixed herring and mackerel catches occur in the northern North Sea, especially in the purse seine fishery. Observer coverage of the North Sea herring fishing fleets suggests that the impact on the seabed is low, and the likelihood of net damage acts as a disincentive to contact with the seabed. Discarding in the herring fishery is also low in the North Sea, with 2-4% discarded by weight (van Helmond & Overzee 2011). The bycatch of sea mammals and birds is also very low, i.e. undetectable using observer programmes (ICES 2011a). There is less information readily available to assess the impact of the industrial fisheries that by-catch juvenile herring.

The other potential impact of the North Sea herring fishery is the removal of fish that could provide other "ecosystem services". The North Sea ecosystem needs a biomass of herring to graze the plankton and act as prey for other organisms. If herring biomass is very low other species may replace its role, such as sandeel (it has been suggested that the shift from herring to sandeel as prey for seals in the 1970s along the English coast, resulted from the collapse of herring) or the system may shift in a more dramatic way. The interaction of herring with cod and Norway pout population dynamics has been alluded to (Cushing, 1980; Huse *et* al., 2008; Fauchald, 2010), and Speirs *et al*. (2010) suggest that the current biomass of herring will prevent the recovery of the cod population even if fishing mortality on cod is reduced. A large cod, cetaceans or seal population will also impact the herring biomass. However many of the current ecosystem models are very sensitive to the assumptions about herring, or do not include herring as a predator and prey species, thus it is difficult to test the impact of increasing or reducing the herring biomass on the ecosystem functioning as a whole. The EU 7th framework project FACTS hopes to provide greater insight into these processes and the impact of harvesting forage fish on the marine ecosystem. It is highly likely, that for Good Environmental Status (GES), the North Sea requires a certain threshold of herring biomass.

5.2.4. Current management (Business as usual)

The current dominant management tool for North Sea herring is the EU/Norway management plan, agreed in 2008 (Fig. 5.2.4.1). The origin of the present management plan was a plan developed between EU and Norway in 1997, after a foreseen imminent stock collapse in 1996 which led to a drastic reduction in the catches in the middle of 1996. The key elements in this initial plan were a fishing mortality set separately for adult and juvenile herring (at 0.25 and 0.12 respectively), and a trigger spawning biomass (1.3 million tonnes) below which the fishing mortalities should be reduced. The target fishing mortalities were decided based on extensive simulations (Patterson et al., 1997) to find levels of adult and juvenile fishing mortalities with a low risk of bringing SSB below 800 000 tonnes, which was the MBAL at the time (Minimum Biological Acceptable Levels). The trigger biomass (1.3 million tonnes) was decided mainly on political grounds, but with a value that also was thought to give some protection against falling below the MBAL.

This plan was then amended in 2004 to include rules on exploitation rate at low biomass, concepts of the precautionary approach and constraints on TAC change, and then again in 2008, to account for the reduced productivity of the stock (ICES 2008). These adjustments were based on further simulations. The existing rule is currently being evaluated and probably will be amended at the end of 2011 (ICES 2011b). So the management plan operates through setting a TAC for the human consumption fishery, and a by-catch maximum limit for the industrial fishery (a by-catch ceiling). In the last four years, catches are in accordance with the TAC.



According to the EU–Norway agreement (November 2008):

The Parties agreed to continue to implement the management system for North Sea herring, which entered into force on 1 January 1998 and which is consistent with a precautionary approach and designed to ensure a rational exploitation pattern and provide for stable and high yields. This system consists of the following

1. *Every effort shall be made to maintain a minimum level of Spawning Stock Biomass (SSB) greater than 800,000 tonnes (Blim).*
2. *Where the SSB is estimated to be above 1.5 million tonnes the Parties agree to set quotas for the directed fishery and for bycatches in other fisheries, reflecting a fishing mortality rate of no more than 0.25 for 2 ringers and older and no more than 0.05 for 0 - 1 ringers.*
3. *Where the SSB is estimated to be below 1.5 million tonnes but above 800,000 tonnes, the Parties agree to set quotas for the direct fishery and for bycatches in other fisheries, reflecting a fishing mortality rate on 2 ringers and older equal to:*

   0.25-(0.15(1,500,000-SSB)/700,000) for 2 ringers and older,*
   and no more than 0.05 for 0 - 1 ringers

4. *Where the SSB is estimated to be below 800,000 tonnes the Parties agree to set quotas for the directed fishery and for bycatches in other fisheries, reflecting a fishing mortality rate of less than 0.1 for 2 ringers and older and of less than 0.04 for 0-1 ringers.*
5. *Where the rules in paragraphs 2 and 3 would lead to a TAC which deviates by more than 15 % from the TAC of the preceding year the parties shall fix a TAC that is no more than 15 % greater or 15 % less than the TAC of the preceding year.*
6. *Notwithstanding paragraph 5 the Parties may, where considered appropriate, reduce the TAC by more than 15 % compared to the TAC of the preceding year.*
7. *Bycatches of herring may only be landed in ports where adequate sampling schemes to effectively monitor the landings have been set up. All catches landed shall be deducted from the respective quotas set, and the fisheries shall be stopped immediately in the event that the quotas are exhausted.*
8. *The allocation of the TAC for the directed fishery for herring shall be 29 % to Norway and 71 % to the Community. The bycatch quota for herring shall be allocated to the Community.*
9. *A review of this arrangement shall take place no later than 31 December 2011.*
10. *This arrangement enters into force on 1 January 2009.*

Fig. 5.2.4.1 The current EU/Norway management plan for North Sea herring.

There are other management tools currently used for the North Sea herring fishery. Details are listed in Annex B. In the following a brief summary:

Minimum landing size is set for herring for human consumption fisheries at 20cm in the North Sea (Council regulation (EC) No 850/98).

Traditionally the EU sets a separate sub-TAC, from within its own North Sea herring TAC, for the southern North Sea and eastern English Channel (Figure 5.2.1.1). This is designed to protect the Downs spawning component as it aggregates to spawn. Downs herring is assumed to be more susceptible to the impacts of exploitation (Cushing, 1992). This sub-TAC is re-negotiated every year and is generally fixed at approximately 11-14% of the total TAC (EU and Norway; see Council regulation (EU) No 57/2011).

Closed areas for both herring and/or sprat fisheries to protect either spawning or juveniles (Council regulation (EC) No 850/98). These closed areas are relatively small and localised, and usually seasonal (Figure 5.2.4.2).

The industrial fishery is not only limited by the bycatch ceiling which is set every year based on the EU/Norway management plan (Council regulation (EU) No 57/2011) but also by a by-catch percentage for each haul. This was initially set such that 10% of the catch of the sprat can be herring (Council regulation (EC) No 850/98) but in recent years this by-catch proportion has been increased to 20% of the catch as the total mixed catch has declined.

In 2009, the EU and Norway agreed a ban on high grading in the North Sea and eastern English Channel (Council Regulation (EC) No 43/2009). This prevented the discarding of fish of a size that could be landed for which there was still quota available.

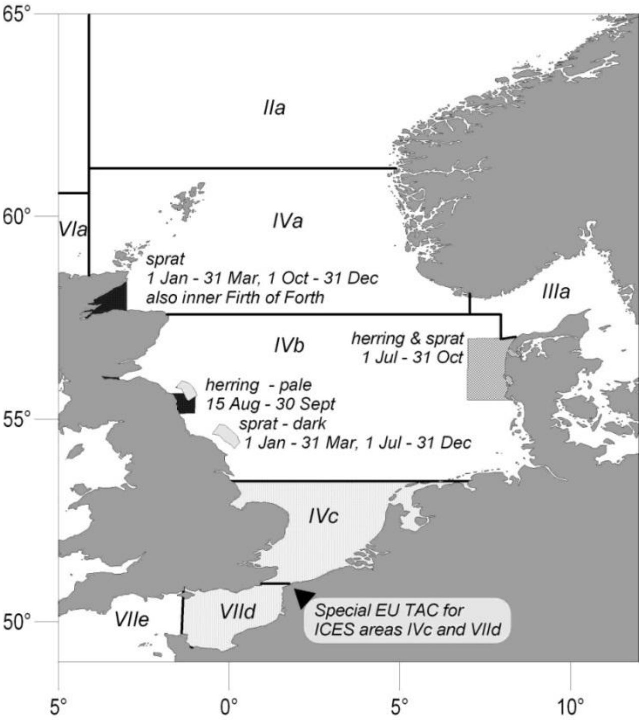


Fig. 5.2.4.2 Map showing ICES areas and areas closed to fishing on herring and sprat under EU legislation. Black areas denote three small sprat closures to protect juvenile herring. Pale areas denote two closures on the herring fisheries to protect spawning herring around the Banks spawning ground. The shaded area to the west of Denmark is closed to the juvenile herring and the sprat fishery (although there is no targeted juvenile herring fishery).

Within and between the countries in the fishery, the TAC is greatly swapped, with ITQs (or *de facto* ITQs) in most countries and some countries selling much of their annual quota (e.g. Belgium). As the fishery catches against an area TAC and the advice is for a stock TAC, the landings against the TAC do not completely reflect the exploitation on the stock, or the true catches from the stock. Fisheries scientists reallocate catch from areas IV and IIIa, based on sampling, to determine the catches from the stock. In addition, there are two boundary areas where misreporting is a problem: ICES areas

IV/IIIa and IVa/VIa. There are different regulatory solutions to each. Area-misreporting from catches taken in ICES area IV to IIIa is allowed through EU/Norway agreements, i.e. herring caught in IV can be written off against IIIa quota. In contrast, in the northern North Sea there are specific licensing regulations to prevent area misreporting, that control the landing of herring catches from and at the border of ICES areas IVa and VIa.

As with all fisheries under the CFP, engine size and vessel power are not allowed to increase across the fleets. The North Sea herring fishery is not specifically managed by other tools, such as days at sea, by-catch devices, extra taxes or fees or transferrable effort. In most fisheries on shoaling pelagic fish, effort is a very poor proxy for fishing mortality (Cunningham et al., 1985; Bjørndal 1987). If a fish aggregates at a known location whatever the size of the stock, fishing effort cannot be used to regulate exploitation as the fleet will always have good catches. North Sea herring do aggregate like this, and the use of fishing effort to monitor the exploitation in the 1960s was one of the likely reasons for a failure to pre-empt the collapse of the stock and lead to the closure of the fishery (Bjørndal, 1989; Dickey-Collas *et al.*, 2010a). Thus effort is not used in neither the assessment nor management of the stock.

5.2.5. BAU performance

The management plan has the following objectives stated in its preamble:

- Consistency with the Precautionary Approach
- A rational exploitation pattern
- Stable yield
- High yield

ICES recently evaluated this plan (ICES 2011b) and concluded:

“The management plan appears to operate well in relation to the first two objectives, but not in relation to achieving stable and high yield. The main weakness appears to be the 15% IAV limit on TAC change which leads to restricted TACs when the stock is improving.”

As a result of the conclusion that the objectives of stable and high yield are probably in conflict, ICES and the EU/Norway are currently working to clarify the objectives. The evaluation also assumed that the phrase “rational exploitation pattern” meant achieving a fair balance in the trade-off between the needs of the human consumption and the industrial fleet. Reducing the fishing mortality on the juveniles gives better fishing opportunities on the adults, with one tonne of juvenile catch “costing” approximately 2-3 tonnes of adult catch. The mortality on the juveniles has now been minimised and is currently no higher than by-catches in other fisheries and much lower than natural mortality.

The ICES evaluation agreed that the F_{MSY} target of F=0.25 for North Sea herring, ages 2 to 6, was appropriate and that the SSB limit reference point of B_{lim}=800,000 tonnes was also appropriate (ICES, 2011b). These values are incorporated into the management plan. The management plan is only single species oriented, and in this context it appears that when considering the control of catch through target fishing mortalities, the management plan conforms to both the precautionary and

MSY approaches (Simmonds, 2007; Dickey-Collas *et al*., 2010a). There are currently no problems in terms of enforcement or conforming to the plan by catching sector.

There are no clear management objectives within the management plan for protecting the diversity of spawning beds, maintaining sub-stock structure and the provision of other ecosystem services by herring.

The EU/Norway management plan also forms the basis for the Marine Stewardship Council (MSC) accreditation of five fisheries on North Sea herring. In 2010, the majority of the catch was MSC certified (www.msc.org). The MSC scheme is a commercial initiative that benefits the certified companies through higher prices and a larger potential market. Fisheries that exploit the stock were first certified in 2006. This suggests that the management plan, plus the additional measures by the five certified fleets in terms of reducing discards and more selective fishing methods, conforms to the MSC objectives of sustainable fishing practices.

The minimum landing size for herring of 20cm is for all herring caught in EU waters outside the Baltic Sea. This minimum landing size is just below the length at sexual maturity, but does not seem to cause problems in terms of the evolutionary effect of fishing, an over-selectivity for smaller fish or the productivity of the stock. The by-catch ceiling, and the regulated maximum ratio of herring to sprat caught in the industrial fisheries has regulated the impact of those fisheries on the productivity of the stock. Although almost impossible to enforce, the ban on high grading will in theory also ensure that the selectivity of the human consumption fishery is efficient.

ICES advice states that the separate sub-TAC for ICES areas IVc and VIId was established for the conservation of the spawning aggregation of Downs herring. The effectiveness of the sub-TAC has not been fully evaluated. This protection of the Downs spawning component is not year-round, as Downs herring migrate north to feed and are caught in areas IVa and IVb in the summer (Bierman *et al*., 2010). In the absence of data to the contrary ICES proposes that a share of 11% of the total North Sea TAC (average share 1989–2002) would still be appropriate for the southern North Sea, but there is no science to back up this statement. The Downs component has recovered since the 1990s (Fig. 5.2.5.1).

The closed areas for sprat and herring fishing (Fig. 5.2.4.1) were introduced to protect either juvenile herring or spawning herring. The effect of these seasonal closures has not been evaluated. It seems highly unlikely that the four areas closed to protect juveniles (cf. the three black areas and the one shaded area in Fig. 5.2.4.1) have an impact on the stock dynamics as a whole, as the majority of herring nursery grounds are outside these areas and the fishing mortality on the juveniles is very low. The closure of the Moray Firth and Firth of Forth may protect local populations of fish.

The closures to protect Banks spawning herring are the only spawning closures in the North Sea. The Downs spawning component is not protected by a closure and the fishery targets the spawning fish, although limited by the sub-TAC. In addition the Orkney/Shetland and Buchan spawning areas have no protection at all. Thus the most productive areas have active fisheries at spawning time which appear to be sustainable as long as fishing mortality is constrained. This raises questions about the effectiveness of this technical measure as a management tool to protect the spawning of Banks herring.

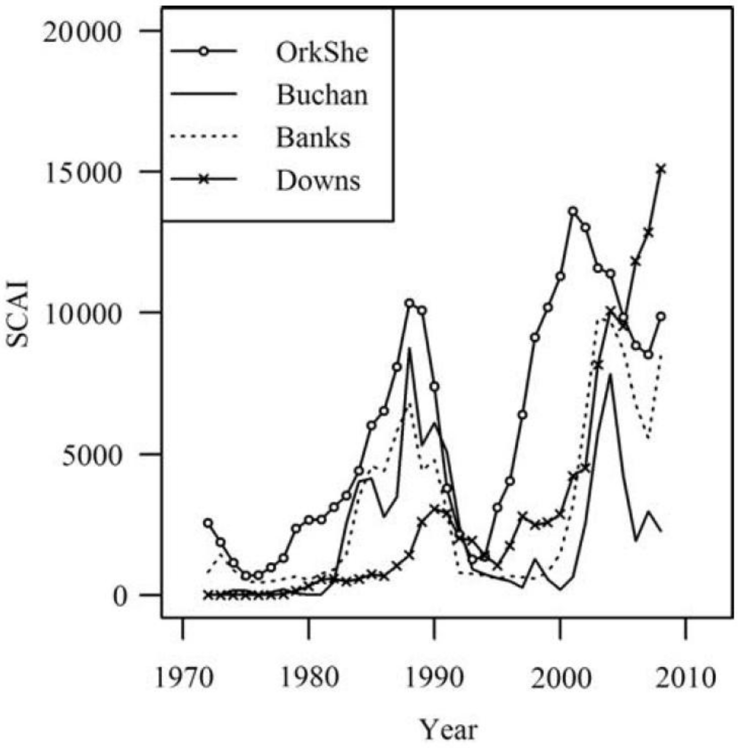


Fig. 5.2.5.1 Comparitive size of spawning components in North Sea herring(1972-2009), based on larval production (taken from Payne 2010). SCAI= Spawning Component Abundance Index.

The operation of ITQs (or *de facto* ITQs) has worked well in rationalising the exploiters and increasing their profitability. The market for herring quota is strong and advanced. Some of the measures to reduce area misreporting (e.g. the separate licensing of landing catch from IVa and VIa) has worked well, although this has more impact on the exploitation of the smaller VIa herring stocks, than the larger North Sea herring stock. The variable and *ad hoc* nature of the annual agreements that “legalise” area misreporting from ICES area IV into IIIa make evaluations and simulations of the exploitation of herring very difficult. Again, this has more impact on the exploitation of the smaller IIIa stock, rather than the North Sea herring, but this does prevent the development of transparent management measures that can be tested and built into management plans.

5.2.6. Other potential management tools

Beyond the MSY and the Precautionary Approach, other management objectives should be considered when looking into the future management of the North Sea herring fishery. These could have ecosystem, economic or social objectives. The role of herring in providing other ecosystem services needs to be considered (ICES 2010). Maintenance of diversity of sub-stock structure is probably important to ensure resilience of the stock and is linked to the maintenance of a diversity of spawning habitats. The role of herring fisheries in a North Sea with Marine Protected Areas (MPAs) needs to be addressed, as does the driver to simplify management measures.

The North Sea herring fishery is executed by large trawlers (>40m), many of which process on-board. Most of the fishing enterprises own more than one vessel. Fuel cost is the major variable factor that impacts on the profitability of the fishery, and combined with the availability of TAC. The market price for herring is fairly stable due to the dominance of the Norwegian spring spawning herring supply. Few coastal communities are now directly reliant on the North Sea herring fishery. Employment is not seen as an important objective for the fishery, neither by managers nor the vessel owners. Profits appear to be the overriding objective of the fishing companies. The existing fishing fleets have the ability to catch the TACs many times over. Also under the CFP the fleets are not allowed to increase their capacity. The freezer trawlers are limited by their processing capacity. Thus an increase in available fish will not lead to new employment, other than in shore based processing. Understanding the social and economic dynamics of the fishery is difficult as Germany (a significant operator in the fishery) does not publish economic information about its pelagic fleet, which is operated by one company (STECF, 2010). The management plan already includes stability in TAC change. The imposition of MPAs, including Natura 2000 areas, may affect the catching ability of the fleet, e.g. if the MPAs ban pelagic fishing in areas of herring abundance, or effect the distance travelled to areas of herring abundance.

The North Sea herring fishery does provide a high biomass of relatively low cost, locally sourced, protein. Like the other high biomass pelagic fisheries (mackerel, sprat, horse mackerel, other herring fisheries and blue whiting), this protein is produced within Europe and is relatively cheap to harvest. This harvesting has a relatively low environmental impact compared to the production of other animal protein such as beef, pork or chicken (Hilborn, 2010). Thus in terms of food security to Europe, this fishery could play an important role (as was previously the case from 1700 to 1850; Poulsen, 2008). The objective of food security would suggest a need to maximise yield and maintain stable production. These objects are already written into the EU/Norway management plan.

North Sea herring is seen as important for the cultural tradition of various countries that bound the North Sea (The Netherlands, northern Germany and Denmark). However, the origin of the herring that maintains the brand “North Sea herring” has been kept vague by the retail chains, e.g. most of the traditional cured herring eaten in the Netherlands is not fished by Dutch boats and also is not North Sea herring but from the Skagerrak and the Norwegian Sea. So the branding and traditions do not necessarily require a locally sourced herring.

In terms of ecosystem functioning, there is a lack of management objectives for top predators in the North Sea. Increasingly issues associated with sea mammals and birds are impacting on fisheries, e.g. sandeel fisheries closed for perceived impact on birds and Wadden Sea cockle fisheries closed for birds (Goss-Custard *et al.*, 2004). There need to be clear and feasible objectives for top predator populations including birds, seals and cetaceans. Without these clear objectives, the trade-offs with herring fisheries, cannot be assessed. The approach could either be the maintenance of biomass of herring for predators, or management of exploitation based on total mortality of the fish (Z) rather than just fishing mortality (F).

The proactive intervention by managers to catch more herring to increase the likelihood of the recovery of the cod population has been discussed in various fora. A proactive bio-manipulating approach is gaining ground in the ecologically less complex Baltic Sea. Considering the complexity of the North Sea and the unpredictable nature of second order interactions, it would be naive to assume that interacting cod and herring populations could be proactively managed to attain certain preferred states. Trying to bring about a recovery in cod or other demersal stocks by manipulating pelagic fisheries would be a precarious challenge.

5.2.7. Management strategy matrix evaluation

The North Sea herring fisheries already operate within the precautionary and MSY approaches through an internationally agreed and evaluated management plan. The fisheries conform to the plan. They are also relatively clean fisheries, in terms of discards, selectivity of target species and target size of fish. The by-catch of protected species and disturbance of the sea bed is also very low. With these factors in mind some additional potential management strategies have been considered in a qualitative analysis.

5.2.7.1. Overview of management strategies

Management strategy A: Simplify management by removing sub-TAC for the southern North Sea.

This scenario considers the removal of the separate sub-TAC for ICES areas IVc and VIId. Fisheries regulations have the tendency to increase in complexity over time. There are many causes of this. It is pertinent to address whether all of these regulations are appropriate. Thus the removal of the separate sub-TAC for ICES areas IVc and VIId could be a realistic scenario. It is feasible that the impact of the fishery could be managed by limiting fishing mortality alone.

Management strategy B. Simplify management by removing seasonal local fishing closures

Another way to simplify the management would be to remove all the seasonal closures. This scenario considers the removal of the seasonal closures of the herring and sprat fisheries, i.e., in the Moray Firth and Firth of Forth as well as around the Banks spawning ground and to the west of Denmark (cf. Fig. 5.2.4.1).

Management strategy C. Maintain sub-stock structure (phenotypic diversity).

There may be mechanisms to protect, sustain or even encourage the phenotypic diversity of North Sea herring. This would require more science and monitoring and result in more complicated management measures. It will be necessary to facilitate science and management measures that respond to the fluctuations and variability between spawning components, i.e. sub-stock structure. This could include a combination of more area sub-TACs, real time closures, monitoring of the spawning origin of the catch, sub-stock assessments etc. The clear objective would be management of the fishery to maintain diversity, and thus management would need to target the protection of the least productive components (ICES 2011c). This scenario considers the introduction of mechanisms to protect, sustain or even encourage the phenotypic diversity of North Sea herring. Such mechanisms would involve more science, monitoring and/or more flexible management.

Management strategy D. Greater conservation – Introduce MPAs

MPAs are about to be introduced in the North Sea as part of the Natura 2000 framework mostly to conserve habitats or bird species according to the Habitats and Birds directives. Pelagic fisheries would probably not be affected. However, pelagic fisheries may be impacted by MPAs if these areas would be closed to all fishing. This scenario considers the introduction of total fishery closures, i.e. MPAs where all fishing activity is prohibited.

Management strategy E. Protect sensitive habitats – close all spawning beds to active anthropogenic impact.

This scenario considers the closure of all herring spawning habitats to any kind of anthropogenic activity. Note that this scenario does not constitute a fisheries management scenario as such; it is rather a marine spatial planning management action that would have an impact on the herring fisheries.

Herring spawning beds are sensitive to anthropogenic impact, such as the extraction of aggregates or development/construction (e.g. of windfarms) on the banks. North Sea herring has yet to re-populate all of the spawning areas it abandoned during the 1970s collapse (e.g. Dogger Bank). Other banks are used sporadically by herring. Management would define all potential spawning habitat for herring in the North Sea and prevent any future construction or developments on those gravel beds, including old spawning areas such as Dogger Bank, or at a minimum ensure that any development had no impact on herring. This strategy would be aimed at maintaining the potential diversity of spawning habitats, thus providing increased resilience of the herring stock to environmental or fishing induced pressures.

Management strategy F. Prey for predators

Currently the size of herring populations required to maintain ecosystem services is unclear. This strategy would consider provision of prey as one of the objectives of a management plan. The scenario considers the management of the fishery such that the herring biomass increases to such an extent that it can be considered a sufficiently abundant prey source for predators.

Management strategy G. Fish down to allow cod to recover

This scenario considers fishing down the herring population to such an extent that it is expected that there will be much lower predation by herring on cod eggs. This bio-manipulation approach is high risk, in that it assumes a direct causal link between the cod productivity and the abundance of herring; herring prey on cod eggs, thus with less herring, cod will recover. The strategy would have the rebuilding of the cod populations as the main objective, and in the short term would lead to great benefits to the herring fisheries in terms of yield, but in the medium term, it might result in another collapse of North Sea herring, with drastic effects on the herring fisheries. The naive simplistic linear thinking, and associated arrogance of this proposed strategy make it very unpalatable, but concepts like this are being considered in other regions. Sand eel and sprat may replace the role of herring so this approach has a high likelihood of failure.

Management strategy H. No change in the current management approach

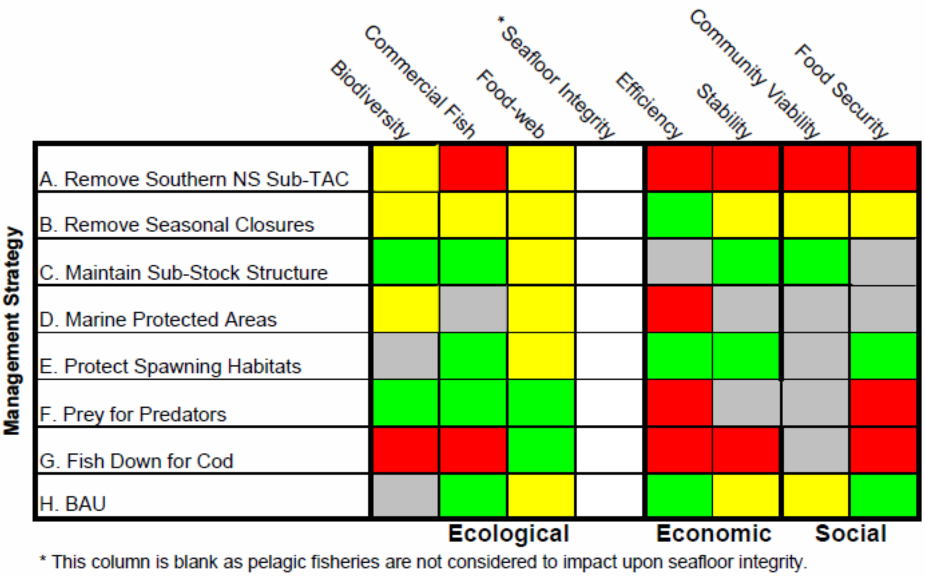
This scenario considers a continuation of the current fisheries management sticking to the existing management plan.

The existing management plan (or a slightly amended plan) should with time lead to a greater understanding of fishing at F_{MSY}. Theoretically the biomass of herring in the North Sea should increase. The fishing on the juveniles will continue to be restrained by the bycatch ceiling. Any increase in productivity of the stock (recruitment) to similar rates as the 1990s will lead to an increase in biomass and hopefully to a further recolonisation of abandoned spawning grounds (such as Dogger Bank). In the past the North Sea has supported approximately 4.5 million tonnes of mature herring. The last time herring was this abundant, Bluefin tuna was also present and supported a local fishery in the North Sea (Dickey-Collas *et al.*, 2010a).

5.2.7.2. Management strategies matrix

The probable impact of these strategies on ecological, economic and social descriptors is given in the matrix below (Table 5.2.7.2.1). These assessments are based on expert judgement and thus are speculative, and should be interpreted with caution. Notes are explained below. Also note, that the evaluation is carried out based on the indicators that were selected for each descriptor in MEFEPO-WP2. This means that when arguing from a more holistic perspective, the colouring would be different from what is presented in the matrix below. Such arguments are explicitly described in Annex C.

Table 5.2.7.2.1 Management strategies matrix: expected long term impacts of potential management strategy scenarios on the eight descriptors. Blank cells indicate no impact. The evaluation is qualitative, based on expert judgement.



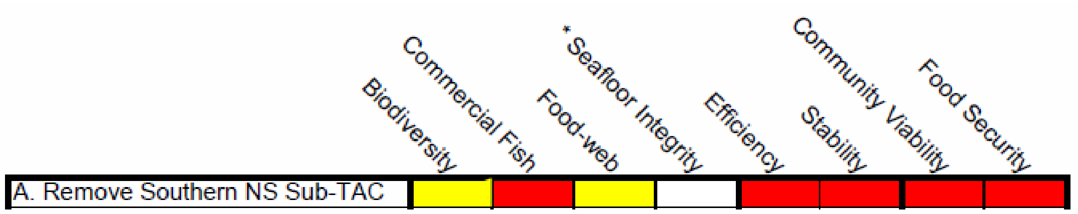
Management Strategy	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
	Ecological				**Economic**		**Social**	
A. Remove Southern NS Sub-TAC	🟨	🟥	🟨		🟥	🟥	🟥	🟥
B. Remove Seasonal Closures	🟨	🟨	🟨		🟩	🟨	🟨	🟨
C. Maintain Sub-Stock Structure	🟩	🟩	🟨		▨	🟩	🟩	▨
D. Marine Protected Areas	🟨	▨	🟨		🟥	▨	▨	▨
E. Protect Spawning Habitats	▨	🟩	🟨		🟩	🟩	▨	🟩
F. Prey for Predators	🟩	🟩	🟩		🟥	▨	▨	🟥
G. Fish Down for Cod	🟥	🟥	🟩		🟥	🟥	▨	🟥
H. BAU	▨	🟩	🟨		🟩	🟨	🟨	🟩

* This column is blank as pelagic fisheries are not considered to impact upon seafloor integrity.

🟩 Expected improvement in the status of the descriptor
🟨 Stable (i.e. no change in the status of the descriptor)
🟥 Expected deterioration in the status of the descriptor
▨ Outcome unknown

5.2.7.3. Qualitative evaluation of the management strategy scenarios, based on expert judgement

Management strategy A. Simplify management by removing sub-TAC for the southern North Sea.



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
A. Remove Southern NS Sub-TAC	🟨	🟥	🟨	⬜	🟥	🟥	🟥	🟥

Assumptions

Removing the sub-TAC would infer that managers perceive North Sea herring as one unit, with no underlying complexity.

Ecological descriptors

Maintaining sub-stock structure is important, as it is thought to provide resilience to natural fluctuations and exploitation, especially as differing environmental drivers influence the productivity of the spawning components (cf. Section 4.1.1.1). Downs has been described as more susceptible to overfishing (Cushing, 1980). It was the first to collapse (late 1960s) and one of the last to recover (late 1990s), so the argument for extra protective measures appears strong. However, the setting of the current sub-TAC lacks scientific basis. If fishing mortality on the whole stock is kept low enough, then the risks would be reduced also on the Downs component.

Economic descriptors

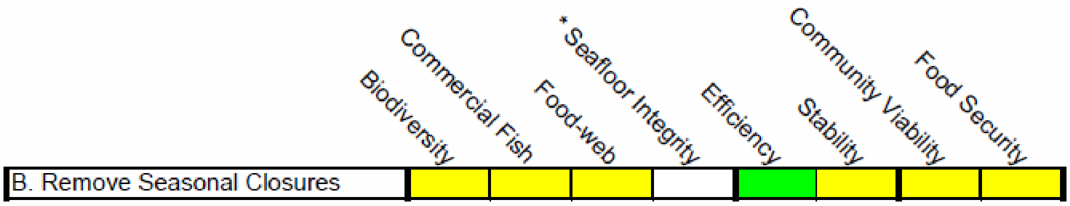
If the herring stock is in good/bad shape, then this also has a positive/negative effect on the economic performance of the fishing sector. Assuming that less protection of the Downs subcomponent means higher susceptibility to overfishing, and thus negative consequences for the herring stock, efficiency is expected to deteriorate, i.e., it follows the colouring of the commercial fish descriptor.

Stability here refers to stability of harvest, hence, the same argument applies as with efficiency: If the herring stock is in good/bad shape and resilient, then harvest possibilities will be good/bad, thus allowing for more/less stable harvest limits.

Social descriptors

If efficiency and stability of the sector are poor, then a community linked to the sector might not remain viable, and jobs are not attractive. Food security here refers to the amount of protein that can be harvested from the sea. If F is reduced on the whole stock in order to avoid collapse of the Downs component, then this might curtail the total amount of marine protein being caught. Hence, from a food security perspective it could be preferable to keep the separate Downs TAC, thereby allowing a higher F for the rest of the stock. On the other hand, one could also apply the same argumentation as for efficiency and stability: If the herring stock is in good/bad shape and resilient, then harvest possibilities for marine protein will be good/bad, thus allowing for more/less stable harvest limits. Both arguments suggest a deterioration of the food security descriptor under management strategy A.

Management strategy B. Simplify management by removing seasonal local fishing closures



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
B. Remove Seasonal Closures	🟨	🟨	🟨		🟩	🟨	🟨	🟨

Assumptions

This scenario considers the removal of the seasonal closures of the herring and sprat fisheries, i.e., in the Moray Firth and Firth of Forth as well as around the Banks spawning ground and to the west of Denmark (cf. Fig. 5.2.4.1).

Ecological descriptors

Management scenario B is not expected to have any effect on the four ecological descriptors.

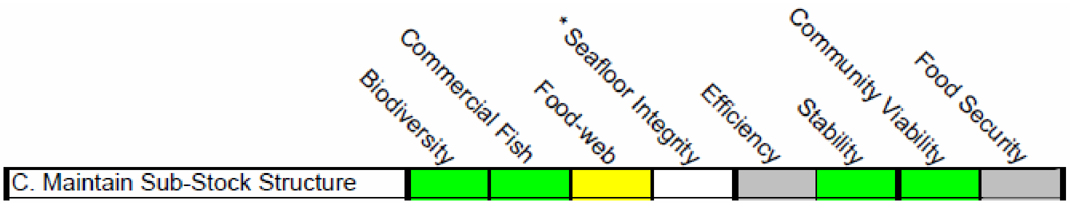
Economic descriptors

In general, less regulation means less administrative costs. This should result in more efficiency.

Social descriptors

Under the condition that efficiency and stability do not deteriorate, then a simplification of administration and management complexity is expected to increase job attractiveness.

Management strategy C. Maintain sub-stock structure (phenotypic diversity).



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
C. Maintain Sub-Stock Structure	🟩	🟩	🟨		▒	🟩	🟩	▒

Assumptions

This scenario considers the introduction of mechanisms to protect, sustain or even encourage the phenotypic diversity of North Sea herring. These mechanisms would involve more science, monitoring and/or more flexible management.

Ecological descriptors

The biodiversity indicators considered in MEFEPO do take into account the existence of "sub-species and populations where they need to be assessed separately". Therefore, management strategy C could potentially result in positive effects through phenotypic diversity with respect to biodiversity and commercial fish, as management strategy C should enhance herring sub-stock structure.

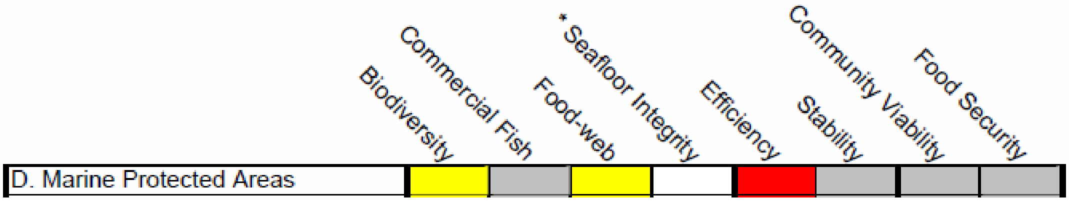
Economic and social descriptors

The effects on efficiency cannot be evaluated, because an estimation of costs and benefits requires more knowledge about details: On the one hand, management and administration costs will increase under management strategy C; on the other hand, catch opportunities and yields are also expected to improve.

If the stock size increases due to improved stock resilience, then harvest stability, community viability, and food security will also improve. Increasing management complexity will not increase job attractiveness.

From a food security perspective it is difficult to determine if high yields and lower stability outweigh lower yields but higher stability. Hence it could only be speculated that maintaining a resilient and diverse population with complex sub-stock structure should make the population more resilient and thus increase food security.

Management strategy D. Greater conservation – Introduce MPAs



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
D. Marine Protected Areas	🟨	▨	🟨	⬜	🟥	▨	▨	▨

Assumptions

This scenario considers the introduction of total fishery closures, i.e. MPAs where all fishing activity is prohibited.

Ecological descriptors

The large fish indicator would not be influenced by management strategies that only impact the herring fisheries. From a general food-web perspective, such a measure is expected to be beneficial, but it is not captured in the indicator used here. As mentioned above, the evaluation is carried out based on selected indicators. This means that when arguing from a more holistic perspective, the colouring would be different from what is presented in the matrix below (cf. Annex C).

Since the impact of the herring pelagic fisheries on the seabed is low already, any positive effect on the seafloor of closing areas might be negligible. From a general seafloor perspective, such a measure is expected to be beneficial, in particular if the MPA areas coincide with sensitive habitat for sensitive benthic species. So, in general, management strategy D would be beneficial for the seafloor, but currently this is not captured in the indicator used.

If the MPAs and fish distributions overlapped, fish might be given the time to grow bigger and older within an MPA. For North Sea herring, however, this is an unrealistic scenario, as the natural herring life cycle implies wide displacements of the different life stages over the entire North Sea. Any effects on biodiversity of management strategy D would thus depend on the size of the MPAs, on the degree of overlap with fish distribution and on spill-over effects. From a general biodiversity perspective, such a measure is expected to be beneficial, in particular if the MPA areas coincide with sensitive habitat for sensitive species, e.g. rays. So, in general, management strategy D would be beneficial for biodiversity, but currently this is not captured in the indicator used.

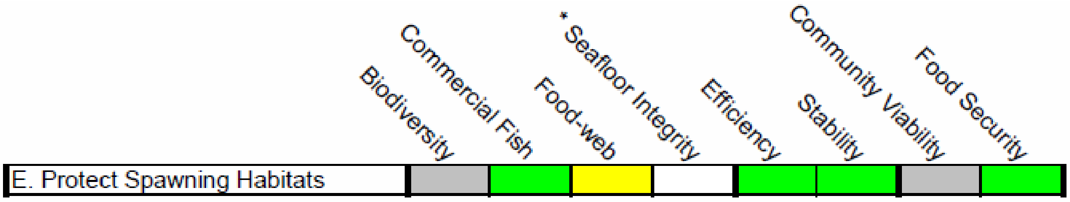
Economic and social descriptors

Effects on the herring stock size of management strategy D would depend on the size of the MPAs, the degree of overlap with fish distribution, spill-over effects and the efficiency of fishing effort redistribution to areas where the herring can be caught. Potential effects on the stability of the herring catch/ yield in turn depend on the effects on the stock size. In turn, community viability depends on the shape of the stock and the fishing industry.

If the MPAs and fish distributions overlapped, then, in general, the establishment of an MPA increases the fishing effort required to catch the TAC, as the fleets would have to fish outside the MPAs. This would reduce the profitability of the fisheries. Moreover, effects on efficiency of management strategy D also depend strongly on potential spill-over effects. Any effects on marine protein supply strongly depend on all ecologic and economic effects, in particular assumptions of spill over effects.

In general, introducing more conservation measures, and in particular area closures, decreases job attractiveness.

Management strategy E. Protect spawning habitats – close all spawning beds to active anthropogenic impact



	Biodiversity	Commercial Fish	Food-web	* Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
E. Protect Spawning Habitats	▨	🟩	🟨		🟩	🟩	▨	🟩

Assumptions

This scenario considers the protection of herring spawning habitats by closing the spawning habitats to any kind of anthropogenic activity. Note that this scenario does not constitute a fisheries management scenario as such; it is rather a marine spatial planning management action that would have an impact on the herring fisheries.

Ecological descriptors

A crucial question to keep in mind with this scenario is: Where else are these activities going to take place under management strategy E? The need for anthropogenic aggregate extraction does not stop. Hence, management strategy E will automatically lead to spatial changes, a redistribution of activities, i.e. other areas that are being explored for sand or wind farm construction. The effects of this activity displacement could be positive or negative.

Effects on the herring stock size of management strategy E are expected to be positive, under the crucial assumption that any activity displacement would neither affect herring biology nor herring fisheries negatively.

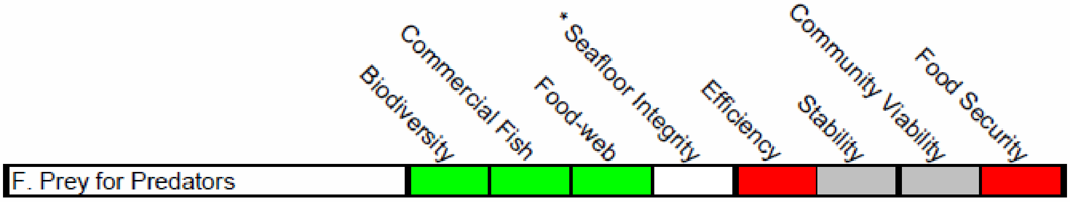
Economic descriptors

If the stock is doing well under this scenario, efficiency and stability will also improve.

Social descriptors

Benefits for the herring stock and in turn herring yields automatically mean a good supply of marine protein, i.e. benefits for food supply. Effects on community viability of management strategy E would depend on how well the current catching and processing sectors can deal with any increase in landings.

Management strategy F. Prey for predators



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
F. Prey for Predators	🟩	🟩	🟩	⬜	🟥	▨	▨	🟥

Assumptions

This scenario considers the management of the fishery such that the herring biomass increases to such an extent that it can be considered a sufficiently abundant prey source for predators.

Ecological descriptors

Management strategy F is expected to have a positive effect on the food-web and biodiversity descriptors, as the objective is to ensure enough herring as food for higher predators (large fish). The most likely overriding impact of management strategy F is a reduction in fishing effort, which is expected to have a positive effect for the descriptors commercial fish, biodiversity and food-web structure. The impact of the herring pelagic fisheries on the seabed is low, because the likelihood of net damage acts as a disincentive to contact with the seabed.

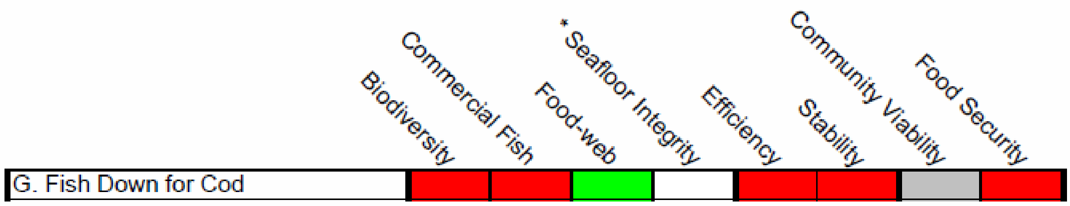
Economic descriptors

Herring fisheries would probably have second claim to the herring, after the predators had been accounted for, hence, a major loss in efficiency but not necessarily stability is expected.

Social descriptors

Putting top predators before the fisheries will result in a less secure food supply. Also producing cheaper larger quantities of herring products is better for food security than higher priced less abundant cod products.

Management strategy G. Fish down to allow cod to recover



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
G. Fish Down for Cod	🟥	🟥	🟩		🟥	🟥	▒	🟥

Assumptions

This high-risk, bio-manipulation scenario considers fishing down the herring population to such an extent that it is expected that there will be much lower predation by herring on cod eggs.

Ecological descriptors

The bio-manipulation approach is high risk, in that it assumes a direct causal link between the cod productivity and the abundance of herring; herring prey on cod eggs, thus with less herring, cod will recover. The naive simplistic linear thinking, and associated arrogance of this proposed strategy make it very unpalatable, but concepts like this are being considered in other regions. Sand eel and sprat may replace the role of herring so this approach has a high likelihood of failure.

Management strategy G aims at reducing the herring population at the benefit of the cod population, a larger fish than herring. The LFI would therefore increase.

The impact of the herring pelagic fisheries on the seabed is low, because the likelihood of net damage acts as a disincentive to contact with the seabed.

If a management strategy involves depleting one stock to attempt to help another stock (herring verses cod), with a low risk of success this would negatively impact on biodiversity and on the commercial stock that is being fished down.

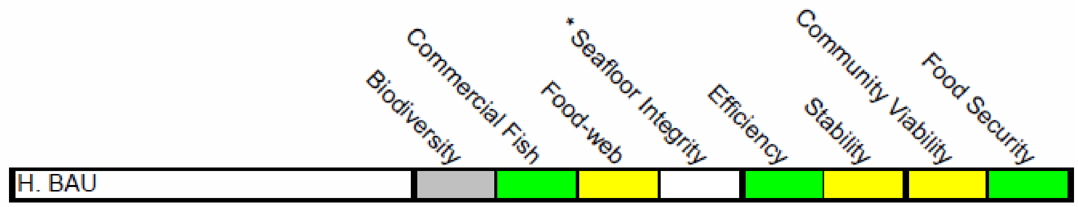
Economic and social descriptors

If a management strategy involves depleting one stock to attempt to help another stock (herring verses cod), with a low risk of success, this would also negatively impact on economic efficiency, stability, and job attractiveness.

It could be argued that this strategy will increase employment as cod fisheries require more labour than herring fisheries per tonne. However, it is unlikely that this approach would actually work, and if it fails more herring fishers would be jobless without the benefit of increased opportunities for cod fishers.

Putting top predators before the fisheries will result in less secure food. Also producing cheaper larger quantities of herring products is better for food security than higher priced less abundant cod products.

Management strategy H: No change in the current management approach (BAU)



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
H. BAU	▨	🟩	🟨	⬜	🟩	🟨	🟨	🟩

Assumptions

This scenario considers a continuation of the current fisheries management sticking to the existing management plan.

Ecological descriptors

The existing management plan (or a slightly amended plan) should with time lead to a greater understanding of fishing at FMSY. Theoretically the biomass of herring in the North Sea should increase. The fishing on the juveniles will continue to be restrained by the bycatch ceiling. Any increase in productivity of the stock (recruitment) to similar rates as the 1990s will lead to an increase in biomass and hopefully to a further recolonisation of abandoned spawning grounds (such as Dogger Bank). In the past the North Sea has supported approximately 4.5 million tonnes of mature herring. The last time herring was this abundant, Bluefin tuna was also present and supported a local fishery in the North Sea (Dickey-Collas et al., 2010a).

Biodiversity may include phenotypic diversity and sub-stock structure. It is not probable that – but unknown whether –the current management plan will impact on this. It might be worth introducing a threat indicator for vulnerable species: How many species are decreasing over a period of time?

Economic and social descriptors

The measurement baseline is the current status, so management under the current management plan is expected to improve the current status.

The current management plan does not include any employment objectives.

There are no social objectives in the current management plan, for example, attempting to increase job attractiveness. Any potential indirect effects cannot be evaluated here.

The measurement baseline is the current status, so management under the current management plan is expected to improve the status quo. Producing cheap, large quantities of herring products is good for food security.

5.2.8. Discussion

The approach of how to evaluate the effects of each management strategy on each descriptor affects the evaluation results. We have highlighted different ways of argumentation in the explanatory text (Annex C). The evaluation matrix has to be read with caution, because the uncertainties and differences in the evaluation approaches are not shown. The matrix represents an evaluation of each descriptor based on the indicator(s) that were selected in MEFEPO's WP2 and WP5. These indicators often consider only one of the criteria that characterize a descriptor. The evaluation can thus turn out in a biased way, since only "measurable" indicators were considered in MEFEPO. Another evaluation approach draws on a more holistic perspective, which does not rely on a few measurable indicators per descriptor only, but rather tries to take into account all possible criteria and indicators related to the descriptor. We have included this line of thought in the additional explanatory texts to each management strategy and descriptor (cf. Annex C).

The proposed new management strategies, which incorporate a range of ecological, economic and social objectives, all show benefits and disadvantages. Some are fairly benign (such as removal of the small localised seasonal closures) and some have only expectations of stability or improvements (protect spawning habitats from development or disruption) although other non-fisheries related industries will be more deleteriously effected. Maintaining the current management approach (Strategy H) also shows improvements in the descriptors. The complexity of strategy C (proactively manage for sub-stock structure) shows the greatest variability in terms of improvement and deteriorating descriptors. The strategy with the greatest risk of deteriorating the marine system and the fisheries is the "fishing down herring to encourage the increase in cod" strategy (strategy G). There may be other factors that will force various strategies onto the fisheries, such a social pressure ensuring that the other ecosystem services of herring are maintained (strategy F) or the setup of MPAs (strategy D). The impact on the fishery of these two may override whatever the expectations are in terms of the descriptors in the matrix.

Working with such a management strategy matrix can help illustrate trade-offs between environmental/ ecological, economic and social objectives. For example, if a management objective is to achieve good environmental status (GES), then – based on the underlying evaluation assumptions applied here (as described in the text above) – management strategy F (prey for predators) is expected to deliver the best results. However, this strategy would result in negative consequences on some economic and social descriptors. Strategy C (Maintain sub-stock structure) appears to be the second best ecological option to achieve GES. Additionally, this strategy is also expected to improve catch stability and community viability, although some economic and social effects are rather unknown.

The current management plan (BAU) is expected to improve the status of the herring stock, the efficiency of the sector and food security, i.e., improvements in all three pillars of sustainability. Nonetheless, there are alternative strategies that are expected to improve more than only those three descriptors. Managers could think about combining alternative management strategies. Future research should focus on evaluating the impacts of such combined strategies, which cannot be evaluated yet.

5.2.9. Management guidance

It is best to consider any other strategies as additions to the existing management plan for North Sea herring (or future amended plans). The plan has successfully delivered a fishery that exploits at, or below, FMSY; it allows the fishery and managers to respond to changes in the productivity of the stock and ensures that the juvenile herring are not unsustainably exploited. It also keeps the spawning biomass well above the 800,000 tonnes biomass limit thus maintaining the stock at full reproductively capacity. However, the current management plan could be improved with regard to achieving GES in terms of biodiversity and food-web, catch stability, and social community objectives.

5.3. Case study: Flatfish beam trawl fishery

5.3.1. Introduction to the fishery

A more detailed description of the North Sea beam trawl fishery can be found in **Annex D**.

The dominant demersal fishery in the North Sea targeting flatfish is the beam trawl fishery. The beam trawl derives its name from the beam supported by two shoes at either end of the trawl. The net is attached to the beam, shoes and ground rope, thus the mouth of the net is held open regardless of the speed at which it is towed. Shoes of the beam glide across the surface of the seabed and prevent the beam from sinking into soft substrata. Beam trawls are deployed with tickler chains to disturb or dig out the target species. The larger beam trawls can be fitted with more than 20 tickler chains and penetrate soft sands to a depth of more than 8 cm. Beam trawls with standard tickler chains tend to be fished over clean ground as on rougher grounds the net would soon fill with rocks. To be able to fish on rougher ground chain mats are added, along with a flip up gear fitted to the ground rope.

The beam trawl fishery in the North Sea has been dominated by the Dutch fleet but this has been decreasing recently. However, in some cases, reflagging vessels to other countries and slight increases in the technical efficiency of vessels has partly compensated these reductions (ICES 2008).

This case study focuses on the beam trawl fisheries targeting sole and plaice. The distributions of these two stocks differ, with plaice being generally more widespread while sole is located primarily in the southern North Sea. Beam trawlers centred on the southern North Sea using mesh sizes of 80-89mm take the majority of the catches of plaice and sole. However, in terms of efficiency, the large beam trawls with a mesh size >100mm are most efficient in capturing plaice.

5.3.2. State of the stocks

The most recent assessments of the North Sea sole and plaice stocks (ICES, 2011) show F to be well below the precautionary reference levels. SSB of plaice is currently at its highest observed level. Similar trends have been observed for sole, where the SBB has been below B_{lim} for two years. In recent years sole too has seen an increase in SSB and is currently above precautionary reference levels. These assessment results show that for the last two consecutive years both stocks have been within safe biological limits (Fig. 5.3.2.1).

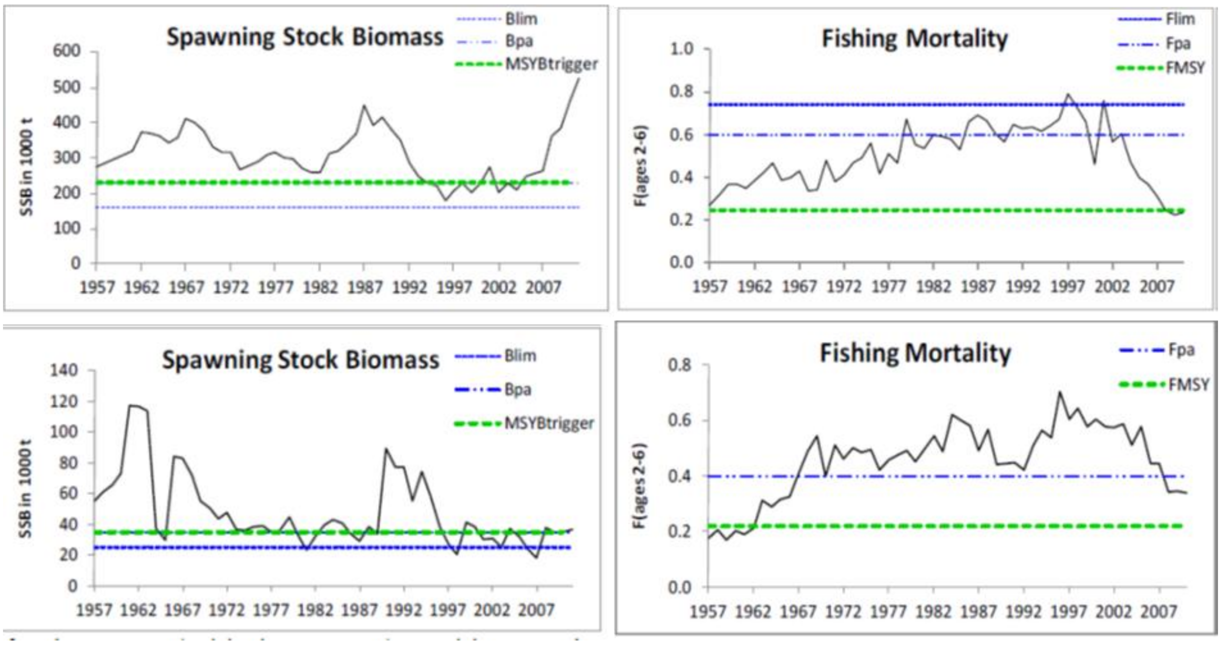


Fig. 5.3.2.1 SSB and F of plaice (above) and sole (below) over the years, included the different reference levels (ICES 2011).

5.3.3. Main interactions with ecosystem components

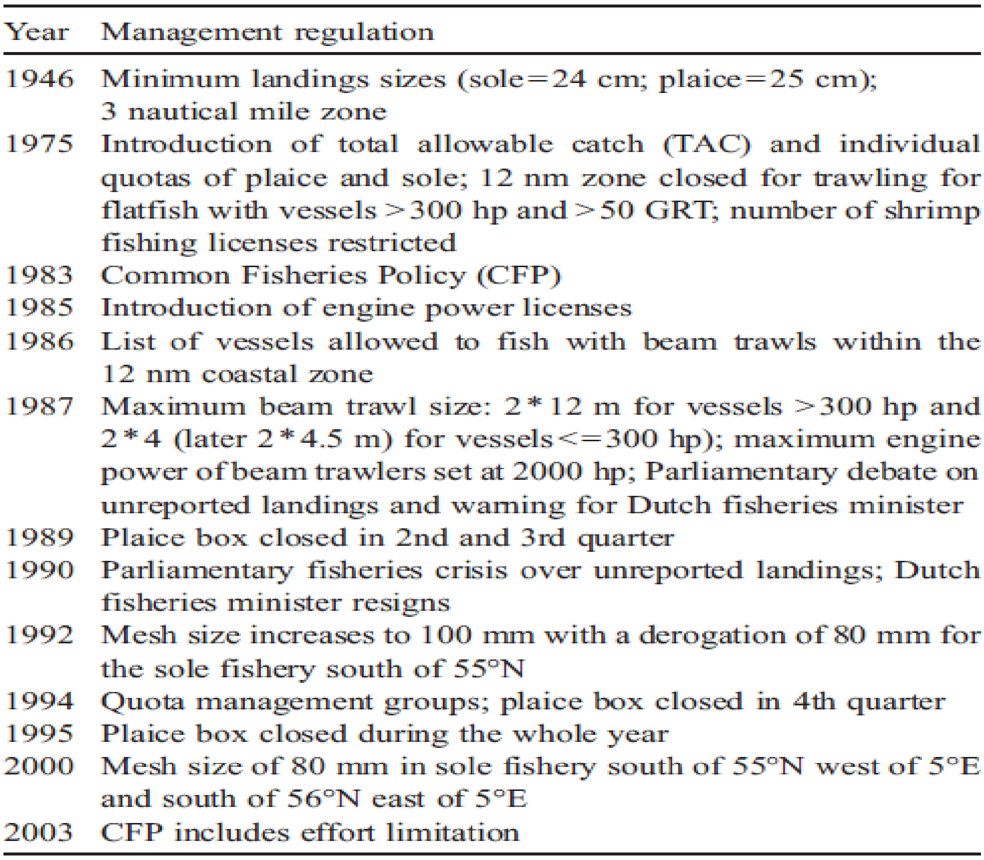
Other species landed by the beam trawl are flatfish species e.g. turbot (*Psetta maxima*), brill (*Scophthalmus rhombus*), dab (*Limanda limanda*) and lemon sole (*Microstomus kitt*); Roundfish species e.g. cod, haddock, whiting, monkfish (*Lophius piscatorius*), tub gurnard (*Trigla lucerna*) and seabass (*Dicentrarchus labrax*); Skates and rays e.g. thornback ray (*Raja clavata*); Molluscs e.g. common whelk (*Buccinum undatum*) and Crabs e.g. edible crab (*Cancer pagurus*). Besides the landed species, a part of the catch is discarded. The discards consist of undersized caught fish, high-graded fish (can be landed, but are discarded because of low value or low TAC), and non-commercial fish and benthos species.

Beam trawling has a high potential to cause collateral damage to other components of marine ecosystems, including fish and benthic invertebrate communities as well as seabed habitat, it has long been the focus of considerable scientific attention. Due to the impacts on the ecosystem, this fleet is in the line of fire of various NGO's: Greenpeace describes beam trawling as "one of the most destructive forms of bottom trawling" and WWF says: "Bottom trawling is described as the most destructive of all fishing practices".

5.3.4. Current management (Business as usual)

Management tools affecting the mixed flatfish beam trawl fishery in the North Sea that were implemented in the past decades are shown in (Table 5.3.4.1). What follows is a brief description of the six most influential current management tools operating in this fishery. More detailed descriptions of these tools can be found in Annex E: Management tools beam trawl fishery.

Table 5.3.4.1 Management constraints imposed on Dutch demersal fisheries in the North Sea (from Rijnsdorp et al. 2008)



Year	Management regulation
1946	Minimum landings sizes (sole=24 cm; plaice=25 cm); 3 nautical mile zone
1975	Introduction of total allowable catch (TAC) and individual quotas of plaice and sole; 12 nm zone closed for trawling for flatfish with vessels >300 hp and >50 GRT; number of shrimp fishing licenses restricted
1983	Common Fisheries Policy (CFP)
1985	Introduction of engine power licenses
1986	List of vessels allowed to fish with beam trawls within the 12 nm coastal zone
1987	Maximum beam trawl size: 2*12 m for vessels >300 hp and 2*4 (later 2*4.5 m) for vessels<=300 hp); maximum engine power of beam trawlers set at 2000 hp; Parliamentary debate on unreported landings and warning for Dutch fisheries minister
1989	Plaice box closed in 2nd and 3rd quarter
1990	Parliamentary fisheries crisis over unreported landings; Dutch fisheries minister resigns
1992	Mesh size increases to 100 mm with a derogation of 80 mm for the sole fishery south of 55°N
1994	Quota management groups; plaice box closed in 4th quarter
1995	Plaice box closed during the whole year
2000	Mesh size of 80 mm in sole fishery south of 55°N west of 5°E and south of 56°N east of 5°E
2003	CFP includes effort limitation

5.3.4.1. TAC

TAC (total allowable catch) regulation is a fundamental regulatory tool in the Common Fisheries Policy. The pressure managed is the fishing mortality (F) on the target stocks. Additionally it potentially also reduces the F on other species and on the discard fraction. The total catch is divided between each member state according to specific distribution formula, and it is then up to each member state to perform a further distribution on vessel types, gear types or according to other criteria. Current TACs for the North Sea flatfish stock are set on the basis of landings and do not include discarded quantities.

In recent years a multiannual management plan for fisheries exploiting stocks of plaice and sole in the North Sea became active (Council Regulation (EC) No 676/2007), providing a predictable basis by which future TACs will be set. The objective of the management plan shall be attained by 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.

5.3.4.2. Area closure

The primary area closure affecting the flatfish beam trawl fishery is the ‘plaice box’ (PB). The ‘plaice box’ (PB) is a technical fisheries management measure where an area in the south-eastern North Sea along the Dutch, German and Danish coast, is closed year round for trawl fisheries with vessels bigger than 221 kW for the conservation of plaice and other species.

The implementation of the plaice box was expected to increase yield, recruitment and spawning stock biomass (SSB) (Grift *et al.* 2004; Beare *et al.* 2010) and protect undersized plaice from discarding. Even though the plaice box resulted in a reduction in beam trawl fishing effort of 86% of the pre-box levels, the management goals for the plaice within the plaice box have not been achieved. In the study of ICES (1994), the results from VPA and demersal fish surveys did not indicate a reduction in fishing mortality on the youngest age groups. In 2004, it was concluded that there was no direct evidence that the abundance of plaice had increased either in terms of recruitment, spawning stock biomass or yield (Grift *et al.* 2004), and later is was found that the abundance of both undersized and marketable plaice decreased and showed the same pattern inside and outside the box (Beare *et al.* 2010). The Plaice Box has not proven to have effectively reduced discarding of undersized target species (Röckmann *et al.* 2011).

The evaluation of Beare *et al* (Beare *et al.* 2010) concluded that the reduced effect of the PB is more likely due to changes in environment (i.e. behavioural response to higher temperatures in combination with a decrease in macrobenthos) and less likely due to a decrease in food within the PB due to the decrease in bottom trawling.

5.3.4.3. Seasonal closure

Seasonal closures affecting the North Sea Beam trawl fishery haven’t been frequently used. The main example would be the early years of the closure of the ‘plaice box’ (PB), which saw this area closed to fishing in the 2nd and 3rd quarters. By seasonally closing the area, the intention was to reduce this pressure during the period the juvenile plaice were most vulnerable for becoming caught when still undersized.

The seasonal closure of the box resulted in a temporal displacement of effort from the 2nd and 3rd quarter before the closure to the 1st and 4th quarter after the partial closure. The increased fishing intensity during the 4th quarter reduced the positive effect of a 2nd and 3rd quarter closure from 25% to 11% (ICES, 1994). Survey data showed no clear indication that a reduced fishing mortality on the younger age groups was achieved. Based on the evaluation of ICES (1994), the EU extended the PB closure to the 4th quarter in 1994 and the whole year from 1995 onwards.

5.3.4.4. Subsidies: Decommissioning

The providing of subsidies for decommissioning of vessels has been used in various ways to manage the effort of the North Sea beam trawl fleet over the years. The objective is to reduce the fleet capacity in order to bring it in line with the available fishing opportunities, in other words, it is focussed on the economic and social pillars rather than on the biological pillar. However, by reducing the number of vessels the level of exploitation (Effort, F) is expected to improve to more sustainable levels.

Reductions of the fleet have not directly lead to an increased profit for individual fisherman, because in the Dutch case the fishing rights and quota were kept by the fishermen that decommissioned their boat. They could rent their rights and quota and thus still take part of the share without going to sea.

The effect of the decommissioning program should thus come from reduced fixed costs for the whole fleet (Frost *et al.* 1995), because the same fishing activity is performed with less boats. Overall decommissioning tended to result in older, less-efficient boats being removed, creating a modern, efficient fleet, essentially failing to reduce capacity and hence reduce F (Tidd *et al.* 2011). Furthermore, in the North Sea beam trawl case, the quota for the targeted fish stayed the same and thus the pressure on these species stayed similar. An important reason for the limited effect of decommissioning is the dependency of this management tool on other legislation.

5.3.4.5. Mesh size

Regulations on mesh size can describe the size and shape of the meshes used in the net. For the beam trawl fishery in the EU there is an overall mesh size regulation in place that defines a minimum mesh size. The main objective of mesh size regulations is stated in the title of the EU regulation (EC No 850/98): the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. However, this should also result in a reduced by-catch of other small fish as well as benthos.

Experiments with Dutch beam trawlers fishing with 70, 80 and 90mm mesh size for sole show that increasing mesh sizes from 80 to 90 mm would lead to a decrease in catches of about 50% of undersized sole and a loss of 32-47% of marketable sole (24-30 cm). The amount of plaice discards was not lower than in the 80 mm. With 70 mm, significant amounts of marketable plaice were lost, and apparently more plaice discards were caught. Catches of sole from 21-27 cm were higher in 70 mm compared to 80 mm. For other sole size categories there are no significant differences between 70 and 80 mm (Quirijns & Hintzen 2007).

A clear problem with mesh-size regulations in the mixed North Sea beam trawl fisheries is that each target species has its specific minimum landing size (MLS) that may not be in line with the size selectivity of the prescribed mesh size. Therefore in the North Sea, there is an additional mesh size regulation in place that defines a different minimum mesh size for different areas. In the case of the mixed beam trawl fisheries the increase in mesh size in the northern area is specifically intended to decrease the F on undersized plaice. As the minimum landing size of plaice is much larger than the 50% retention length of 80mm mesh size, it corresponds better to the larger 100 mm mesh sizes mandatory in the northern area.

There are no results on the state indicators abundance or SSB of plaice or sole that can be directly linked to mesh size regulations. It is very difficult to make these analyses, as many other measures came into place at a similar moment. The evaluation of the effect of the mesh size regulation on the conservation of fishery resources thus stays based on the expectations described above.

5.3.4.6. High-grading ban

High-grading is the practice of discarding low-value small fish above the minimum landing size in order to fill the quota with higher-value big fish. High-grading may result from quota management that restricts the fishery for one species but allows the fishery for another species to continue (Polet et al. 2010). The high-grading ban was introduced in 2009 and includes all species subject to quota in all ICES zones.

High-grading rarely happens with sole, as sole is a species where smaller sizes may have a higher value than larger fish.

It has been suggested that for the beam trawl fleet high-grading may specifically occur at the beginning of the year when catch rates of plaice are high and comprise of less valuable fish, and at the end of the year when catch rates increase owing to the recruitment of a new year class or quota become exhausted.

Over-quota discarding is still allowed, leaving space for high-grading. Enforcement of the rule is difficult and costly, as proving a vessel has been involved in high-grading can only be done by observation or video images.

There is a lack of information on the effects of a high-grading ban. Although there are some studies on the behavior of fishermen, quantitative data are scarce and often limited to general discarding.

5.3.5. BAU performance

The current healthy state of the sole and plaice stocks in the North Sea suggests that current management has been effective in this regard. However, this single species success is not necessarily indicative of success at the ecosystem level. Discarding rates remain high and bycatch is common. Also, the predominant gears used are considered to have a considerable effect on the benthic habitats that are fished.

5.3.6. Other potential management tools/strategies

Six potential future management scenarios were considered. Where possible, full quantitative evaluations were conducted using the best available models, though some scenarios could only be evaluated in a qualitative way utilising best available knowledge on the potential impacts.

5.3.6.1. Overview of management strategies

Management Strategy A: TAC management for maximum sustainable yield (MSY)

TAC regulation is currently the fundamental regulatory tool in the Common Fisheries Policy. The basis by which TACs are set can have a large impact on the effectiveness of this management strategy. In recent years the basis for TAC management has been shifting from a precautionary approach, aiming to keep stocks within safe biological limits, towards a maximum sustainable yield (MSY) approach, aiming to keep stocks at full productive capacity.

This approach is easier in theory than in practice as MSY, and the level of exploitation associated with it, can be difficult to determine, may be vaguely defined and is likely to change over time. Additionally, in mixed fisheries it may not be possible to simultaneously manage multiple stocks at MSY for each stock.

This scenario examines the potential benefits of exploiting the plaice and sole stocks at levels considered to provide high long term yields with low risks to the stocks.

Management Strategy B: Effort control

Output controls such as TACs are most effective for targeted stocks. For species such as brill and turbot that are caught mainly as incidental bycatch in the North Sea beam trawl fleet an output control management system is unlikely to be effective. Coupling these outputs controls with input controls, such as effort limitation, can be more effective in such cases. The utility of input controls on targeted species such as sole and plaice depends to a large degree on the associated TACs and whether effort levels are in fact limiting or not, as discussed previously.

By controlling effort you have an impact on the mixed fishery and associated bycatch species as well. Effort limitation would be most effective if the effort required to land the smallest/easiest TAC is limiting, otherwise some species could still be overfished.

The current North Sea flatfish management plan stipulates that maximum effort levels are set for the fishery, but these are determined as the perceived/calculated effort required to land the set TACs (while also prohibiting effort levels in excess of those observed in 2006). This scenario considers the possible effects of regulating fishery effort, not related to the perceived effort required to land TACs.

Management Strategy C: Mesh size regulations

Increasing the minimum legal mesh size is a simple and straightforward measure to reduce discarding of commercial fish as well as non-commercial fish and invertebrates. In theory, any increase in mesh size would reduce the catch of a fishery operation, be it towed or set gear.

The scenario investigated here is a mesh size increase based on current distribution of the mesh size:

Towed gears: 80mm => 90mm; 100mm => 140mm; 120mm => 140mm

Static gears: 90mm => 100mm; 100mm => 100mm; 120mm => 140mm

This was done for the whole North Sea fleet catching a non-negligible amount of sole and plaice; thus including beam and otter trawls and static gears. The change from 80 to 90mm is one of the changes that has been suggested often, and would mainly affect the beam trawl fishery targeting sole in the southern North Sea.

Management Strategy D: Spawning ground closures

Previous management tools used in the North Sea have included restricted areas and seasonal closures. Spawning ground closures would be a further spatial measure, in place only during the peak spawning seasons of sole or plaice. The protection of spawning fish as a management tool could assist in effective management of the resources and the ecosystem in a number of ways (Rijnsdorp et al. 2011): by (i) enhancing the reproductive success of the population by reducing mortality on the large and old fish (Wright and Trippel, 2009; Trippel and Neil, 2004); (ii) reducing evolutionary effects of exploitation (Law, 2007; Jorgensen et al., 2009); and (iii) reducing disturbance of the reproduction process and impact on spawning habitats (van Overzee & Rijnsdorp, 2010).

In a mixed fishery such as the North Sea beam trawl fishery, target species may differ in time and area of spawning. The design of spawning closures needs to take this into account. For the North Sea flatfish stocks, closures of the main target species spawning areas, those of sole and plaice, would be the most likely approach. This strategy considers either of these options as well as a combination of both (Fig. 5.3.6.1). The selection of spawning areas is based on data on egg distribution and spawning time (Harding et al., 1978; Bolle et al., in prep.). 'Closures' implies no fishing by vessels of any HP class in the areas concerned during the peak spawning periods (weeks 1-8 for plaice and weeks 13-20 for sole).

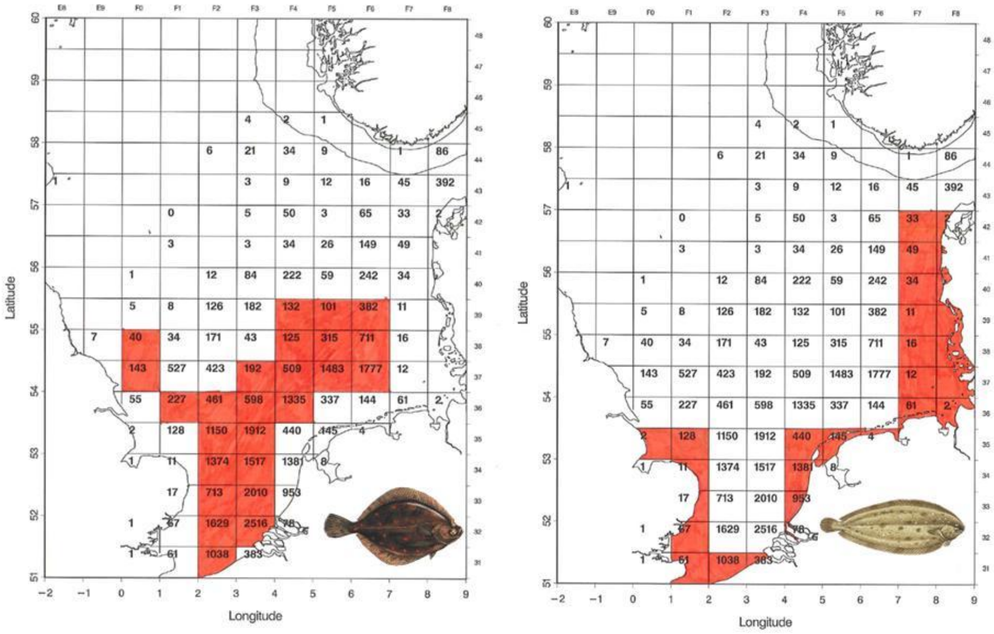


Fig.5.3.6.1 Potential spawning area closures for the North Sea flatfish stocks: sole (left) and plaice (right). Each area would be closed to fishing during the spawning period of the stock: plaice in weeks 1-8 and sole in weeks 13-20. From Rijnsdorp et al. (2011).

As with most other management tools, spawning closures in isolation may not have the desired impact on the stocks and ecosystem. Due to spatio-temporal closures effort of the fishing fleets will be displaced to other areas or times, potentially leading to adverse consequences for the exploited populations or the ecosystem (Dinmore et al., 2003). Additionally, as the size of the areas to be closed would be vast, enforcement of such a regulation would be difficult.

Management Strategy E: Catch quota management

Current TAC management of the North Sea flatfish fishery does not prohibit the practice of discarding. Only landed fish are counted against the TACs, not the discarded portion. Catch-Quota Management (CQM) aims to encourage/incentivise a more efficient fishery by shifting the management output regulations to be based on total *catch* rather than *landings*.

In a CQM-regulated fishery, minimum landing size (MLS) still applies. So while fish below this MLS will still be discarded (as opposed to a discard ban management approach), they are still counted against the overall catch. This is contrary to current regulations where discard amounts are quantified, but do not come with costs on the operating business level. Under such a system fishers can optimise fishing operating profits by catching fewer fish below the MLS. Through this CQM mechanism, the incentive of increasing the landed proportion of the catch is hoped to reduce the discarding rates and ultimately decrease the total level of fishing mortality exerted on the stock.

The implementation of CQM necessitates the need to be able to document fully the entire catch of a fishery, rather than just the registered landings. This can be done through a more expansive observer program or through video monitoring systems. A pilot study in Denmark (Dalskov and

Kindt-Larsen, 2009) found that image recording of catch sorting can with a high degree of accuracy be used to verify the actual amount of fish and shellfish that are discarded, dependant on the set up of the video cameras and the catch sorting working area.

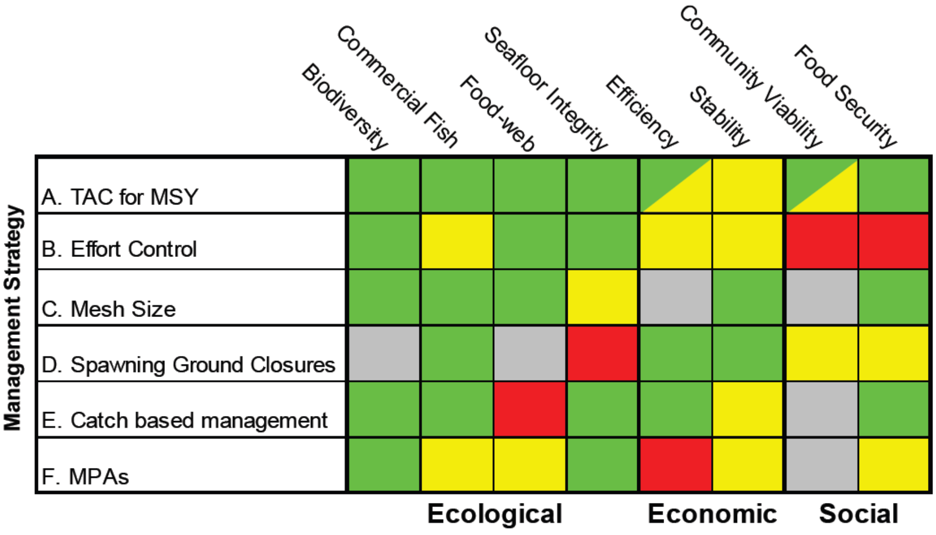
Management Strategy F: Marine Protected Areas

The closed area regulations described above apply specifically to the demersal stocks fished by the beam trawl fishery. In addition to these, marine protected areas (MPAs) will be introduced in the North Sea in the near future (i.e. Natura 2000). These are primarily aimed at addressing concerns about benthic habitats and demersal organisms. The North Sea beam trawl fisheries may be impacted by MPAs if areas are closed to all fishing. This scenario considers the introduction of total fishery closures, i.e. MPAs where all fishing activity is prohibited.

5.3.7. Management strategy matrix

The matrix below (Table 5.3.7.1) compares the expected long-term (5-10 year) outcomes from the potential management strategies described above. The details of the evaluations with regards to each of the descriptors are summarised below and described fully **Annex F: Management Strategy Evaluations beam trawl fishery**. The "job attractiveness" descriptor was included in previous work packages and is dealt with in this Annex F. However, this descriptor has been criticised by stakeholders and is very hard to define. The lack of an appropriate indicator increases uncertainties around predictions of job attractiveness and therefore it has been removed from the management strategy matrix below and subsequent management strategy evaluation descriptions.

Table 5.3.7.1 Management strategies matrix: expected long term impacts of potential management strategy scenarios on the nine descriptors. Blank cells indicate no impact. The evaluation is qualitative, based on expert jugement.



Management Strategy	Ecological				Economic		Social	
	Biodiversity	Commercial Fish	Food-web	Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
A. TAC for MSY	🟩	🟩	🟩	🟩	🟩/🟨	🟨	🟩/🟨	🟩
B. Effort Control	🟩	🟨	🟩	🟩	🟨	🟨	🟥	🟥
C. Mesh Size	🟩	🟩	🟩	🟨	⬜	🟩	⬜	🟩
D. Spawning Ground Closures	⬜	🟩	⬜	🟥	🟩	🟩	🟨	🟨
E. Catch based management	🟩	🟩	🟥	🟩	🟩	🟨	⬜	🟩
F. MPAs	🟩	🟨	🟨	🟩	🟥	🟨	⬜	🟨

🟩 Expected improvement in the status of the descriptor
🟨 Stable (i.e. no change in the status of the descriptor)
🟥 Expected deterioration in the status of the descriptor
⬜ Outcome unknown

Management Strategy A: TAC management for maximum sustainable yield (MSY)

	1 **Biodiversity**	2 Commercial Fish	3 Food-web	4 Seafloor integrity	5 Efficiency	6 Stability	7 Community Viability	8 Food Security
A. TAC for MSY	🟩	🟩	🟩	🟩	▨	🟨	▨	🟩
	Ecological				**Economic**		**Social**	

Assumptions

The management tools in the BAU strategy remain in place. Target exploitation rate (F) values for the multi-annual management plan are revised to levels consistent with F_{MSY} according to the best available knowledge.

Ecological descriptors

Results show that the SSB of both stocks should increase. The Fmsy basis of the scenarios ensures that the fishing mortality levels are maintained at a reasonable level. Further, over the range of F targets evaluated, all showed a short term decrease in the discards proportion of plaice, levelling off at a lower level in the region of 20-30% discards. While it is not possible to predict future trends in the LFI of food web dynamics with this model, the mean weighted age of both stocks is expected to increase as the survival of older fish improves.

The decrease in effort required to land the TACs should reduce the seafloor damage exerted by the beam trawl fleet, improving seafloor integrity. This reduction in effort should also in theory reduce the pressure on the ecosystem, potentially improving the biodiversity status of the ecosystem.

Economic descriptors

Economic efficiency, though not directly assessed in this model, is likely to increase or at very least remain stable. TACs for both stocks are forecast to increase before levelling off as sustainable yield is maximised. The direct effect of this on profits is likely to be complicated by market forces. However, the reduction in effort required to land these high TACs in the long term will reduce operation costs, making for a more efficient fishery.

Current management limits TAC changes to a maximum of 15% from year to year and it is likely such restriction would remain in place even under MSY-based TAC management. Model forecasts show that for both sole and plaice the median annual variation in TAC should reduce over time, but this is unlikely to be a notable improvement on BAU.

Social descriptors

Higher average annual landings and reduced operating costs should lead to a more profitable fishery. Also, a sustainably managed fishery is more likely to remain viable in the long term. Model results show that the percentage chance of falling out of safe biological limits is much lower at Fmsy than in higher Fs that have been observed in the past. These factors should combine to increase community viability. A more sustainable fishery, with higher average annual landings, should also improve food security.

Management Strategy B: Effort control

	1 **Biodiversity**	2 Commercial Fish	3 Food-web	4 Seafloor integrity	5 Efficiency	6 Stability	7 Community Viability	8 Food Security
B. Effort Control	🟩	🟨	🟩	🟩	🟨	🟨	🟥	🟥
	Ecological				**Economic**		**Social**	

Assumptions

The management tools in the BAU strategy remain in place. Total effort by the fleet is controlled is response to TAC levels, but rather a GES indicator, in this case the large fish indicator (LFI). If the LFI is below 0.3 then the effort of all the beam- and otter trawls is decreased by 10%. If the LFI increases above 0.3 again, then effort is allowed to increase.

Ecological descriptors

Results indicate that SSB of commercially interesting stocks is likely to increase under effort management, accompanied by a decrease in F. This impact depends to a large degree on the associated TACs. This strategy is driven to respond to the LFI and, though it fluctuates around this level in response to incoming yearclasses, performance with regards to this indicator is good.

Reducing effort is likely to decrease seafloor disturbance, promoting seafloor integrity. Likewise, biodiversity, though not assessed in this model, is likely to benefit from these effort restrictions.

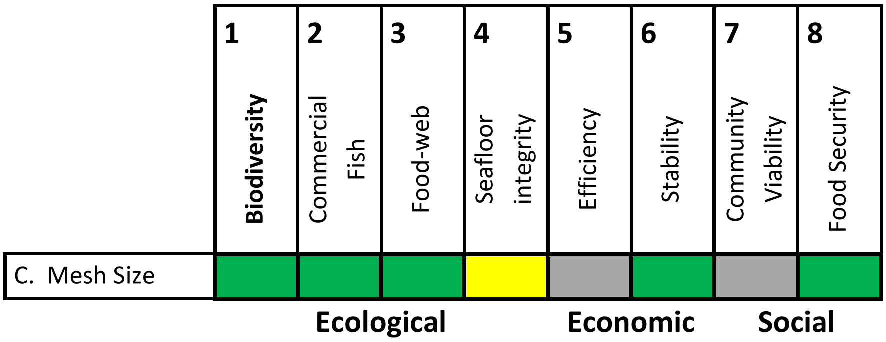
Economic descriptors

Economic efficiency (profit) is not forecast to deviate notably from the current level, despite slightly outperforming the BAU approach. Profit is forecast to remain stable under this management strategy. A reduction in operating costs that would be associated with decreasing effort should allow for greater economic stability as well.

Social descriptors

Restricting the amount of time or vessels that can participate in the fishery is likely to lead to a decrease in employment and therefore community viability. Yield under this approach decreases slightly, and is substantially lower than that from the BAU approach. As a result food security is compromised.

Management Strategy C: Restrictions in Mesh Size



	1 Biodiversity	2 Commercial Fish	3 Food-web	4 Seafloor integrity	5 Efficiency	6 Stability	7 Community Viability	8 Food Security
C. Mesh Size	🟩	🟩	🟩	🟨	▨	🟩	▨	🟩
	Ecological				Economic		Social	

Assumptions

The management tools in the BAU strategy remain in place. Minimum mesh size limits are increased.

Ecological descriptors

The "Conservation Status of Fish" (CSF) would not directly be affected by a change in mesh size. However, the increase in SSB of cod, one of the species listed as threatened or declining, shows that in the long term expectations the increase in mesh size could have a positive effect on the CSF indicator.

Changes in mesh size are intended to decrease F on the smaller length classes, and will thus have a positive effect on the commercial fish indicators. This is also seen in the increase in the SSB of the target species plaice and sole, but also in the increase of the others commercial species as cod, whiting and haddock.

A mesh size change does not change the catchability of large fish, it only reduces the catchability of smaller fish. The shift in selectivity occurs below the 40cm limit, reducing the amount of small fish (small according to the LFI) being caught. Negatively affecting the LFI in the short term expectation, especially because more large fish will be caught to fill the TAC, when days-at-sea are not restricting. The long term expectation is rather positive as it is likely that the survival of more small, juvenile fish will lead to more fish growing large. But with a foodweb context, more small fish means more food available for larger fish.

A change in mesh size will not lead to changes in the percentage seafloor being trawled by the gears. Changes in the percentage seafloor being trawled will only occur if the change in mesh size leads to changes in behaviour e.g. fishing in other areas. No changes in behaviour can be taken into account in the model.

Economic descriptors

The changes in meshes lead to a short term decrease of 10% in revenue over all fleet segments. The profitability decreases but stays positive for the larger vessels, not for the smaller metiers. However, the increases as shown in SSB will probably lead to an increased CPUE, likely having a positive effect on the efficiency in the long term, depending on the market prices and fuel costs. Increases in SSB, and thus likely increases in quota, should be positive for the stability.

Social descriptors

This management strategy, if positive for efficiency and stability, is likely to be positive for community viability. Yield under this approach is likely to decrease in the short term but increase in the long term, as a result it will have a positive effect on food security in the long term.

Management Strategy D: Spatial Closures – temporary closure to fishing of areas utilised by the primary fishery stocks for spawning

	1 **Biodiversity**	2 Commercial Fish	3 Food-web	4 Seafloor integrity	5 Efficiency	6 Stability	7 Community Viability	8 Food Security
D. Spawning Ground Closures	▨	🟩	▨	🟥	🟩	🟩	▨	▨
	Ecological				**Economic**		**Social**	

Assumptions

The management tools in the BAU strategy remain in place. Fishing activity within the spawning areas of the two target species, sole and plaice, is prohibited during the respective spawning seasons of the two stocks.

Ecological descriptors

Broader ecosystem biodiversity was not evaluated in this analysis. However, it is anticipated that such measures would lead to a reduction in bycatch of rays, and presumably other incidentally caught species. Spawning area closures have the potential to promote the sustainability of commercial fish stocks (shellfish not examined). Though there could possibly be an increase in LFI due to increased survival of older fish.

While the benthos in the spawning areas themselves may experience a temporary relief from fishing activity, given the effort reallocation schemes considered, the overall trawling impact indicator increases by 10% due to the re-allocation of fishing effort to previously less intensively trawled fishing areas. This strategy is therefore unlikely to improve seafloor integrity.

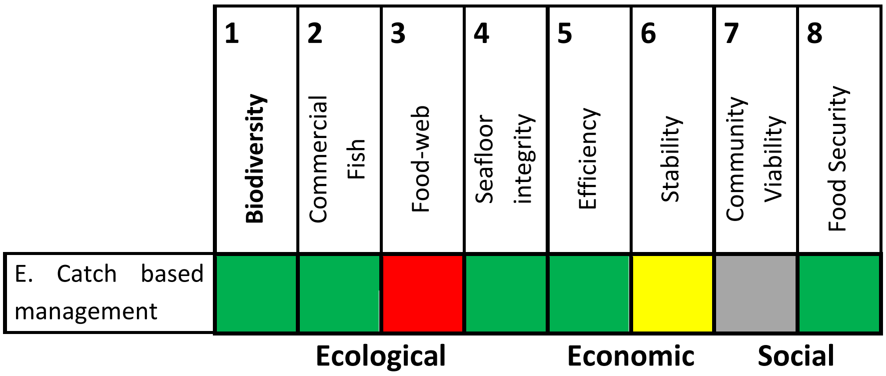
Economic descriptors

Revenue is expected to increase for all species except turbot, indicating an increase in economic efficiency of the fishery. Given the equilibrium nature of the model used in this analysis, inter-annual stability of the fishery was not directly assessed. Seasonal closures may impact on intra-annual stability directly, though this effect is likely to be small. However, by protecting the spawning component of the stock, the likelihood of recruitment failure and poor year classes should be reduced

Social descriptors

Social factors were not directly assessed in this evaluation. However, an increase in profitability and reduction in overall F likely to mean more stable, sustainable stocks. A more sustainable resource is likely to enhance community viability. More sustainable stocks, with a slight increase in landings, should impact positively on food security, though this impact is likely to be minimal. By potentially increasing the distances fishermen need to steam in order to find productive fishing grounds, it could increase operational costs.

Management Strategy E: Managing on the basis of catch quotas rather than landings quotas



	1 **Biodiversity**	2 Commercial Fish	3 Food-web	4 Seafloor integrity	5 Efficiency	6 Stability	7 Community Viability	8 Food Security
E. Catch based management	🟩	🟩	🟥	🟩	🟩	🟨	▨	🟩
	Ecological				**Economic**		**Social**	

Assumptions

The management tools in the BAU strategy remain in place. However, TACs are given on the basis of catch rather than landed totals. Once the catch quota of any of the targeted species of the mixed fishery has been taken, fishing activity must cease unless clean catches of the remaining quotas are possible.

Ecological descriptors

More targeting of commercially interesting species of marketable size may reduce bycatch of other species (e.g. using larger mesh for plaice). Reduced discarding may impact on seabird populations and other scavengers. However, both of these effects are unlikely to be significant so the overall impact on ecosystem biodiversity should be minimal.

The potential protection of incoming year-classes that would be afforded by reducing discard rates could make the fishery more sustainable and potentially even boost the productivity of commercial fish stocks.

Under CQM the selectivity of the fishery likely to target larger fish unless markets are developed for small size class fish. It would remain illegal to land fish under MLS so the increasing proportion of larger fish in the catch is likely to decrease the food web LFI.

Should fishers be able to effectively discard their discard proportion, overall fishing effort could decline. Under CQM fishing has to cease once the TAC has been taken. This also applies in the case of mixed fisheries where one stock may become limiting before the TACs of the other stocks have been caught. Additionally, by targeting mainly large fish, the overall area exploited is likely to reduce, with potentially sensitive coastal areas being less heavily exploited.

Economic descriptors

The impact of this measure on economic efficiency depends to a large degree on how the fishers are able to adapt to it. In the short term as fishermen adapt to the new changes efficiency is likely to decrease. In the longer term, as the fishery becomes more able to effectively target marketable fish, this should increase as the fishery becomes more sustainable.

Interannual variations in TAC are unlikely to be of a different level compared to the current system of landings quotas. Potentially a more sustainable population should have fewer poor year classes, increasing stability to a degree. The overall impact on economic stability should be negligible.

Social descriptors

It is not expected that CQM would impact notably on community viability. If CQM does successfully increase the sustainability of the main target fish stocks, food security should improve. More unwanted fish will need to be landed and opportunities may seem reduced. Also, participating in a fully documented fishery will require extra effort from the fishers.

Management Strategy F: Marine Protected Areas

	1 **Biodiversity**	2 Commercial Fish	3 Food-web	4 Seafloor integrity	5 Efficiency	6 Stability	7 Community Viability	8 Food Security
F. MPAs	🟩	🟨	🟨	🟩	🟥	🟨	▒	🟨
	Ecological				**Economic**		**Social**	

Assumptions

The management tools in the BAU strategy remain in place. NATURA 2000 marine protected

Ecological descriptors

Any effects on biodiversity would depend on the size of the MPAs, on the degree of overlap with fish distribution and on spill-over effects. From a general biodiversity perspective, such a measure is expected to be beneficial, in particular if the MPA areas cover habitats for sensitive species, e.g. rays. The impact on commercial stocks is likely to be small due to the small proportion of the fished area likely to be protected by MPAs. From a general foodweb perspective, such a measure is expected to be beneficial. However, the impact of MPAs through their restrictions on the flatfish fishery itself is likely to be minimal. From a general seafloor perspective, such a measure is expected to be beneficial, in particular if the MPA areas coincide with sensitive habitats for sensitive benthic species.

Economic descriptors

The establishment of an MPA increases the fishing effort required to catch the TAC, as the fleets would have to fish outside the MPAs. Particularly if MPAs are established in productive fishing areas, this would reduce the profitability of the fisheries. In addition fishers may need to increase steaming time to cross the MPA areas thereby increasing their cost. The introduction of MPAs is unlikely to have a notable effect on economic stability, which is already high for this fishery.

Social descriptors

Community viability is difficult to assess due to numerous factors. As with the impact on commercial fish stocks, the impact of MPAs on food security is assumed to be low.

5.3.8. Discussion

The management strategies matrix reveals some common patterns across management strategies. Almost all proposed strategies are predicted to have a positive impact on the long term prospects of the ecological descriptors. This reflects the current high-impact nature of this fishery. The gear used, the mixed nature of the catches and the high level of effort mean that most management regulations applied should be able to have some positive influence on the long term improvement of the ecological descriptors. Conversely, the current management of this fishery is considered to be reasonably stable. TAC change limits have been in place for a number of years and for the sole fishery a system of ‘banking’ and ‘borrowing’ is in place whereby excess TAC can be held over to the next year or additional TAC may be taken against this. These factors result in a very stable fishery, fluctuating mainly in response to the strength of incoming year classes. A management strategy was only considered to improve the likely stability if it has potential to reduce the occurrence of particularly bad year classes (i.e. recruitment failure).

The impact on economic efficiency of almost all new regulations is expected to be negative in the short term as the fishery adapts to the new changes. The values shown above are the expected long term benefits, once the fishery has fully adapted to the new regulation. The impact of management on the community viability descriptor, interpreted mainly as the provision of long term employment, is unknown in most cases. This is due to the difficulties involved in modelling such an impact, and the many potential factors, biological and social, that can impact on this descriptor.

Of the proposed new management strategies, scenario A is the closest to the current management regime. This approach alone is likely to show improvements in the descriptors, though potentially further improvements could be achieved by incorporating additional management measures. It could be best to consider the remaining scenarios as additions to the existing management plan for North Sea sole and plaice. The plan has successfully delivered a fisheries aiming for MSY exploitation.

5.3.9. Management guidance

If the overarching management objective is to work towards GES in the context of the MSFD, then BAU can be slightly improved upon, or at least remain unaffected, by most of the suggested strategies. In this case, not implementing catch quota management (potential negative impacts on the food web descriptor) or spawning ground closures (increase seafloor impact in surrounding areas) is recommended.

Almost all proposed strategies are predicted to have a positive impact on the long term prospects of the ecological descriptors; this reflects the current high-impact nature of this fishery. The impact on economic efficiency of almost all new regulations is expected to be negative in the short term as the fishery adapts to the new changes. The values shown above are the expected medium term benefits, once the fishery has adapted to the new regulation. From an economic point of view, spawning ground closures are likely to have the greatest positive impact. If economic factors are most important, MPAs should be avoided. However, the current management of this fishery is already considered to be reasonably stable, so there is limited scope for improvement in this regard. It is expected that stability can be improved by implementing management strategies that dampen the fluctuations in the strength of incoming year classes, as current TACs vary in response to these.

If social factors are of primary concern, then modification of the current management plan to more suitable MSY targets is likely to have the greatest positive impact. Food security can also be enhanced through appropriate mesh size regulations and catch quota management. Of the proposed new management strategies, scenario A is the closest to the current management regime. This approach alone is likely to show improvements in the descriptors, although potentially further improvements could be achieved by incorporating additional management measures.

TAC for MSY is expected to improve the status of all ecological descriptors and has no expected negative impacts on other descriptors. Mesh size regulations and effort control are also expected to perform very against ecological criteria. However, effort control, like catch based management and MPAs, has some potential negative impacts on economic and/or social descriptors. From an economic standpoint spawning ground closures are expected to have the greatest positive impact, though this is traded off against minimal social impact and potential damage to seafloor integrity. In terms of overall performance with the least negative impacts, TAC for MSY is expected to perform best. This could be applied together with mesh size restrictions for improved all-round performance.

5.4. Case study fishery 3: Large mesh demersal otter trawl (TR1)

5.4.1. Introduction to the fishery

This case study examines the North Sea large mesh otter trawl fishery as regulated by the long-term management plan for cod (EC Reg. No. 1342/2008), under the cod management plan this is known as the TR1 effort group. The primary objective of the cod management plan is to "ensure the sustainable exploitation of the cod stocks on the basis of maximum sustainable yield", which is to be attained whilst maintaining a fishing mortality of 0.4 on the appropriate age groups.

A variety of fleets operating with different gear types catch demersal fish in the North Sea RAC region either as the primary target species or as incidental catch. The gears taking demersal fish includes large, medium and small mesh demersal otter trawls, beam trawls, gill nets, long lines and demersal seine nets. The main target species of demersal fisheries in the North Sea are cod, haddock, whiting, saithe, plaice, sole and *Nephrops* although other species such as dab and lemon sole can form an important component of the landings of individual vessel operators. Historically cod have been one of the most important fish species targeted by North Sea demersal fisheries. Cod are caught by nearly all North Sea demersal fisheries but large mesh otter trawls (TR1, >100mm mesh size) are responsible for the greatest catch and landings of cod (Rätz et al 2007). In addition to cod, haddock whiting and saithe are the predominant species taken by the TR1 gear. Assessment and management of multi-fleet, multi-gear mixed fisheries is complex as although specific fleet segments operating in a particular metier may predominantly target one, or a subset of species within the mixed fishery, the fleet segment is likely to catch some individuals from nearly all species within the mixed fishery. Thus although TR1 causes the greatest mortality on cod haddock whiting and saithe, it also exerts mortality on the species predominantly targeted by other metiers, and vice versa.

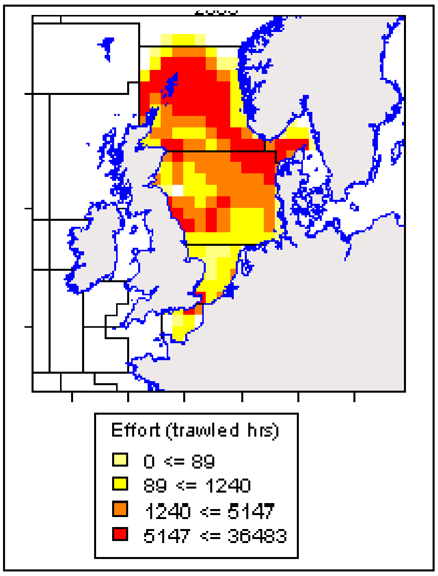


Fig. 5.4.1.1 Otter trawl effort in the North Sea (STECF 2010).

The TR1 gear operates across the entire North Sea with highest levels in northern areas; other areas of significant TR1 activity are the western-central North Sea and small pockets around the eastern channel and Thames estuary (Fig 5.4.1.1). The fishery operates throughout the year though some parts follow seasonal fishing patterns (CEFAS 2001). At a regional scale there is a high degree of spatial overlap of catches of cod, haddock and whiting, whereas saithe are mainly caught in deeper waters of the Norwegian trench (Fig. 5.4.1.2).

Cod, haddock, whiting and saithe are widespread demersal species occurring across the North Sea; of these species adult saithe show the greatest spatial segregation predominantly occurring in deeper waters of the continental shelf and slope at depths of 80-450m off the north east of Shetland and along the Norwegian trench (Jakobsen & Olsen 1987). These species are generalist demersal predators feeding on a variety of fish and benthic invertebrates, with their diets varying over their lifetime and varying depending on the locally available prey at any given location and time (Pinnegar 2009). The species have complex interactions with one another and the wider North Sea marine environment, acting both as prey for larger fish and marine mammals and as predators of fish and invertebrates including commercially important species.

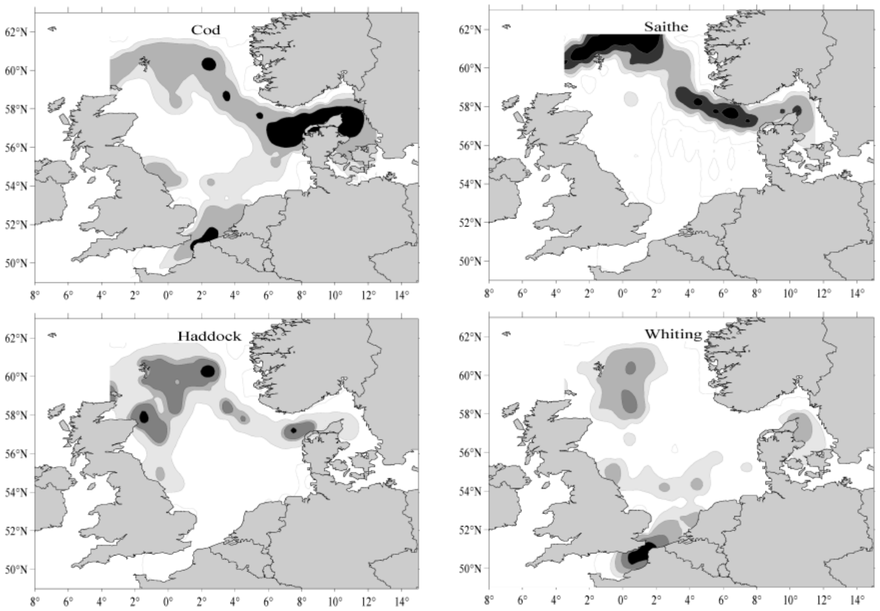


Fig. 5.4.1.2. Otter trawl effort in the North Sea (Rätz *et al.* 2007)

Cod spawn over a wide area of the North Sea, although there are several areas where spawning is concentrated, particularly in the northern North Sea, the central North Sea around the Dogger Bank and in the southern North Sea and the German Bight. The main spawning areas for whiting are in the Southern Bight, in the central North Sea north of the Dogger Bank, and off the east coast of Scotland. The main spawning area of haddock is in the central northern North Sea between the Shetland Islands and the Norwegian Deep, and southwards towards the Fladen Ground. The main spawning areas for saithe are east of Shetland and along the Norwegian trench (Cefas 2001).

5.4.2. Impacts on ecosystem components

Otter trawl fisheries have direct impacts on fish, invertebrates and benthic habitats in addition to any subsequent indirect impacts. Trawling impacts on benthic habitats are due to direct physical contact between trawl gear and the seafloor, and includes removal of large physical features, reduction in structural biota and a reduction in complexity of habitat structure (ICES 2002; ICES 2003). The nature and extent of trawl impacts on benthic habitats depends on the substrate type (e.g. sand, mud, gravel) as this affects the sensitivity to trawl impacts and the longevity of impacts (Jennings and Kaiser 1998; Schwinghamer et al. 1998; Ball et al 2000), as well as influencing the type of gear used (e.g. tickler chains are used on the trawl bottom line on softer substrates; rock-hoppers are used for fishing over rough and rocky grounds).

Benthic invertebrates can suffer mortality or injury both in the gears and in the towpath of the gear. Impacts of otter trawl on benthic community are considered to be less severe than those from beam trawls, due to less intense contact with the seafloor (Hallet al., 2008). However, in areas such as the northern North Sea, where beam trawling is less intensive, the relative impact of the otter trawl fishery is greater. Benthic species that live deep in the sediment, or that are more mobile, smaller or hard bodied, are less likely to be affected by fishing activity. Within a community, selective mortality is likely to lead to reduced abundance of large species with low intrinsic rates of increase, and dominance of smaller species with higher intrinsic rates of increase (Jennings et al. 2001; Duplisea et al., 2002;Robinson and Frid 2008).The implications of this on secondary productivity have been discussed (Hiddinket al. 2006). The most important ecological changes are changes in ecological function; for the North Sea demersal system we still do not have the evidence to describe where this has occurred nor conclude whether or not it is as a result of fishing (Robinson and Frid 2008).

Mortality caused by otter trawling is not evenly distributed over species and length, and is higher for larger roundfish species and elasmobranchs, while pelagic and small specimens are much less impacted. Uneven fishing mortality has been demonstrated to lead to changes in the size composition of the community (Jennings et al. 1999), and selective mortality of larger fish can result in changes in growth rates and sexual maturation within a species. The increase in relative abundance of small fish compared to large fish is likely due to a release from competition and predation due to the decrease in the large, often piscivorous, species.

Notable discarding occurs in the North Sea TR1, although estimates of discarding across all species by the TR1 fleet are not available. Analysis of the English and Welsh otter trawl fishery between 2003-2006 operating with mesh sizes >80mm (not including *Nephrops* trawlers) concluded that 44% of fish by number, and 18% by weight were discarded (Enever et al 2009). These discards consist of undersized target species, over quota landable target species and non-commercial species in addition to invertebrates, which could have a significant effect on both the populations of commercially and non-commercially targeted species, as well as the wider marine environment. This discarding is driven by a combination of non-selective gears and management constrains on the proportion of the catch that can be landed (Catchpole et al 2005). Technical measures, such as square mesh panels, can reduce the level of discards, but have not been found to completely stop discarding.

The large mesh TR1 otter trawl fishery removes both prey and competitors of marine mammals, however, marine mammals are opportunistic feeders, capable of switching diets to reflect local abundance, and it is therefore unlikely that the otter trawl fleet has a significant impact at the population level (ICES 2006). Research by CEFAS CDSP (2002-2008) indicates that the North Sea demersal fishery causes little direct mortality on marine mammals or seabirds. Discarding by North Sea fisheries has been linked to an overall increase in seabird numbers in the North Sea (food subsidy), and changes in the seabird community composition although it is difficult to disentangle the effect of discards from TR1 gears from discarding by other gears and other factors influencing seabird populations (ICES 2003).

5.4.3. Stock assessment

The current overriding management objective is for stocks to be fished at mortality rates leading to MSY. The management of cod, haddock and saithe is currently conducted under multi-annual management plans in accordance with management reference points set by the European Council and agreed with Norway under EU-Norway agreements. ICES does not currently specify reference points for whiting and the management plan is currently under development and evaluation (ICES 2010).

5.4.3.1. Cod *(Gadus morhua)* in VI, VIId and IIIa west

F (Fishing Mortality)						**SSB (Spawning-Stock Biomass)**					
MSY (F_{MSY})		Precautionary approach (F_{pa}, F_{lim})		Management plan (F_{MP})		MSY ($B_{trigger}$)		Precautionary approach (B_{pa}, B_{lim})		Management plan (SSB_{MP})	
2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
✗	✗	O	O	✗	✗	✗	✗	✗	✗	✗	✗

Stock assessments indicate that the SSB of cod has been below B_{pa} (150,000t) since 1982 and below B_{lim} (70,000t) since 1999, with a historical low in 2006. The SSB has shown an increase since then but remains below B_{lim}(ICES 2010, Fig 5.3.4.1).The European Commission adopted a cod management plan (CRP)in 2004 and revised in 2008, recent evaluation of the state of the stock indicates that the plan has so far failed to achieve its objectives and F remains above the management plan objective although F has been declining since 2000 (STECF 2011).

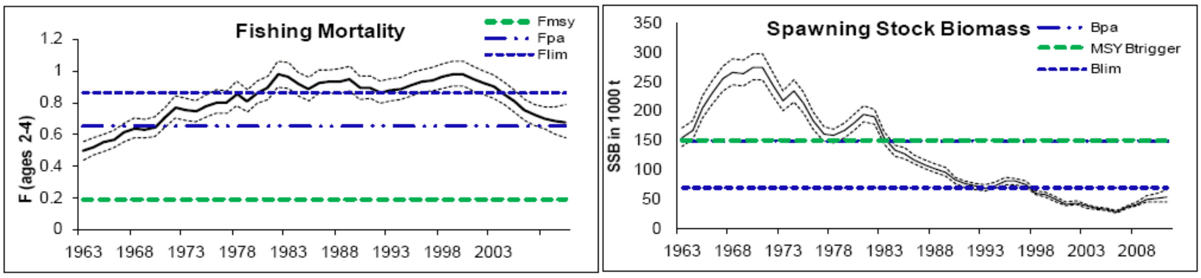


Fig. 5.3.4.1 Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak). Summary of stock assessment with point-wise 95% confidence intervals, catch estimated, and adjusted for unallocated removals (from 1993). From ICES 2010.

5.4.3.2. Haddock *(Melanogrammus aeglefinus)* in VI and IIIa west

F (Fishing Mortality)						**SSB (Spawning-Stock Biomass)**					
MSY (F_{MSY})		Precautionary approach (F_{pa}, F_{lim})		Management plan (F_{MP})		MSY ($B_{trigger}$)		Precautionary approach (B_{pa}, B_{lim})		Management plan (SSB_{MP})	
2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The stock assessment shows that through time the SSB has been mostly above the precautionary limit (B_{pa}=140,000t). The fishing mortality seems to have declined since 1990 and has been below F_{pa} (0.7) since 1996. ICES current classifies the stock as having full reproductive capacity and being harvested sustainably in accordance with the multi-annual plan (ICES 2010, Fig. 5.3.4.2).

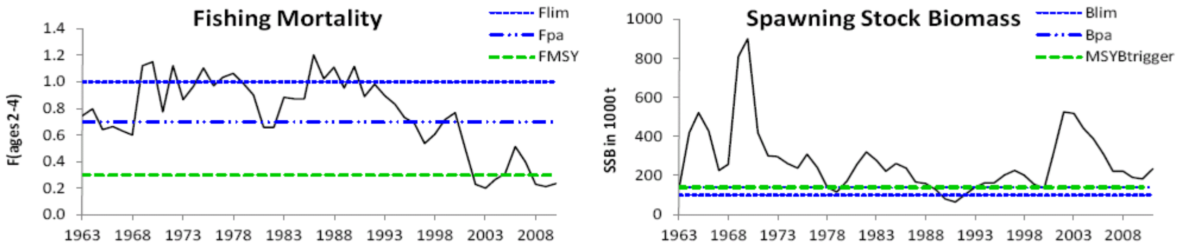


Fig. 5.4.3.2 Haddock in Subarea IV (North Sea) and IIIa West (Skagerrak). Summary of stock assessment (weights in '000 tonnes), including intermediate-year forecasts for 2011. From ICES 2010.

5.4.3.3. Saithe *(Pollachius virens)* in VI, VIIIa and VI

F (Fishing Mortality)						SSB (Spawning-Stock Biomass)					
MSY (F_{MSY})		Precautionary approach (F_{pa}, F_{lim})		Management plan (F_{MP})		MSY ($B_{trigger}$)		Precautionary approach (B_{pa}, B_{lim})		Management plan (SSB_{MP})	
2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
✗	✗	O	O	✗	✗	✓	✗	✓	O	✓	✗

From 2001-2007 F was at or below the management plan target mortality during which time SSB grew to substantially above the MSY trigger level. Since 2007 F has increased to F_{lim} and SSB has correspondingly declined to just above B_{lim}. The latest assessment indicates that F is above, and SSB below, the management plan targets and that in accordance with provisions within the management plan the TAC should be reduced beyond the 15% TAC constrain (ICES 2010, Fig. 5.4.3.3).

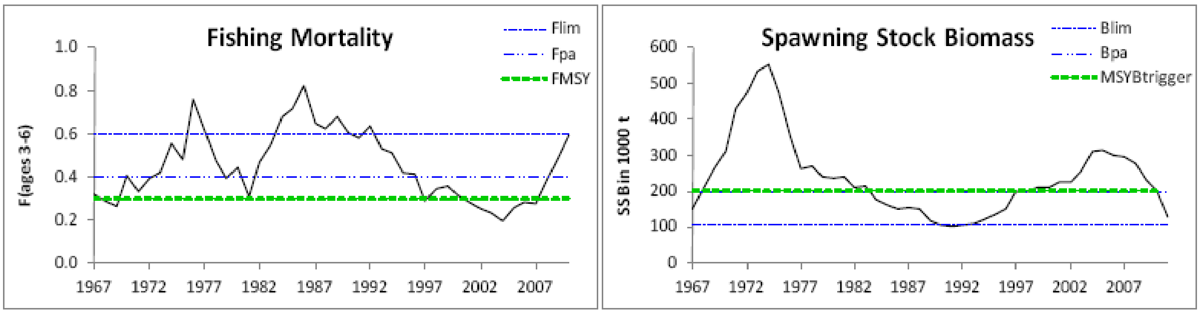


Fig. 5.4.3.3 Saithe (in Subareas IV and VI, and Division IIIa. Summary of stock assessment (weights in '000 tonnes). From ICES 2010.

5.4.3.4. Whiting *(Merlangius merlangus)* in VI and VIId

F (Fishing Mortality)						SSB (Spawning-Stock Biomass)					
MSY (F_{MSY})		Precautionary approach (F_{pa}, F_{lim})		Qualitative evaluation		MSY ($B_{trigger}$)		Precautionary approach (B_{pa}, B_{lim})		Qualitative evaluation	
2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
?	?	?	?	→	→	?	?	?	?	↗	↗

No reference points for whiting are currently defined by ICES, although ICES are developing and evaluating a management plan.In the absence of defined reference points an analytical assessment can not be conducted and advice is based on a qualitative evaluation of the status of the stock. The EU and Norway have agreed the interim plan of maintain F at 0.3, conditional on 15% TAC constrain (ICES 2011, Fig. 5.4.3.3).

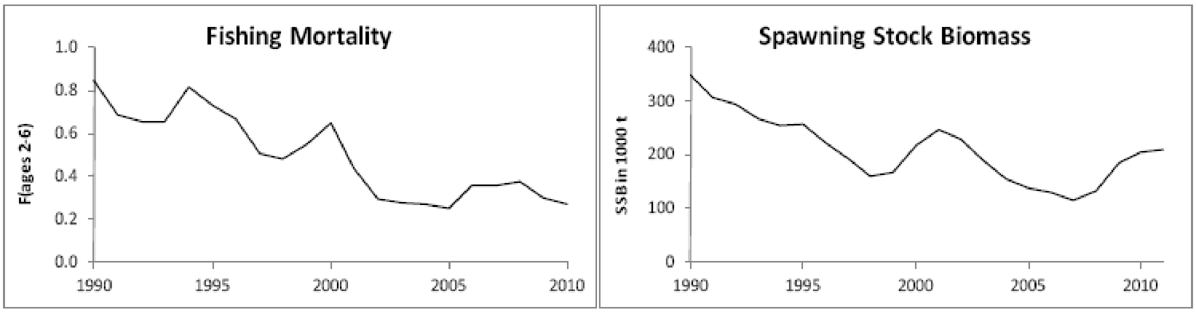


Fig. 5.4.3.3 Whiting in Subarea IV (North Sea) and Division VIId (Eastern Channel). Summary of stock assessment (weights in '000 tonnes), including intermediate year forecasts for 2011. From ICES 2010.

5.4.4. Current management (Business as Usual)

Currently the predominant legislation regulating the TR1 effort group is the long-term management plan for cod (EC Reg. No. 1342/2008) which came into operation in 2008 replacing the initial cod management plan, which came into operation in 2004 (EC Reg. No. 423/2004).

The following tools are currently being employed to manage the TR1 group in the North Sea RAC region:

- Total allowable catch (TAC)
- Minimum landing size
- Effort regulation
- Gear regulation
- Spatial management

5.4.4.1. Total allowable catch

The TAC for cod is set on the basis of the size of the stock on 1st January of the year prior to the application of the TAC according to the procedures defined in CE 1342/2008, whereby:

- if the stock is above the precautionary spawning biomass level (SSB) the TAC shall correspond to a fishing mortality of 0.4 on appropriate age groups
- if the stock is between the minimum SSB level and the precautionary spawning biomass level the TAC shall not exceed a level corresponding to a fishing mortality rate calculated according to:

$$0.4 - 0.2 \times (\text{precautionary SSB} - \text{SSB}) / (\text{precautionary SSB} - \text{minimum SSB})$$

- if the stock is below the limit SSB the TAC shall not exceed a level corresponding to a mortality rate of 0.2 on appropriate age groups.
- notwithstanding the above conditions the TAC will not be set at a level that is more than 20% above or below the TAC that was set for the previous year.

5.4.4.2. Minimum landing size

Minimum landing sizes (MLS) for fish caught in European waters are defined under EC Reg No. 850/98, although some modifications are made by member states in national waters. The MLS for cod caught in sub-areas IV and VII is 35cm, and in sub-area IIIa is 30cm. The MLS for haddock in IV & VII, and IIIa is 30cm and 27cm respectively. The MLS for whiting in IV & VII, and IIIa is 27cm and 23cm respectively. The MLS for saithe in IV & VII, and IIIa is 35cm and 30cm respectively.

5.4.4.3. Effort regulation

The cod management plan specifies fishing effort regulations to complement TACs in order to try and establish coherence between opportunities to fish and opportunities to land fish. The effort regulations stipulated under the cod management plan are moderately complex, but can be roughly summarised as below:

- total cod catches (including discards) are calculated for each effort group and the effort groups are ranked in ascending order of cod catch
- the cumulative % of the total cod catch is calculated for each effort group; calculated as the % of the total catch taken by a given effort group and all preceding effort groups
- for groups contributing to equal or greater than 20% of the total cod catch, the maximum effort that can be exerted by a group is adjusted annually in proportion to any changes in the cod TAC
- for groups contributing to less than 20% of the total cod catch, the maximum effort can not exceed the initial baseline (vessel groups for which the cod catch does not exceed 1.5% of the total catch are exempt from effort regulation)
- additional effort allocation is allowed for vessel groups using highly selective gears and conducting cod-avoiding fishing trips (see gear regulation and spatial management below) where

the additional effort allocation is not more than for effort adjustments defined by the above provisions.

5.4.4.4. Gear regulation

Maximum allowable effort can be increased for vessel groups which are only carrying one gear which has been designated by STECF as catching less than 1% cod.

5.4.4.5. Spatial management

Maximum allowable effort can be increased for vessels fishing in an area and/or manner resulting n less than 5% cod per fishing trip. Spatial management areas where fishing is stopped include defined seasonal spawning closures and real time closures defined on the basis of proportion of juveniles in the catch and LPUE of large mature cod; currently there is no common European system of real time closures and they are implemented under national programmes (Bailey et al 2010).

5.4.5. BAU performance

The main conclusions of the recent STECF evaluation of the cod management plan (STECF 2011) are that:

- the plan has reduced mortality on cod as intended, but has not achieved its stated objectives
- mortality of some other stocks, such as haddock and whiting have declined, possibly to levels consistent with CFP objectives, and that this may be partly due to the cod management plan
- effort levels for gear groupings to which cuts have been applied have not declined in accordance with the plan
- cod mortality reduction measures that allow additional effort, such as real time closures, allow for local, flexible responses; however verification of the benefits of these can be too complex.

However it should be noted that the current plan has only been in place for 3 years and therefore the medium to long term impacts of the plan could not be evaluated by STECF. A further conclusion of the STECF evaluation is that fishing mortality should not be expected to follow trends in fishing effort.

Although mortality estimates for cod remain above target, and cod SSB remains below reference points, other stocks contributing to landings by the TR1 effort group have shown larger declines in fishing mortality and greater improvements in SSB indicating that there is a mismatch in fishing opportunities for species within the multispecies fishery.

5.4.6. Other potential management tools / strategies

Six potential management strategies were evaluated. The evaluations were based on qualitative evaluations of the potential trends in the outcomes of 'successful' applications of the management tools that achieved full compliance. In many cases predicting even the qualitative response of descriptors to management strategies is associated with significant uncertainty, and in some instances evaluation of descriptors is not possible even in a qualitative sense. Changes in behaviour of the managed gear grouping and other gear groups may follow the 'law of unintended consequences' confounding the initial intentions, and attempts to evaluate outcomes, of the management strategy.

5.4.6.1. Overview of management strategies

Management strategy A: Land everything plus status quo management structures

The European Commission has stated a desire to reduce, or completely ban, discarding. The motivations for discarding are numerous and various (Catchpole et al 2005), although three main types of discarding can be identified, i) discarding of over quota landable commercial species, ii) discarding of below minimum landing size commercial species, and iii) discarding of species for which no viable market exists.

In its simplest and crudest form a discard ban could simply be a regulation specifying that everything that is caught must be landed without altering any other aspects of fisheries management. Obviously this would require fishers landing under Minimum Landing Size (MLS) and over quota fish, in addition to landing (currently) unmarketable fish and invertebrates. To avoid abuse of the discard ban due to the requirement to land under MLS and over quota commercial fish, fishers would not be able to receive any financial benefit from landing these fish.

Beyond that simple prohibition the strategy of discards management could proceed according to current management regulations. Although this strategy would be consistent with the literal meaning of a discard ban it is not necessarily consistent with the original intentions behind the concept of a discard ban.

Management strategy B: Catch quota plus status quo management structures

The current TAC based system states that it regulates the 'total allowable catch', however this is incorrect as it only regulates total allowable landings. Under a catch quota management (CQM) system all individuals, whether retained or discarded, would count against the quota. A CQM system could operate under status quo management regulations with the only difference being that all individuals caught would count towards the quota.

Under the current TAC system there is no disincentive to discarding of species under quota management, regardless of whether the discarding is of under-MLS individuals or high grading of landable individuals. A CQM system would switch the nature of incentives and fishers would be penalised by catching under-MLS individuals, or discarding landable individuals, as this would count against the quota.

This would not stop discarding, and as there is no requirement to stop fishing once the first quota is reached this could even lead to an increase in discarding, if quotas for some stocks with high levels of under-MLS bycatch fill their quota more rapidly. However it would put the onus for reducing under-MLS bycatch onto fishers, who would be incentivised to modify fishing operations to reduce under-MLS bycatch.

Management strategy C: Catch quota with fishing halted when any stock reaches TAC

Under the current TAC system once landings from a stock have reached the TAC limits there is nothing to stop mortality still being applied to the stock as fishers continue to catch other stocks for which there is remaining quota, albeit that all individuals caught from stocks that have reached their quota have to be discarded. This can lead to stocks being fished below SSB targets even though the TAC is set to avoid excess mortality. This excess mortality could be halted if all fishing activities by a gear group had to stop once the TAC had been reached for any of the species taken by the gear group.

Under status quo management conditions the onus is on managers to match TACs and fishing opportunities across a range of species, which is a challenging task given uncertainties over understanding fishers behaviour and the flexibility of fishing units. If all fishing activities had to stop once the TAC had been reached for any stock taken by a gear group the onus would be shifted on to fishers to modify their fishing operations such that TAC for one stock was not exhausted whilst there were still large amounts of quota remaining for other stocks taken by the gear group. However if this were not possible it would lead to the ‘lowest common denominator’ effect, where vessels can not fish healthy stocks due to exhausting the quota on the stock with the lowest quota.

It would be possible to modify this management strategy to make it slightly less restrictive on fishing opportunities, such as allowing a buffer of an additional 10% of quota for the first stock (and only the first stock) to reach its quota limit. Application of the buffer quota could be deducted from the following year’s quota.

Management strategy D: Discard ban with a multispecies TAC

A high level policy objective is for all stocks to reach MSY. However given the realities of multispecies fisheries it is not realistic to simultaneously achieve F_{MSY} for all species simultaneously. (Note, this is different to getting all stocks to SSB MSY *or above*, which would be a close equivalent of Management Strategy C.) Under a multispecies TAC a single quota would be defined that would cover the catches of several species together, and fishing could continue to target all stocks within the stock complex until the overall TAC had been achieved. This strategy is a compromise between Strategy C, where all fishing has to cease when the first stock fills its quota and a strategy where fishing continues until all species have achieved their quota (analogous, but not identical, to Strategy A).

Under such a strategy there is a danger that fishers would specifically target the most valuable stock within the stock complex, driving it to very low levels of SSB, before switching to target other stocks within the complex. However the risk of this occurring could be reduced if TAC setting rules were established that took account of the stock status of all the stocks within the complex and that the overall TAC was significantly constrained if any of the stocks were reduced towards precautionary or limit biomass levels. Under these circumstances the onus would be placed on fishers to fulfil the multispecies quota in such a way as to maintain the stock status of all stocks within the complex, otherwise the overall TAC would be reduced compromising fishing business opportunities. This would have a similar effect to Management Strategy C of shifting the onus for matching fishing operations and effort allocation to the available fishing opportunities from managers to fishers. The success of a multispecies TAC strategy would critically depend on establishing appropriate TAC setting rules. Furthermore co-ordination and co-operation between fishers would be required to enable this strategy to be implemented successfully.

If a multispecies TAC was applied along with a discard ban, and all landed individuals from quota stocks counted against the quota, this would carry many of the benefits of a CQM system (Management Strategy B) and fishers would be disincentivised from catching unmarketable under-MLS individuals.

Management strategy E: Achieve wider GES biodiversity targets through MPAs plus status quo management structures

The MSFD states the objective of achieving GES by 2020. Within the GES descriptors, descriptors 1 (biodiversity), 4 (food webs) and 6 (seafloor integrity) have been referred to as the ‘biodiversity descriptors’. This management strategy considers the case where MPAs are used as the main mechanism to achieve GES for the biodiversity descriptors. In this management strategy it is assumed that no fishing by the TR1 gear group is allowed within MPAs and that existing management structures are applied in a manner to achieve the requirements of GES descriptor 3 (commercial species).

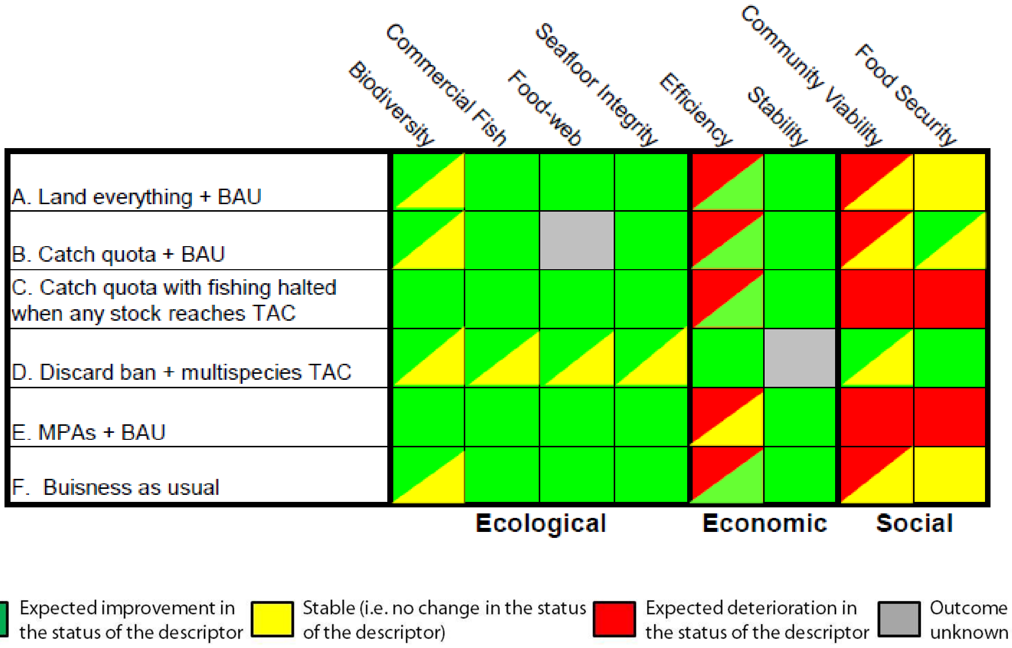
Two of the main aspects of descriptor 1 are the conservation of species and habitats. The use of MPAs for species conservation is considered with reference to spurdog (*Squalus acanthias*) and common skate (*Dipturus batis*), both are species that occur in the North Sea and are currently categorised by the IUCN as critically endangered in this region. Spurdog is a mobile species that can make long distance movements (unpublished CEFAS tagging data), and common skate is similarly assumed to be a mobile species, and both would therefore need very large MPAs across their distribution for the MPAs to have a notable impact on the fishing mortality to which they are exposed (Le Quesne and Codling 2009). The establishment of MPAs for the protection of habitats in EU waters are currently being developed as Special Areas of Conservation as part of the Natura 2000 network under the Habitats directive. The Dogger Bank candidate Special Area of Conservation covers 12,000 km^2 and gives an indication of the potential spatial scale of MPAs required for habitat protection. (It should be noted that the actual designation of the Dogger Bank SAC would not necessarily exclude all fishing activities.)

It should be noted in relation to descriptors 1 (biodiversity) and 4 (food webs) that it is unclear what further protection would be required if existing management structures were used to achieve the objectives of descriptor 3 (commercial species). However in the case of species such as common skate that can only withstand very low levels of fishing mortality (Le Quesne & Jennings, in press) it is assumed for this case study that further extensive MPAs would be required to achieve management objectives.

The size and extent to which MPAs would need to be applied to achieve GES objectives for descriptor 6 (seafloor integrity) are currently unclear due to the lack of thresholds and targets relating to the seafloor integrity descriptor.

5.4.7. Management Strategy Evaluations

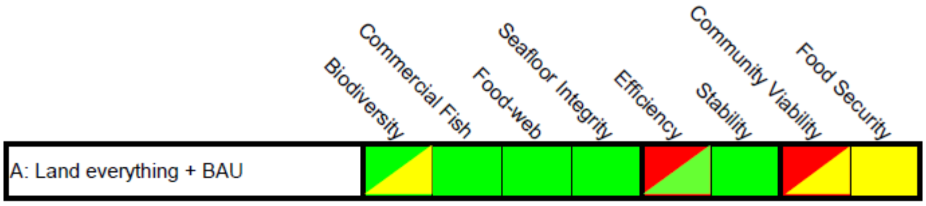
Table 5.4.7.1 Management strategies matrix: expected long term impacts of potential management strategy scenarios on the nine descriptors. Blank cells indicate no impact. The evaluation is qualitative, based on expert judgement.



	Ecological				Economic		Social	
	Biodiversity	Commercial Fish	Food-web	Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
A. Land everything + BAU	🟩🟨	🟩	🟩	🟩	🟥🟩	🟩	🟥🟨	🟨
B. Catch quota + BAU	🟩🟨	🟩	⬜	🟩	🟥🟩	🟩	🟥🟨	🟩🟨
C. Catch quota with fishing halted when any stock reaches TAC	🟩	🟩	🟩	🟩	🟥🟩	🟩	🟥	🟥
D. Discard ban + multispecies TAC	🟩🟨	🟩🟨	🟩🟨	🟩🟨	🟩	⬜	🟩🟨	🟩
E. MPAs + BAU	🟩	🟩	🟩	🟩	🟥🟨	🟩	🟥	🟥
F. Buisness as usual	🟩🟨	🟩	🟩	🟩	🟥🟩	🟩	🟥🟨	🟨

🟩 Expected improvement in the status of the descriptor
🟨 Stable (i.e. no change in the status of the descriptor)
🟥 Expected deterioration in the status of the descriptor
⬜ Outcome unknown

Management Strategy A: Land everything plus status quo management structures



	Biodiversity	Commercial Fish	Food-web	Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
A: Land everything + BAU	🟩/🟨	🟩	🟩	🟩	🟥/🟩	🟩	🟥/🟨	🟨

Assumptions: Under this scenario the cod management plan achieves its objectives and effort and mortality on cod is brought in line with objectives for MSY. Fishing operations do not sufficiently discriminate between cod and other key TR1 stocks, so overall effort is reduced to achieve the management plan objectives. Reductions in effort mean that harvest opportunities for other species within the multispecies stock complex are forgone. All catch is landed. No other changes to fisheries or management structures occur.

Ecological descriptors

Effort by the TR1 group is reduced, this leads to a reduction in the impact of the TR1 group on the wider environment and the ecological indicators improve. However the reductions in effort are not sufficient to allow the most sensitive long lived species to rebuild and improvements in the biodiversity status are limited.

Economic descriptors

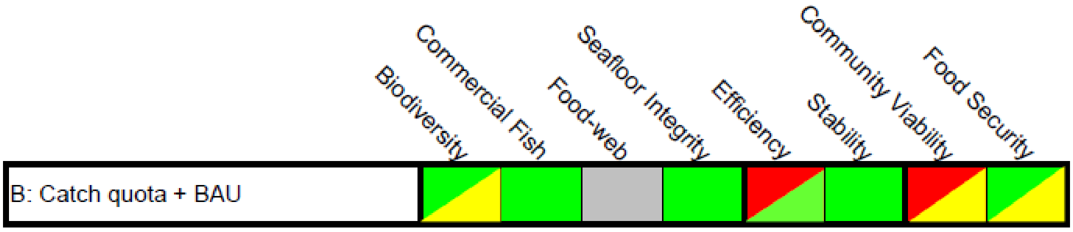
To achieve the reductions in effort and mortality required by the cod management plan to achieve its objectives further constraints are put on the fishing industry limiting the ability of the industry to adjust its fishing patters and effort distribution and thereby reducing the efficiency of the sector. Effort restrictions placed on the fleet to achieve the cod management plan objectives limit the ability of the industry to effectively target other species in the stock complex reducing the overall efficiency of fishery operations albeit that individual fishers may achieve a higher catch per unit effort (CPUE).

Increases in the cod stock, and other stocks targeted by the TR1 group lead to more stability in annual TAC allocations.

Social descriptors

The reduction in effort required to achieve the objectives of the cod management plan mean that fewer boat days are spent at sea by the fleet potentially leading to a reduction in employment in the at-sea catching sector. Under utilisation of stocks other than cod taken by the TR1 group fail to maximise the multi-species yield and thus limit the food production by the fleet, albeit that over time cod TACs increase as the stock rebuilds.

Management Strategy B: Catch quotas plus status quo management structures



Assumptions: The catch quota system incentivises fishers to improve gear selectivity and fishing operations to reduce under MLS bycatch, which in turn supports improvements in cod stock status and reduces the extent of further effort controls required to allow cod stocks to rebuild in accordance with the cod management plan. Effort reductions are still required to achieve the management plan objectives and limit ability to fully utilise other stocks within the stock complex, however incentives placed on fishers to modify catch compositions due to the catch quota system allow other stocks to be more fully utilised than under management strategy A.

Ecological descriptors

Overall reductions in effort and mortality on juveniles lead to improvements in indicators for commercial species and seafloor integrity. However the reductions in effort are not sufficient to allow the most sensitive long lived species to rebuild and improvements in the biodiversity status are limited. Effects on the food web, in terms of the large fish indicator, are difficult to determine. The reduction in effort reduces mortality across the fish community, however the specific reductions in juvenile bycatch may allow for a greater increase in smaller size classes thus may lead to no improvement, or even a reduction in the proportion of large fish.

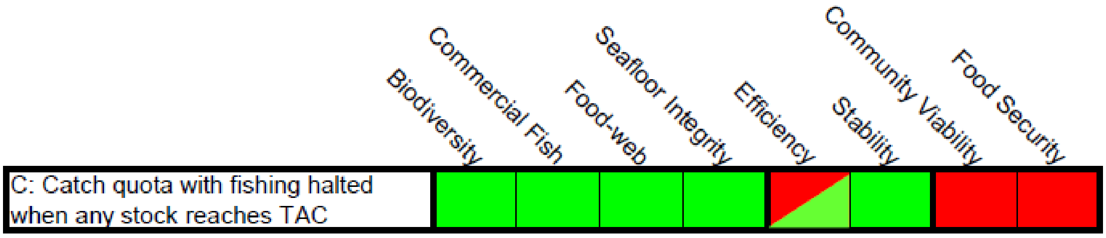
Economic descriptors

Increases in the cod stock, and other stocks targeted by the TR1 group lead to more stability in annual TAC allocations.

Effort restrictions placed on the fleet to achieve the cod management plan objectives limit the ability of the industry to effectively target other species in the stock complex reducing the overall efficiency of fishery operations albeit that individual fishers may achieve a higher CPUE.

The reduction in effort required to achieve the objectives of the cod management plan mean that fewer boat days are spent at sea by the fleet potentially leading to a reduction in employment in the at-sea catching sector. Under utilisation of stocks other than cod taken by the TR1 group fail to maximise the multi-species yield and thus limit the food production by the fleet, albeit that over time cod TACs increase as the stock rebuilds. However incentives placed on fishers to modify catch compositions due to the catch quota system allow other stocks to be more fully utilised than under management strategy A.

Management Strategy C: Catch quota with fishing halted when any stock reaches TAC



	Biodiversity	Commercial Fish	Food-web	Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
C: Catch quota with fishing halted when any stock reaches TAC	🟩	🟩	🟩	🟩	🟥🟩	🟩	🟥	🟥

Assumptions: Catch quotas and complete closure of the fishery once the first species has reached its quota drives significant changes in stock specific targeting by fishing operations and reductions in under MLS bycatch to try and maximise utilisation of individual species quotas and to avoid wasting quota by discarding under MLS fish. Despite improvements in species specific targeting by fishers overall fishing effort is notably reduced due to the whole fishery being closed once the first quota is full.

Ecological descriptors

All ecological descriptors improve due to the notable reductions in fishing effort as a result of the whole fishery being closed once the first quota is full. The reduction in effort coupled with greater species specific targeting of stocks by fishing operations may be sufficient to lead to an improvement in the state of even the more sensitive long lived species.

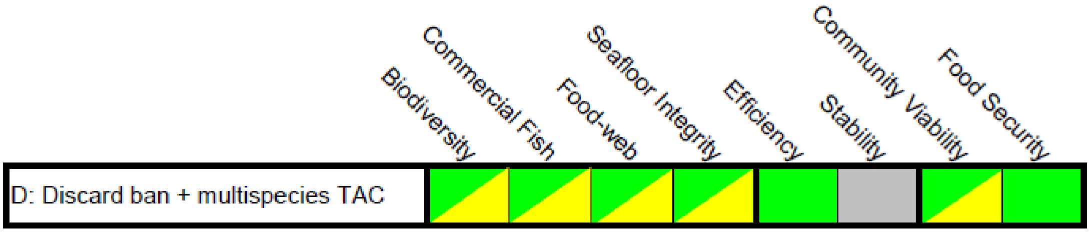
Economic descriptors

Closing the fishery when the first TAC is full constrains the ability of fishers to fully utilise all the species within the multistock complex and reduces efficiency of the fishery albeit that individual fishers may achieve a higher CPUE. As stock status of all the stocks is expected to improve or remain above SSB_{MSY} TACs are expected to become more stable and buffered against year to year recruitment events.

Social descriptors

The significant reduction in opportunities to exploit all species within the stock complex, and the notable reductions in effort associated with the whole fishery being closed when the first TAC is full lead to a decline in food provision and days at sea (hence employment in the catching sector).

Management Strategy D: Discard ban with multispecies TAC



Assumptions: The discard ban, and counting all landings against quotas for all landing, incentivises fishers to improve gear selectivity and fishing operations to reduce under MLS bycatch for cod and all other stocks contributing to the multispecies TAC (mTAC). This leads to a general improvement in stock status for all stocks. As cod has the highest landing value of the round fish species within the stock complex covered by the mTAC fishes preferentially target cod reducing stock size below SSB_{MSY}, however due to the penalties in future mTACs if any stock is reduced towards SSB_{lim} cod mortality is controlled and the stock remains around SSB_{pa}. The flexibility of the mTAC allows fishers to more fully utilise the other stocks covered by the mTAC than under the other management strategies.

Ecological descriptors

There is a general improvement in the status of commercial stocks, but cod, and possibly other species, remain below SSB_{MSY}. Due to the change in fishing patterns it is difficult to fully determine the impact of the mTAC on the other ecological descriptors. As cod can be fished below SSB_{MSY}, and there is more opportunity fully exploit other stocks covered by the mTAC effort will not be reduced as much as under the other management strategies so there may not be as much improvement in the ecological descriptors as under the other management strategies, but the indicators for ecological status are not expected to deteriorate.

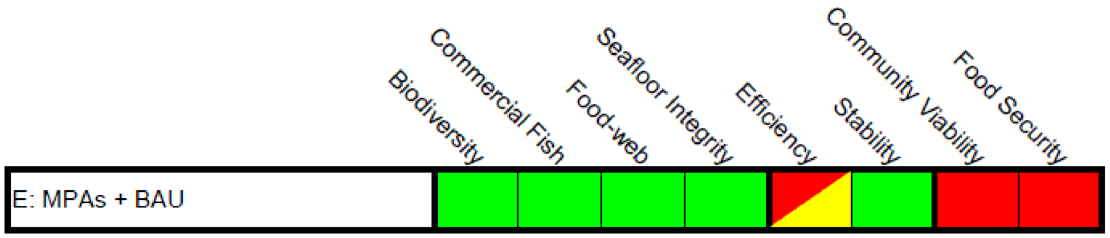
Economic descriptors

The flexibility of the mTAC, and the ability to exploit stocks other than cod more fully allows the fleet to operate more freely allowing for efficient operations. As there is little track record of applications of mTACs in multispecies demersal fisheries it was not possible to determine the impact of mTAC management on stability.

Social descriptors

As effort is not as constrained under the mTAC compared to the other management strategies there is not expected to be a decline in the days at sea, and the ability to more fully utilise other stocks within the mTAC indicates that food provision will increase and employment within the catching sector will remain stable, or potentially increase due to increased opportunities to fish for species other than cod.

Management Strategy E: Achieve wider GES biodiversity targets through MPAs plus status quo management strategies



	Biodiversity	Commercial Fish	Food-web	Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
E: MPAs + BAU	🟩	🟩	🟩	🟩	🟥🟨	🟩	🟥	🟥

Assumptions: The requirement for very large MPAs to protect mobile and sensitive long lived species of conservation concern greatly reduces the spatial freedom of fishers to choose fishing grounds. TACs are applied to manage commercial species, but given the reduced ability of fishers to target stocks in areas with limited stock mixing increased discarding occurs in localised areas, and the ability of fishers to economically fulfil quotas is reduced.

Ecological descriptors

The large widespread MPAs closed to achieve GES biodiversity targets lead to an improvement in all ecological descriptors.

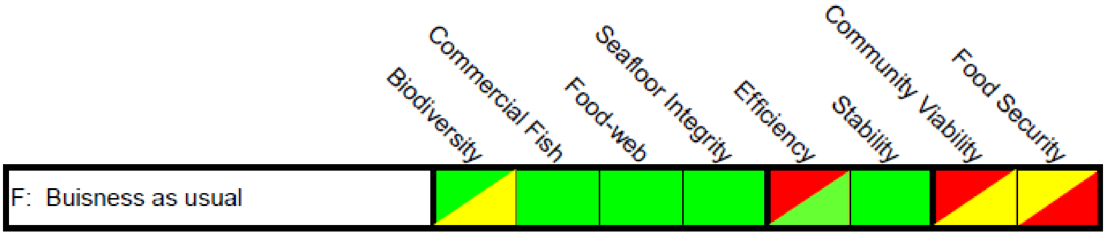
Economic descriptors

The large MPAs reduce fisher's ability to choose where to fish, hindering their ability to fulfil TACs and in places forces fishers from fishing in preferred locations reducing the overall efficiency of fishing operations. Depending on the location of the MPAs this may, or not, force fishers to fish in less productive areas offsetting any increases in biomass making it difficult to determine the impact on CPUE. The increase in stock sizes due to TAC management and large MPAs increases stability of TAC allocation, albeit that fishers may struggle to economically fulfil the quotas.

Social descriptors

Due to a reduction in the ability of fishers to fulfil quotas in an economic fashion there is a general decline in effort leading to a reduction in employment in the catching sector. Similarly the inability to fulfil quotas leads to a reduction in food provision.

Management Strategy F: Business as usual (BAU)



Assumptions: For this evaluation of the BAU strategy it is assumed that thecombined TAC and effort controls defined under the cod management plan are successfully applied to reduce mortality applied to cod, so that cod stocks rebuild and fishing mortality stabilises at the long term target for the plan. Fishers are limited in their ability to discriminate between stocks in catches limiting the ability to fish under effort exemptions, therefore overall effort allocations are reduced and fishers are unable fulfil quotas for species other than cod.

Ecological descriptors

Effort by the TR1 group is reduced, this leads to a reduction in the impact of the TR1 group on the wider environment and the ecological indicators improve. However the reductions in effort are not sufficient to allow the most sensitive long lived species to rebuild and improvements in biodiversity status are limited.

Economic descriptors

To achieve the reductions in effort and mortality required by the cod management plan to achieve its objectives further constraints are put on the fishing industry limiting the ability of the industry to adjust its fishing patters and effort distribution and thereby reducing the efficiency of the sectoralbeit that individual fishers may achieve a higher CPUE. Effort restrictions placed on the fleet to achieve the cod management plan objectives limit the ability of the industry to effectively target other species in the stock complex reducing the overall efficiency of fishery operations.

Increases in the cod stock, and other stocks targeted by the TR1 group lead to more stability in annual TAC allocations.

Social descriptors:

The reduction in effort required to achieve the objectives of the cod management plan mean that fewer boat days are spent at sea by the fleet potentially leading to a reduction in employment in the at-sea catching sector. Under utilisation of stocks other than cod taken by the TR1 group fail to maximise the multi-species yield and thus limit the food production by the fleet, albeit that over time cod TACs increase as the stock rebuilds.

5.4.8. Management considerations:

Under all of the management scenarios considered the ecological descriptors are expected to improve or remain stable given the assumptions of the evaluations. However it cannot be determined whether the improvements in ecological status would be sufficient to allow the system to achieve objectives for GES, in part this is due to uncertainty associated with the assessments, and in part as the ecological targets for GES have yet to be fully elaborated. Management strategies C (catch quotas with fishing stopped when the first species reaches its TAC) and E (large MPAs), are predicted to provide the greatest benefits to ecological status, albeit with the greatest trade-offs in terms of meeting social and ecological objectives.

Indicators for the social objectives are generally expected to decline or remain stable under the management strategies considered. This is because in all the management strategy evaluations, apart from strategy D (multi-species TAC) it was assumed that fishing opportunities for some species could not be fulfilled, thus limiting the effort that could be applied which limits employment in the catching sector, and limiting the multi-species yield which limits food production. In the case of strategy D (multi-species TAC) the maximum multi-species yield could be achieved as individual stocks could be exposed to limited overfishing, and thus maximising food production and employment opportunities in the catching sector.

In the case of the economic objectives many management strategies showed conflicting responses with efficiency declining and stability increasing. In the case of stability of opportunities for the catching sector it was assumed that more stable fishing opportunities would be available when stocks were at higher stock biomasses, therefore stability could increase whilst total fishing opportunities become significantly limited. Whilst stability in fishing opportunities may be a desirable objective for the fishing industry, there will be limits to the trade-offs associated with increasing stability that the industry would consider desirable. In the case of increasing efficiency none of the management scenarios considered providing property rights to individual fishers or groups of fishers, as such none of the management scenarios considered would provide a mechanism to increase true economic efficiency in the market, albeit that in cases where stocks increase TACs could be fulfilled for less effort and thus increasing simpler measures of efficiency. Management strategy D (multi-species TAC) is the only strategy where there could be opportunity for true increases in economic efficiency where by the industry would be given greater freedom on how to apply capital and effort in the search for maximising revenues.

5.5. Case study: Sandeel industrial fisheries

Due to a lack of resources, the MEFEPO project was not able to examine the sandeel industrial fisheries in the North Sea in the same level of detail as the other case studies. This section therefore presents an initial, higher-level assessment of the sandeel fishery as a starting point for further research and consideration.

5.5.1. Introduction to the fishery

The industrial fisheries in the North Sea are dominated by vessels from Denmark and Norway, although some other countries also participate on a smaller scale (e.g. UK, Faeroe Islands and Sweden). The main target species are the lesser sandeel (*Ammodytes marinus*) and Norway pout (*Trisopterus esmarki*); the lesser sandeel fishery is the largest single species fishery in the North Sea. These species are targeted using trawls with mesh sizes as small as 5mm. Landings from the industrial fisheries are reduced to extract fish-meal and oil that are principally used as feed in agriculture and aquaculture; some oil is also added to human food (e.g. biscuits and margarine).

Five species of sandeel occur in the North Sea but the majority of commercial landings are of *Ammodytes marinus*. Sandeels are a shoaling species which bury in the sand during the night and feed (predominantly on plankton) in mid-water during daylight hours (Winslade 1974). They are present throughout the North Sea, although their distribution is limited by the availability of their preferred sandy habitat (pers comm. Marine Scotland). Tagging experiments have demonstrated that there is little movement between spawning and feeding grounds (Kunzlik et al. 1986).

Sandeels are comparatively-short lived compared to other commercial fish species in the North Sea with a lifespan of <10 years. They are an important component of food webs in the North Sea and important prey species for many marine predators, including seabirds and fish. Sandeels are caught using fine-meshed trawls; the footrope of the trawl is lightly weighted so that it makes minimal contact with the seafloor (Macer and Burd 1970). The fishery is seasonal (April to August) as sandeels are believed to over-winter buried in the sand, however, spatial and temporal management restrictions have been introduced.

On a European scale, the industrial fisheries recorded total landings of 2.97 million tonnes, turnover of €211m and provided 4,920 jobs in 2001 (STOA 101/2001). The majority of sandeel landings come from the central North Sea (Fig. 5.5.2.1); landings are dominated by the Danish and Norwegian fleets (Kunzlik et al. 1986; STECF, 2008b). Industrial fleets have changed in the last decade to fewer, larger, more powerful and more efficient vessels; the introduction of individual tradable quotas (ITQ) is thought to have accelerated this change (ICES 2008).

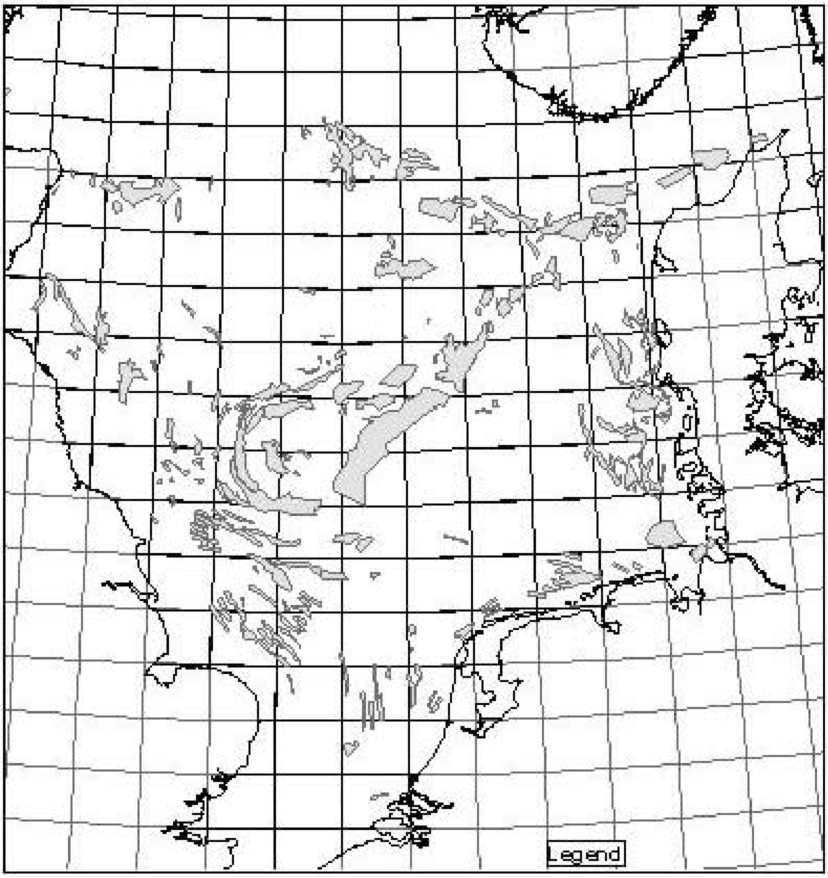


Fig. 5.5.1.1 Spatial distribution of sandeel fishing grounds (INEXFISH, 2008).

5.5.2. State of the stocks

Prior to 2010, ICES advice for sandeels stocks in Division IIIa and Subarea IV was provided based on three region units: North Sea excluding the Shetland area, the Shetland area and the Skagerrak Kattegat. However, ICES advice is now provided based on seven areas to better reflect the stock structure and enable management to direct action to avoid local depletions (ICES 2011). The quality of the assessment is considered to be improved compared to the combined assessment undertaken pre-2010 as the 7 stock assessment areas better reflect the spatial stock structure and dynamics (ICES 2011). However, the amount of scientific and fisheries data, and thus the level of detail in advice, differs among areas (see area explanations below; adapted from ICES 2011).

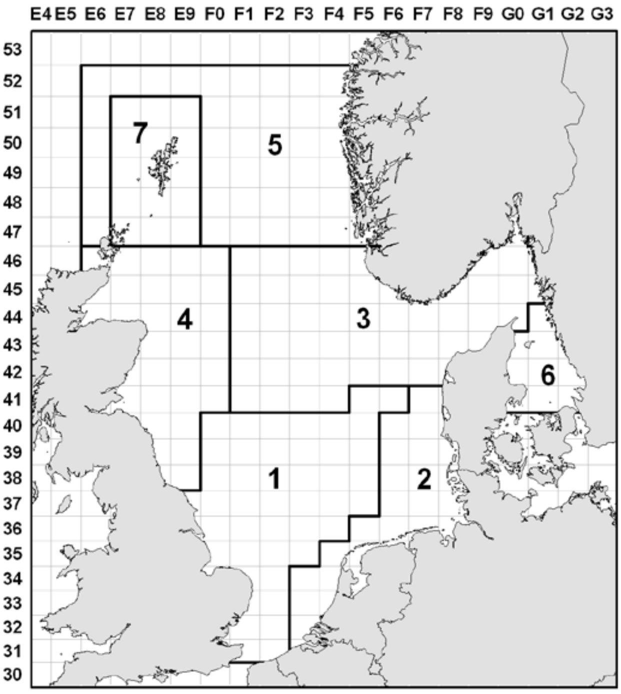


Fig. 5.5.2.1 Sandeel areas used in ICES advice in 2011 for Sandeel in Division IIIa and Subarea IV (Source: ICES 2011).

ICES's interpretation of the MSY concept uses B_{pa} estimates as the default value for MSY $B_{escapement}$ for short-lived species such as sandeel. It is thought that this strategy should allow for sufficient stock to remain for successful recruitment and providing adequate resource for predators of sandeel. Advice is based on the sandeel stock being at or above MSY $B_{escapement}$ in the year after the advised fishery has taken place and is summarised in Table 5.5.2.1.

Table 5.5.2.1 Sandeel in Division IIIa and Subarea IV. TAC advice overview for all areas: 2010 vs. 2011, refer to Fig. 5.5.2.1. Weights in '000 t (modified from ICES Advice 2011).

Sandeel Area	Name	2010	2011
1	Dogger Bank area	-	< 320
2	South Eastern North Sea	-	< 34
3	Central Eastern North Sea	-	0
4	Central Western North Sea	-	40821
5	Viking and Bergen Bank area	-	No advice[3]
6	Division IIIa East (Kattegat)	No advice	
7	Shetland Area	No advice	
Agreed TAC[1]		400	
ICES landings		398[2]	

[1] Advice for Subarea IV excluding the Shetland area.

[2] Preliminary

[3] No increase in effort unless evidence that this is sustainable

5.5.2.1. Sandeel Area 1

At the start of 2011 the stock was expected to be at full reproductive capacity due to high recruitment in 2009. Fishing mortality decreased in 2005 from a high level and has since fluctuated without trend. ICES advised that a management plan be developed for this SA due to a mismatch between MSY $B_{escapement}$ levels and associated Fs. A management plan should include an upper limit on effort estimated on the basis of the effort applied in the most recent years.

5.5.2.2. Sandeel Area 2

As a result of low F (~ 0.1) since 2007, and the strong 2009 year class, SSB in 2011 is estimated around twice as high as B_{pa}. ICES advised that a management be developed for this SA for similar reasons as given in Area 1.

5.5.2.3. Sandeel Area 3

The stock has increased from a record low SSB in 2004 (at half of Blim) to above Bpa in 2010 and SSB in 2011 is estimated to be just above Bpa and MSY Bescapement. However, recruitment has been below the long-term mean since 2001, with very low recruitment in 2010. F has been highly variable since 2004 but remains below the long-term mean.

The Norwegian management plan is based on preserving local spawning stocks using a rotational system of opening and closing fishing grounds. The Norwegian EEZ has been divided into six areas, five of which are located in SA 3. If the abundance of sandeel in an area is above a predefined level, half of the area will be opened for fishing. If sandeel abundance remains above the predefined level, the second half of the area will be opened for fishing the following year and the first half will then be closed. ICES has not evaluated the Norwegian management plan for sandeel in the Norwegian part of SA 3.

5.5.2.4. Sandeel Area 4

Fishery independent data indicates an increasing stock size in recent years. However, catch and survey data were not sufficient to conduct a traditional age-based assessment. Results from a dredge survey indicated that recruitment (measured as cpue of 0-group) was high in 2009 and low in 2010 (this pattern was also noted in SA 1 and 2). Based on the 3 years of data the temporal changes in 0-group abundance for this SA appears to follow that in the Firth of Forth. Very limited effort in this SA indicates very low F.

Because low sandeel availability affects the breeding success of kittiwake, all commercial fishing in the Firth of Forth has been prohibited since 2000, except for a limited fishery conducted in May and June to monitor the stock. This closure includes most of the fishing banks in SA 4. A few banks (e.g. Turbot bank) outside the closed area have historically provided large landings. Almost no sandeel fishery occurred in SA 4 in 2010, probably due to very high catch rates on other fishing banks closer to the landing sites in Denmark and Norway.

5.5.2.5. Sandeel Area 5

No catch was recorded in this SA in 2010. ICES reported that there was no basis for advice and should therefore no increase of the fisheries should take place unless there is evidence that this will be sustainable. While catch statistics and acoustic data were available for this stock, the information was not adequate to evaluate stock status or trends; the state of the stock is therefore unknown.

Norway has closed fisheries on the Viking Bank Area in 2011 because of very low estimates of sandeel abundance as measured using acoustics in 2007–2010 (ICES, 2010b).

5.5.2.6. Sandeel Area 6

The total catch in this SA in 2010 was 0.1 kt. As for SA5, ICES reported that there was no basis for advice in SA 6 and should therefore be no increase of the fisheries should take place unless there is evidence that this will be sustainable. Only catch statistics were available for this stock which were not adequate to evaluate stock status or trends; the state of the stock is therefore unknown.

5.5.2.7. Sandeel Area 7

No catch was recorded in this SA in 2010. As for SAs 5 and 6, ICES reported that there was no basis for advice and should therefore be no increase of the fisheries should take place unless there is evidence that this will be sustainable. While catch statistics and trawl survey data are available for this stock, this data was not adequate to evaluate stock status or trends; the state of the stock is therefore unknown.

A national management plan was introduced by the Scottish Government for this stock in 2007 and sandeel fishing around Shetland is restricted to small inshore grounds. The management plan has included (a) a precautionary TAC of 1000 tonnes; (b) closure of grounds south of 60° 10' N, including around Foula and Fair Isle; (c) a seasonal closure of the fishery in June and July during the chick rearing period of seabirds and (d) a vessel length restriction of 20 metres. ICES has not evaluated this management plan.

5.5.3. Main interactions with ecosystem components

The gears used in the industrial sandeel fishery have minimal contact with the seafloor and are not considered to directly impact on habitats and associated benthic communities. Where contact is made, effects are considered to be short-lived given than sandeels generally live in sandy habitats characterised by high levels of natural disturbance. Fisheries are also seasonal which allows for periods of recovery (ICES, 2006).

There has been little evaluation of the consequences of fishing small mesh targeted species on their main prey, which is dominated by phytoplankton and zooplankton, including juvenile fish and eggs (Macer, 1966). The importance of sandeels as prey for many seabirds is well established (Tasker and Furness, 1996) and in particular black-legged kittiwakes, *Rissa tridactyla* (Frederiksen et al. 2004). On a North Sea wide scale sandeel fishing is not considered to have a notable impact on seabird populations (ICES, 2006). However concerns have been raised that sandeel fisheries may impact seabird populations when sandeel fishing occurs close to breeding colonies and localised breeding failure has been noted following depletion of local sandeel populations (ICES, 1996), particularly in the case of kittiwakes (Tasker et al., 2000; Daunt et al. 2008).

Industrial fish species form a valuable proportion of the food for predatory fish (e.g. saithe, whiting, cod, mackerel and haddock) in the North Sea (Gislason, 1994; Greenstreet 1996; Pope and Macer, 1996). Sandeels comprise 40-60% of the fish biomass consumed and 15-25% of the total biomass in the North Sea (ICES, 1997). Changes in the size of the sandeel stocks in the North Sea clearly have potential implications for its main predators. However, investigations into the local effect of the closure of an industrial fishery off the east coast of Scotland (ICES, 2004b) indicated that there was no beneficial effect (i.e. no increase) on gadoid predator biomass in the region; the absence of an effect was ascribed to the fact that fish predators mainly target 0-group sandeels (Greenstreet, 2006) whereas the fishery targetted older sandeels (from ICES, 2006).

The sandeel fishery is generally considered a “clean” fishery and has a low percentage of bycatch of other species, including those for which a TAC has been set (Raakjær Nielsen and Mathiesen 2006; ICES 2010). By-catch of undersized and non-consumption species are landed for reduction purposes, while some human consumption species are landed as such. The by-catch of undersized human consumption species (e.g. herring, cod, haddock) is a topic of discussion due to its possible negative effects on these stocks. The industrial sandeel fishery is considered to cause only minimal direct mortality of marine mammals although occasional reports of by-catch of mammals exist (ICES, 2006). Sandeels do occur in the diets of marine mammals, but North Sea marine mammals are opportunistic feeders and a direct link between sandeel numbers and cetacean populations has yet to be demonstrated in any population (ICES, 2006).

5.5.4. Current management (Business As Usual)

5.5.4.1. Total allowable catch

The TAC is now divided into 7 management areas to account for spatial variation in sandeel growth, recruitment and mortality. See Table 5.2.2.1 above for recommended TACs in 2010.

5.5.4.2. Individual transferrable quotes

The introduction of individual tradable quotas (ITQ) for the Danish fleet in 2007 has accelerated the change towards fewer and larger vessels (ICES 2008; ICES 2011).

5.5.4.3. Spatial and temporal closures

There is concern that the removal of sandeels by the industrial fisheries causes food deprivation for predators such as larger fish, seabirds and marine mammals (Furness 1990; Furness 2002; Frederiksen et al. 2005). This led to the closure of an area in the Firth of Forth (Sandeel area 4) for sandeel fisheries since 2000 (ICES 2008; ICES Advice 2011). There is a limited opening for fishing in May and June to allow the stock to be monitored (ICES Advice 2011).

5.5.4.4. Mesh size and catch composition

For towed gears with mesh sizes less than 16mm the minimum percentage of sandeel retained in the catch is 95%. The maximum percentage of cod, haddock, hake and saithe for such gears is 2%.

5.5.5. Management strategy evaluation

5.5.5.1. Overview of management strategies

Management Strategy A: Transferable Fishing Concessions

The recently released package on the reform of the CFP (COM 425/2011) includes plans to introduce transferable fishing concessions (TFC) to European waters (Part IV: Access to Resources). TFCs are a specific form of rights based management (RBM, see the discussion for a general overview). Under TFC it is proposed to allow the transfer of quota between fishers, organisations and member states and for rights to be valid for a minimum of 15 years.

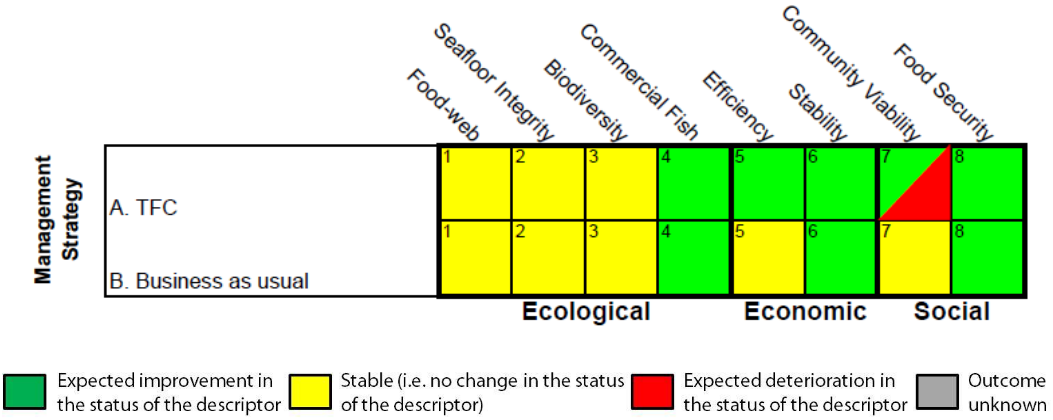
Management Strategy B: Minimise Discards

Technical measures concerning the obligation to land all catches are also included in the recently released package on the reform of the CFP. Article 15 of COM 425/2011 outlines plans to eliminate the discarding of commercial fish species by 2016.

5.5.6. Management strategies matrix

Below is a matrix comparing the expected long-term (5-10 year) outcome from the other possible sandeel management strategy to “business as usual” (Table 5.5.6.1). The comparisons were made in consultation with an external expert and are supported by relevant literature. The assessments of the management measures are made under the assumptions of the long term perspective (5-10 years); this means that other effects may take place in the short term.

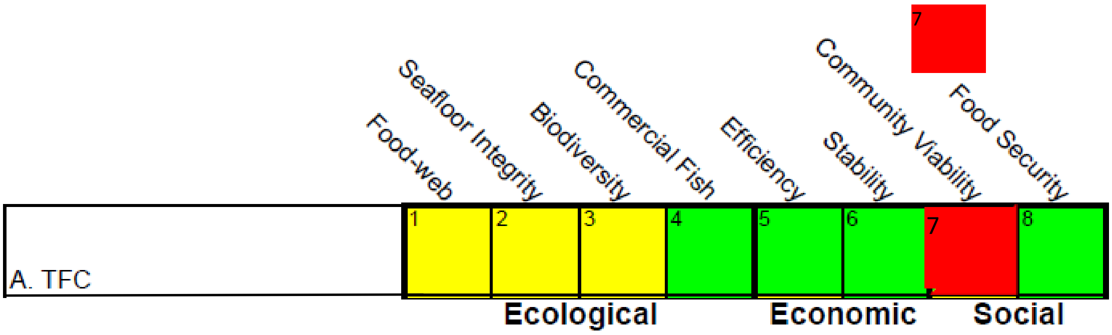
Table 5.5.6.1 Management strategies matrix: expected long term impacts of potential management strategy scenarios on the nine descriptors. Blank cells indicate no impact. The evaluation is qualitative, based on expert judgement.



Management Strategy	Ecological				Economic		Social	
	Food-web	Seafloor Integrity	Biodiversity	Commercial Fish	Efficiency	Stability	Community Viability	Food Security
A. TFC	1 🟨	2 🟨	3 🟨	4 🟩	5 🟩	6 🟩	7 🟩/🟥	8 🟩
B. Business as usual	1 🟨	2 🟨	3 🟨	4 🟩	5 🟨	6 🟩	7 🟨	8 🟩

🟩 Expected improvement in the status of the descriptor
🟨 Stable (i.e. no change in the status of the descriptor)
🟥 Expected deterioration in the status of the descriptor
⬜ Outcome unknown

Management strategy A: Increase Rights Based Management (TFCs)



	Ecological				Economic		Social	
	Food-web	Seafloor Integrity	Biodiversity	Commercial Fish	Efficiency	Stability	Community Viability	Food Security
A. TFC	1 🟨	2 🟨	3 🟨	4 🟩	5 🟩	6 🟩	7 🟥	8 🟩

Assumptions

All other management measures used in the fishery are kept constant. Constant surroundings: all exogenous conditions, such as world market price on fish, fuel prices, water temperature, etc. are constant.

This strategy calls for the introduction of transferable fishing concessions (TFCs) for the NS fishery as per COM 425/2011.

Ecological descriptors

The sandeel fishery is generally considered a “clean” fishery and has a low percentage of bycatch of other species, including those for which a TAC has been set (Raakjær Nielsen and Mathiesen 2006; ICES 2010). Hence impacts on the biodiversity of the ecosystem are limited. Likewise, the gears used in the industrial sandeel fishery have minimal contact with the seafloor and are not considered to impact directly on habitats and associated benthic communities.

SSB is currently above the MSY B_{esc} trigger in three out of the seven management areas where the vast majority of sandeel landings occur (ICES Advice 2011). A new management plan in Norwegian waters and the introduction of ITQs in Denmark should also improve the situation in the other areas.

Sandeels are an important prey item for many seabirds but on a North Sea wide scale sandeel fishing is not considered to have a notable impact on seabird populations (ICES, 2006). However, see section 5.5.1 for more details. Sandeels also feature in the diets of marine mammals and gadoid fish but marine mammals are opportunistic feeders with varied diets and gadoids usually prey on 0-age sandeels before they are recruited to the fishery.

Economic descriptors

Under a business as usual strategy, efficiency would be expected to stay stable (or possibly decline) as there is no control on effort, therefore boats would continue to fish until costs are equal to revenues. However, the introduction of ITQs to Danish boats should improve economic efficiency in that fleet although it may reduce the profitability of some individual fishers. See discussion (section 5.5.4) for more details.

Due to the introduction of advice at a regional level in 2011 and a management plan in Norwegian waters stability is expected to improve. This proposal, calling for fishing rights that last for a minimum of 15 years, should provide a level of security to further increase stability in the sandeel fishery.

Social descriptors

Commercial stocks and profitability are expected to improve under this strategy, which should lead to a sustainable fishery and a conservation of employment opportunities. However the following is an extract from the 2011 ICES advice for NS sandeel:

"*The number of Danish vessels has declined from 200 vessels in 2004 to 84 in 2009, leading to a 43% reduction in total kilowatt days. In 2007, the Danish industrial vessels were given individual tradable quotas (ITQ) on sandeel which prompted a change towards fewer and larger vessels. The Norwegian fleet fishing for sandeel declined from 90 to 33 vessels between 2002 and 2009*."

Also, the acceptability of rights based management systems varies; of particular concern is the aggregation of fishing rights, and therefore employment, to a few geographical areas.

Yield and stability under this strategy are expected to improve, which would ensure future food security.

Management strategy B: Minimise discards

	1 **Biodiversity**	**2** Commercial Fish	**3** Food-web	**4** Seafloor integrity	**5** Efficiency	**6** Stability	**7** Community Viability	**8** Food Security	**9** Job Attractiveness
B. Minimise discards	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
	Ecological				**Economic**		**Social**		

Assumptions
All other management measures used in the fishery are kept constant. Constant surroundings: all exogenous conditions, such as world market price on fish, fuel prices, water temperature, etc. are constant.
Legislation is enacted to prohibit discarding.

Ecological, economic and social descriptors

As the sandeel fishery is relatively clean and maximum percentages for vulnerable fish species in the catch exist, a strategy to minimise discards will not be likely to impact on any of the ecological, economic or social descriptors in a significant way.

5.5.7. Discussion

A property rights based system is a way of assigning an individual the property right to either the inputs into the fishery (i.e. how much effort can be put in, for instance number of days at sea), or the outputs from the fishery (i.e. how much catch is taken, for instance in individual quota share). It is then up to the individual fisher how (within present regulations) and when (usually within a calendar year) and where (within geographic limits) the fish will be caught. The fisher will then decide the most efficient (profitable) way to harvest the assigned fish, within the given regulations, and thus increased efficiency is achieved at an individual (fisher) level. If the rights are transferable, then efficiency is ensured also at the level of the fisheries. This is the case since, if fisher A can harvest more efficiently (at lower costs) than fisher B, fisher A can offer B a price for the right, which makes B indifferent between using the right or not. By this mechanism the rights end up with the most efficient fishers, i.e. fishers that have the lowest harvesting costs, ensuring economic efficiency but probably reducing community viability.

A big issue in the debate on transferable property rights in fisheries is whether the rights should have an infinite term, be valid for some years or only for a single year. Eternal rights, given that the control mechanisms for the quota system are effective and the fishing mortality for the stocks can be controlled, give the highest stability, whereas annual quotas give the lowest ex ante stability. However, with a well-functioning market for rights, longevity of the rights is not necessarily an issue.

5.5.8. Management guidance

Current (recently introduced) management has resulted in an improved status of the ecological pillar that may further improve. However, there may still be scope for other measures that improve other descriptors than commercial fish. Rights-based management can then improve the economic pillar with possible repercussions on the social pillar. For better management guidance a more comprehensive evaluation of the possible management measures would be required.

6. STEPS REQUIRED FOR IMPLEMENTATION

The MEFEPO project has demonstrated the application of a management strategy evaluation matrix approach to the development of regional Fisheries Ecosystem Plans (FEPs) to help decision-makers to simultaneously consider ecological, social and economic implications of decisions, and to inform the development of ecosystem based fisheries management (EBFM) for European fisheries. We have identified 5 key steps to developing such an integrated ecosystem based fisheries management regime (Box 6.1) and have illustrated our approach using a number of case study fisheries. The case study fisheries examined should be seen as heuristic examples and not definitive assessments of the potential effects of different management strategies.

Box 6.1 Key steps to make ecosystem based fisheries management a reality for European fisheries

- Develop long-term management plans (LTMPs) for each of the region's fisheries considering the ecological, economic and social implications for ecosystem components. LTMPS should be integrated into regional FEPs.
- Develop closer integration among stakeholders, fisheries scientists, ecologists, social scientists and economists to develop effective management advice for LTMPs. Social and economic descriptors, and appropriate (region specific) indicators, require further scrutiny and development.
- Develop qualitative assessments and expert judgement to supplement analytical modelling to meet the increased data requirements of LTMP development and make them operational in the short term.
- Ensure that the management framework is adaptive and able to respond to new information and understanding to allow decisions based on the best available evidence.
- Implement appropriate governance mechanisms that facilitate true stakeholder engagement to generate credibility in the management process and foster stakeholder support, this includes both definition of objectives and indicators as well as the development and evaluation of LTMPs.

The transition from single species management to EBFM will have significant implications for the knowledge base required to underpin management. Long term management plans (LTMPs) should be developed for each of the region's fisheries that include consideration of the wider ecosystem (ecological, social and economic) interactions. Implementation of the management strategy evaluation matrix (hereafter the matrix) approach developed by the MEFEPO project will allow the broad range and quantity of information on potential impacts of different management strategies to be summarised in a concise manner, accessible to all stakeholders and so support the production of robust, evidence based and inclusive Long Term Management Plans.

Whilst the matrix approach is conceptually simple, a considerable amount of information is required to support its application. Much of this information, while routinely collected, is 'new' to a formal fisheries advisory process. It is also clear that it is not possible to meet all the additional data requirements using the data that are currently collected. For example, the ecological descriptors utilised were drawn directly from the Marine Strategy Framework Directive (MSFD), and were selected as those most likely to be impacted by fishing activities (biodiversity, commercial fish, food-webs and seafloor integrity). Social and economic descriptors were defined to monitor some of the main aspects of fishing contributing to the economic and social wellbeing of coastal communities but the choice was constrained by available data. Concerns therefore remain over the choice and application of all the descriptors utilised, and the definition of social and economic descriptors and appropriate indicators requires further scrutiny and development before this approach is applied within a formal advisory framework. However, these concerns need not be a barrier to implementation of EBFM due to the adaptive and consultative management process within the new management regime (Fig. 6.1), and we recommend a process of collaborative (Member State, scientists, and industry) to ensure that descriptors and indicators for all pillars are fit-for-purpose.

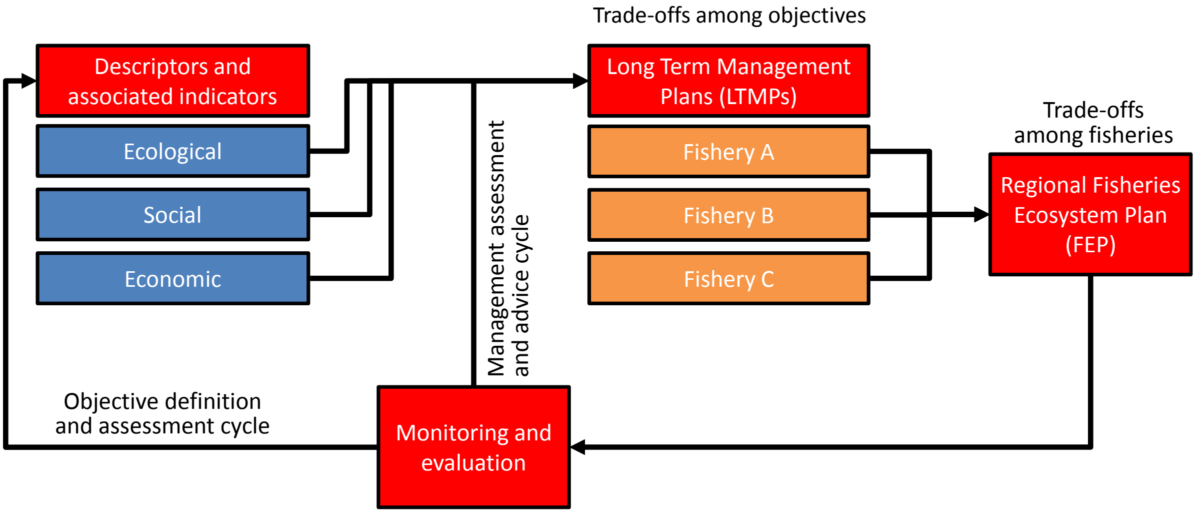


Fig. 6.1 Adaptive management framework proposed by the MEFEPO project for the development of Fisheries Ecosystem Plans to support ecosystem based fisheries management in European fisheries.

The institutional framework developed by MEFEPO (Section 2) would enhance stakeholders' participation in management at the regional scale, and facilitate stakeholders' involvement in the development of management objectives and appropriate descriptors for all three pillars, and in the evaluation of management strategies to give credibility to the processes and foster stakeholder support. If effectively implemented, this governance structure should serve to increase the legitimacy of the CFP and associated instruments among stakeholders (which presently is low) and reduce conflict between administrators and industry.

The absence of data must not be allowed to prevent decisions from being made and management advice should be formulated based on the best available evidence (be it modelled, empirical or expert opinion), consistent with the FAO Code of Conduct for Responsible Fisheries (FAO 2005) and the precautionary principle. Development of matrices for the case study fisheries demonstrated that qualitative assessments and expert judgement are needed to supplement analytical modelling, particularly with respect to social and economic pillars, if EBFM is to be made operational. Effort should be expended on developing approaches to incorporate qualitative data, expert judgment and data from outside of the traditional scientific fisheries advice domain (e.g. from industry, environmental scientists) to ensure that management decisions are appropriately informed.

LTMPs developed based on best available evidence must be implemented within an adaptive management regime, responsive to changes in environmental conditions, and new knowledge and understanding on the marine environment. Furthermore, the regime should be able to respond to advances in technology and associated changes in fishers' behavior to ensure that the long term sustainability is not compromised. Monitoring should be implemented to report on progress in meeting management objectives, with action taken where objectives are not being met (Fig. 6.1).

Ultimately management decisions will be made by politicians or managers (at EU and MS level), on the basis of overarching objectives. However, the joint development and evaluation of management strategies in the format described here has the potential to develop common understanding of the long-term implications of management decisions, and build communication and trust between industry and managers. Trade-offs are required among the pillars of sustainability in the development of LTMPs, and among fisheries when integrating LTMPs into regional FEPs; managers and stakeholder must work together to address priorities. Due to the nature of the trade-offs, it may not be possible to satisfy all stakeholder groups simultaneously (e.g. high level objectives call for EU fisheries to be exploited at MSY, however it may not be possible to achieve this for all fisheries simultaneously). Resolution of these trade-offs is not a technical scientific decision, however development of decision support frameworks such as the management strategy evaluation matrices can aid managers in making appropriate decisions on the basis of the best available information.

7. SYNTHESIS

Over the past decade the use of Long Term Management plans in the North Sea area has increased. However, these LTMP have predominantly taken a single stock perspective and a rather limited scope on the related fishing fleets. In the current set up management plans are generally based on a biological assessment and wider ecosystem considerations are lacking. Also in the majority of cases, if at all, the economic analysis is only included after the biological assessment has been implemented. A firm bio-economic feedback loop is generally lacking and social considerations of reliance and resilience are excluded.

In order to curb this trend an effort should be made to devise analytical tools that do enable an integrated assessment of ecological, economic and societal impact of LTMP. This will also require a considerable effort in making available relevant economic and social indicator data, equivalent to the ecological data

Pivotal in the analysis of a LTMP is the evaluation of measures at the geographical ecosystem level. This will require a regional scope in the analysis and thus an integration of data sets on ecological, economic and societal aspects from different nations, both EU MS and third countries. Also it will call for cooperation between MS, EC and stakeholders at the regional level. Currently this regional level has no formal position in the EU treaty.

Central to this analysis will be appropriate governance mechanisms that facilitate true stakeholder engagement to generate credibility in the management process and foster stakeholder support. The North Sea RAC is, according to its members, partly living up to this expectation. However, the policy development cycle is currently geared towards a traditional science-policy interface, with a linear process form science to policy. In the evaluation of LTMP it is recommended to acknowledge that traditional science is not fit to meet the challenges of many policy questions of today, but that these questions require (1) new, trans-disciplinary approaches, (2) an awareness of how values are embedded in the framing of policy questions and the choices of scientific methods and (3) that uncertainty be addressed more adequately.

These challenges are not specific to the North Sea and in fact at the NS already data availability and cooperation are advancing. Yet in order to fuel a participatory regional ecosystem evaluation of fisheries plans more and other data are required as well as the development of tools that facilitate a participatory science-policy interface servicing the needs of all parties involved in the policy evaluation cycle.

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9. ANNEXES

9.1. Annex A: Descriptors and related indicators.

For these descriptors/indicators is indicated how they were considered within the case study fisheries' management strategies matrices. One descriptor for the social pillar, job attractiveness, was dropped in this exercise as it was severely criticised in a previous stakeholder workshop and was believed to be very difficult (if not impossible) to determine the effect of management measures on this descriptor.

Pillar	Descriptor	Indicator(s) used in MEFEPO*	Consideration
Ecological	Biodiversity	Conservation Status of Fish	Related to fishing pressure (mortality) applied to fish. Measures of genetic diversity are not taken into account. The existence of "sub-species and populations where they need to be assessed separately" is included. It may also be related to more specific known impacts (particular gears impacting particular vulnerable species) that may be mitigated by specific spatial or technical regulations.
	Commercial fish	Proportion of stocks within safe biological limits (SBL) with regard to SSB and fishing mortality (F)	Related to the state of the case study fishery stock and other commercial stocks that interact with the case study fishery.
	Food-webs	Large fish indicator (LFI)	Related to fishing pressure on the fish community (especially larger longer lived fish). Indirectly, it may also be related to effects of discards on local food webs.
	Seafloor integrity	Proportion of area not impacted by mobile bottom gears	Pressure indicator of the extent of trawling impacts, related to the effort applied by mobile bottom gears and to the areal coverage of bottom trawling.
Economic	Efficiency[1]	Fishers' ability to take a given harvest at the lowest possible cost	Related to benefits and costs: social, economic (e.g. input) and ecosystem (externalities e.g. costs of by-catch and discarding).
	Stability	Minimising fluctuations in harvesting possibilities over time	Related to stability in fishing opportunities (e.g. fluctuations in TAC). If stock above SBL it is more likely that it will be more robust to short term environmental 'noise', therefore less need for regular changes to quotas to respond to changes in recruitment/environmental noise. Note that this is only true for stocks with strong stock-recruit linkages.
Social	Community viability	Employment linked with fisheries	Related to employment (e.g. catching, amount and type of employment, processing, administration, science,…) As this is a social descriptor, including cultural values, it is not only linked to "efficiency". .
	Food security	Securing a sustainable and sufficient supply of marine protein as food	Related to marine protein caught from the sea, hence this is related to yield, but not exclusively to commercial fish stock status.

* Earlier in the MEFEPO project, more than one indicator per descriptor had been suggested.

[1] NS beam trawl: Net revenues were the prime consideration.

9.2. Annex B: Management tools in the herring pelagic fishery

Table: List of management tools, aims/objectives, strategies and effects in the North Sea herring fishery.

			Sustainability objectives?			Effects?
Tool	**Aim**	Description operational strategy	Biological	Economic	Social	wrt Governance, regionalisation, knowledge base
Mesh size	Limit the catch of undersize fish	Free choice of mesh size? MLS for human consumption fishery (see below)	Control F on juvenile fishery; achieve a balance between juveniles and adults	Compromise: 1) Sustain human consumption fishery 2)allow industrial (DK) fishery to continue fishing with herring "bycatch"	No	Compromise between human consumption and industrial fleets in the EU and Norway
Gear type	Limit catch or type of catch	Free choice?	Influences gear selectivity on target stock?	?	No	?
Limited licensing	Limit catch, or number or vessels	EU regulation: no further expansion of the EU fleet in EU waters	To achieve a balance between resource and exploiters	Sustainable exploitation	?	Companies still investing in fleet expansion, to fish in non EU waters → threat to other marine ecosystems outside of the EU.
Engine size	Limit catch	EU regulation (check Ref): no further increase of engine size in EU waters	To achieve a balance between resource and exploiters	Sustainable exploitation	?	Companies still investing in fleet expansion, to fish in non EU waters → threat to other marine ecosystems outside of the EU.
Seasonal restriction	Limit catch or type of catch	-	-	-	-	-
Days at sea (individual)	Limit catch	?				
Area restriction	Limit catch or impact other species/age groups	EU regulations: Sprat boxes	To protect herring, caught mainly as bycatch in industrial fisheries (e.g. sprat)	?	No	The boxes are still disputed by stakeholders. Their economic effects have not been investigated. They might not have any economic repercussions.
Bycatch devices	Limit catch of non-	Not necessary: Non-target	?	-	-	Bycatch of megafauna (not a big issue in this

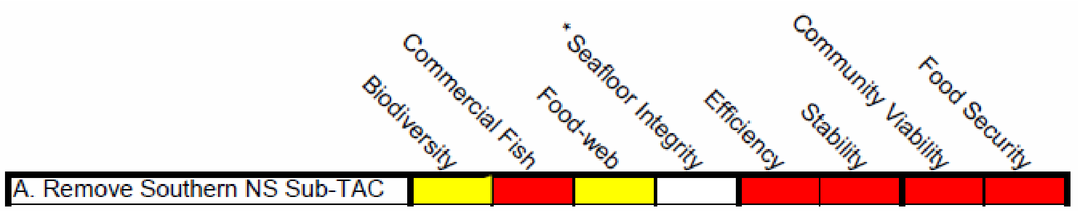
	target species/size	quota species are usually landed.				fishery) has to be monitored (EU regulation)
TAC	Limit total catch	EU-Norway Management Plan (1996) → HCR (F) → TAC for human consumption fishery	conservation of juveniles and adults	High yield and stability; high yield seems to be favoured; industry focuses on profit	No	National allocation based on relative stabilities
Group TAC	Limit or secure catch of certain vessel group	1. split EU-Norway: Article 8 in EU-Norway MP: agreement on herring “bycatch” quota (in industrial fisheries) 2. split: sub-TAC (x% of North Sea TAC) for Southern NS (Downs)	1. - 2. x%: no basis in science, but efficient to protect the Downs spawning component			Re 1: political stability between EU and Norway? Re 2: Scientific basis for the Downs quota split is lacking.
Individual quotas	Control of harvest and improve economic performance	1.Like “Hague preferences”, i.e. some countries (BE) have a special quota stability share; 2. SNS quota share (see 2. Above)	No	?	?	Political issues?
Bycatch regulations	Limit catch of non-target species/size	1. catch of non-target “bycatch” is limited by those species’ TACs 2. in other fisheries, “herring ceiling” are set every year	?	?		
Minimum landing size	Limit catch of undersize fish	20 cm for human consumption herring	No? Control F on juvenile fishery?	To sustain a sufficient adult population for the human consumption fishery		
Subsidies	Encourage certain	National, depends on MS	?	Depends on the	Yes?	social objective: to steer employment in the sector

	behaviour	rules and national decommissioning schemes		programme? Profitablility?		or other sectors??
Taxes/fees	Discourage or reduce certain behaviour. Reduce catch	?				
Individual transferrable effort	Secure efficient effort allocation	Transferable effort through quota swapping (see 2. Below)	To prevent discarding of overquota fish	profit	No	The industry does not have social objectives; 4 NL companies dominate the herring fleets in NL, DE, E, (F).
Individual transferrable quotas	Secure efficient quota allocation	1. Quota allocation of the national quota share via ITQs in DK, NL, and UK; 2. Quotas can be swapped between MS	-	high yield, quota stability, profit	No	The industry does not have social objectives; 4 NL companies dominate the herring fleets in NL, DE, E, (F).

9.3. Annex C: Management strategy evaluations herring pelagic fishery

Below follows a detailed explanation of the quantitative evaluation of the selected management strategies.

A. Simplify management by removing sub-TAC for the southern North Sea.



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
A. Remove Southern NS Sub-TAC	🟨	🟥	🟨	⬜	🟥	🟥	🟥	🟥

Removing the sub-TAC would infer that managers perceive North Sea herring as one unit, with no underlying complexity. It was argued above (section 4.2.1.1) that maintaining sub-stock structure was important, as it is thought to provide resilience to natural fluctuations and exploitation, especially as differing environmental drivers influence the productivity of the spawning components. Downs has been described as more susceptible to overfishing (Cushing, 1980). It was the first to collapse (late 1960s) and one of the last to recover (late 1990s), so the argument for extra protective measures appears strong. However, the setting of the current sub-TAC lacks scientific basis. If fishing mortality on the whole stock is kept low enough, then the risks would be reduced also on the Downs component. However, yield would be reduced, too.

Colouring of the matrix derives from the following reasoning:

A1 – biodiversity: The biodiversity indicators considered in MEFEPO do not include any measure of genetic diversity but this is considered in the GES descriptor. If a genetic measure is considered as part of the biodiversity descriptor, then management strategy A could potentially result in negative effects (red colouring instead of yellow) with respect to genetic diversity, as this management strategy could lead to overfishing of the Downs spawning component.

A2 – commercial fish: As mentioned in section 4.2.1.1, maintaining sub-stock structure is important, because it is thought to provide resilience to natural fluctuations and exploitation, especially as differing environmental drivers influence the productivity of the spawning components. Downs has been described as more susceptible to overfishing (Cushing, 1980). It was the first to collapse (late 1960s) and one of the last to recover (late 1990s), so less protection could mean higher susceptibility to overfishing.

A3 – food web: The large fish indicator (LFI) would not be influenced by management strategies that only impact the herring fisheries, because herring are not included in the calculation of the LFI. Additionally, since the herring fisheries are very targeted, there are very few by-catches of large fish in the fishery (Borges *et al.*, 2008).

A4 – seafloor integrity: The impact of the herring pelagic fisheries on the seabed is low, because the likelihood of net damage acts as a disincentive to contact with the seabed.

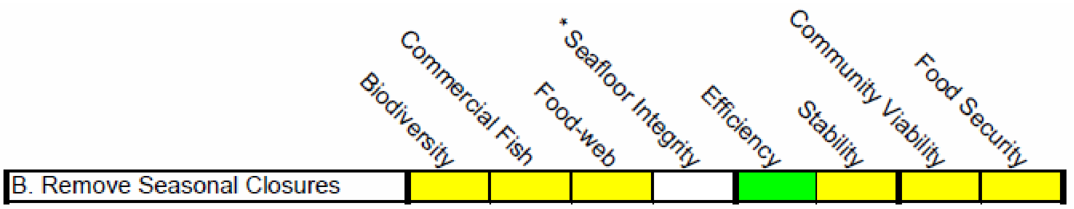
A5 – efficiency: If the herring stock is in good/bad shape and resilient, then this has also a positive/negative effect on the economic performance of the fishing sector. Efficiency should be good/bad, i.e., it follows the colouring of the commercial fish descriptor (A4).

A6 – stability: Stability here refers to stability of harvest, hence, the same argumentation applies as with A5: If the herring stock is in good/bad shape and resilient, then harvest possibilities will be good/bad, thus allowing for more/less stable harvest limits.

A7 – community viability: If efficiency and stability of the sector are poor, then a community linked to the sector might not remain viable.

A8 – food security: Food security here refers to the amount of protein that can be harvested from the sea. If F is reduced on the whole stock in order to avoid collapse of the Downs component, then this might curtail the total amount of marine protein being caught. Hence, from a food security perspective it could be preferable to keep the separate Downs TAC, thereby allowing a higher F for the rest of the stock. On the other hand, one could also apply the same argumentation as for A5 and A6: If the herring stock is in good/bad shape and resilient, then harvest possibilities for marine protein will be good/bad, thus allowing for more/less stable harvest limits. Both ways of argumentation suggest a deterioration of the food security descriptor under management strategy A.

B. Simplify management by removing seasonal local fishing closures



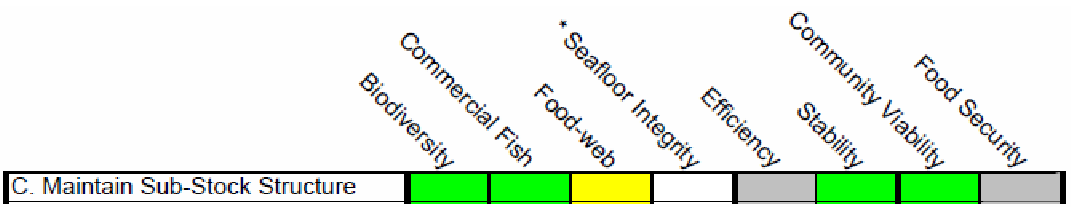
	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
B. Remove Seasonal Closures	🟨	🟨	🟨	⬜	🟩	🟨	🟨	🟨

Another way to simplify the management would be to remove all the seasonal closures. This scenario considers the removal of the seasonal closures of the herring and sprat fisheries, i.e., in the Moray Firth and Firth of Forth as well as around the Banks spawning ground and to the west of Denmark (cf. Figure 4.2.4). These closures of the herring and sprat fisheries have never been evaluated. The closures in the Moray Firth and Firth of Forth, may still be a suitable measure to protect small local spring spawning herring populations but the arguments for the other closures are weak when considering the fisheries exploiting North Sea autumn spawning herring.

B1-B4, B6, B7, B8: Management scenario B is not expected to have any effect on those descriptors.

B5: In general, less regulation means less administrative costs. This should result in more efficiency.

C. Maintain sub-stock structure (phenotypic diversity).



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
C. Maintain Sub-Stock Structure	🟩	🟩	🟨	⬜	▨	🟩	🟩	▨

This scenario considers the introduction of mechanisms to protect, sustain or even encourage the phenotypic diversity of North Sea herring. These mechanisms would involve more science, monitoring and/or more flexible management. There may be mechanisms to protect, sustain or even encourage the phenotypic diversity of North Sea herring. This would require more science and monitoring and result in more complicated management measures. It will be necessary to facilitate science and management measures that respond to the fluctuations and variability between spawning components, i.e. sub-stock structure. This could include a combination of more area sub-TACs, real time closures, monitoring of the spawning origin of the catch, sub-stock assessments etc. The clear objective would be management of the fishery to maintain diversity, and thus management would need to target the protection of the least productive components (ICES 2011c). However drawing from experience to the west of the British Isles (Hintzen *et al.*, in prep), the resources required to monitor smaller components within the larger mix, will be high.

C1 – biodiversity: Although the biodiversity indicators considered in MEFEPO do not take into account any measure of genetic diversity, they do take into account the existence of “sub-species and populations where they need to be assessed separately”. Therefore, management strategy C could potentially result in positive effects with respect to phenotypic diversity, as this management strategy should enhance herring sub-stock structure.

C2, C6, C7, C9: If the stock size (2) increases due to improved stock resilience, then harvest stability (6), community viability (7), and food security (8) will also improve.

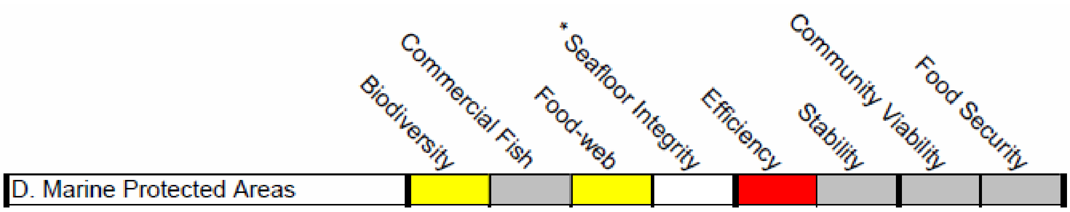
C3, C4: Management scenario C is not expected to have any effect on the foodweb and seefloor integrity descriptors.

C5: One the one hand, management and administration costs will increase under management strategy C. On the other hand, catch opportunities and yields are also expected to improve. In this case, an estimation of costs and benefits requires more knowledge about details, hence we do not provide cell colouring.

C7: This complex mechanism will lead to an increase in employment within enforcement and scientific agencies.

C8: From a food security perspective it is difficult to determine if high yields and lower stability outweigh lower yields but higher stability. Hence it could only be speculated that maintaining a resilient and diverse population with complex sub-stock structure should make the population more resilient and thus increase food security.

D. Greater conservation – Introduce MPAs



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
D. Marine Protected Areas	🟨	▨	🟨		🟥	▨	▨	▨

MPAs are about to be introduced in the North Sea mostly to address concerns about benthic habitats and demersal organisms. Pelagic fisheries may be impacted by MPAs if areas are closed to all fishing. This scenario considers the introduction of total fishery closures, i.e. MPAs where all fishing activity is prohibited. However, none of the current proposed MPAs plan to restrict fishing on herring, or closing areas where herring aggregate. The bio-economic impacts of the establishments of MPAs depend on the degree of overlap between fish distributions and MPAs, and whether there are spill-over effects from the MPA areas to the non-MPA areas.

D1 – biodiversity: If the MPAs and fish distributions overlapped, fish might be given the time to grow bigger and older within an MPA. For North Sea herring, however, this is an unrealistic scenario, as the natural herring life cycle implies wide displacements of the different life stages over the entire North Sea. Any effects on biodiversity of management strategy D would thus depend on the size of the MPAs, on the degree of overlap with fish distribution and on spill-over effects. From a general biodiversity perspective, such a measure is expected to be beneficial, in particular if the MPA areas coincide with sensitive habitat for sensitive species, e.g. rays. So, in general, management strategy D would be beneficial for biodiversity, but currently this is not captured in the indicator used.

D2, D6, D7: Effects on the herring stock size of management strategy D would depend on the size of the MPAs, the degree of overlap with fish distribution, spill-over effects and the efficiency of fishing effort redistribution to areas where the herring can be caught. Potential effects on the stability of the herring catch/ yield in turn depend on the effects on the stock size (2). In turn, community viability depends on the shape of the stock and the fishing industry.

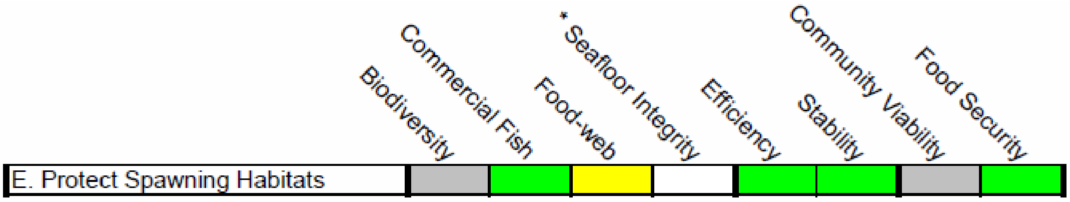
D3 – foodweb: The large fish indicator (LFI) would not be influenced by management strategies that only impact the herring fisheries. From a general foodweb perspective, such a measure is expected to be beneficial, but it is not captured in the indicator used here.

D4 – seafloor integrity: Since the impact of the herring pelagic fisheries on the seabed is low already, any positive effect on the seafloor of closing areas might be negligible. From a general seafloor perspective, such a measure is expected to be beneficial, in particular if the MPA areas coincide with sensitive habitat for sensitive benthic species. So, in general, management strategy D would be beneficial for the seafloor, but currently this is not captured in the indicator used.

D5 – efficiency: If the MPAs and fish distributions overlapped, then, in general, the establishment of an MPA increases the fishing effort required to catch the TAC, as the fleets would have to fish outside the MPAs. This would reduce the profitability of the fisheries. Moreover, effects on efficiency of management strategy D also depend strongly on potential spill-over effects.

D8 – food security: Any effects on marine protein supply strongly depend on all ecologic and economic effects, in particular assumptions of spill over effects.

E. Protect spawning habitats – close all spawning beds to active anthropogenic impact.



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
E. Protect Spawning Habitats	▨	🟩	🟨	⬜	🟩	🟩	▨	🟩

This scenario considers the protection of herring spawning habitats by closing the spawning habitats for any kind of anthropogenic activity. Note that this scenario does not constitute a fisheries management scenario as such; it is rather a marine spatial planning management action that would have an impact on the herring fisheries. Herring spawning beds are sensitive to anthropogenic impact, such as the extraction of aggregates or development/construction (e.g. of windfarms) on the banks. North Sea herring has yet to re-populate all of the spawning areas it abandoned during the 1970s collapse (e.g. Dogger Bank). Other banks are used sporadically by herring. Management would define all potential spawning habitat for herring in the North Sea and prevent any future construction or developments on those gravel beds, including old spawning areas such as the Dogger Bank, or at a minimum ensure that any development had no impact on herring. This strategy would be aimed at maintaining the potential diversity of spawning habitats, thus providing resilience to environmental or fishing induced pressures.

A crucial question to keep in mind with this scenario is: Where else are these activities going to take place under management strategy E? The need for anthropogenic aggregate extraction does not stop. Hence, management strategy E will automatically lead to spatial changes, a redistribution of activities, i.e. other areas that are being explored for sand or wind farm construction. The effects of this activity displacement could be positive or negative.

E1 – biodiversity: The need for anthropogenic aggregate extraction does not stop. Hence, management strategy E will automatically lead to other areas that are being exploited for sand or wind farm construction. So the crucial question here is: Where else are these activities going to take place under management strategy E? The effects of this displacement of activity could be positive or negative.

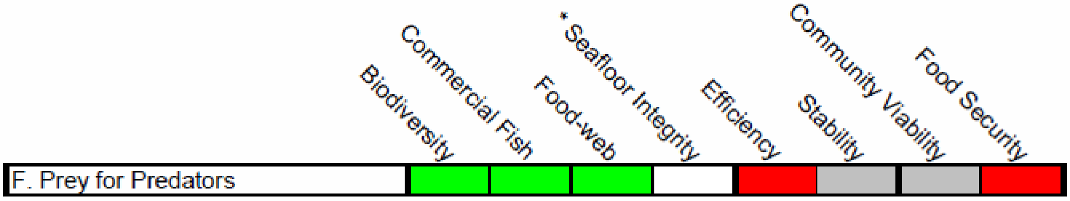
E2, E5, E6, E8: Effects on the herring stock size of management strategy E are expected to be positive, under the crucial assumption that any activity displacement would neither affect herring biology nor herring fisheries negatively. Benefits for the herring stock and in turn herring yields automatically mean a good supply of marine protein, i.e. benefits for food supply.

E3 – foodweb: The large fish indicator (LFI) would not be influenced by management strategies that only impact the herring fisheries. From a general foodweb perspective, such a measure is expected to be beneficial, but it is not captured in the indicator used here.

E4 – seafloor integrity: From a general seafloor perspective, such a measure is expected to be beneficial, in particular if the herring spawning sites coincide with sensitive habitat for sensitive benthic species. So, in general, management strategy E could be beneficial for the seafloor, but currently this is not captured in the indicator used.

E7: Effects on community viability of management strategy E would depend on how well the current catching and processing sectors can deal with any increase in landings.

F. Prey for predators



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
F. Prey for Predators	🟩	🟩	🟩	⬜	🟥	▨	▨	🟥

This scenario considers the management of the fishery such that the herring biomass increases to such an extent that it can be considered a sufficiently abundant prey source for predators. Currently the size of herring populations required to maintain other (potential) predators is unclear. This strategy would consider provision of prey as one of the objectives of a management plan. One option would be incorporating a biomass threshold into the management plan, e.g. the maintenance of top predator populations (sea mammals, elasmobranches and birds). Another approach would be to manage the fishery on the basis of total mortality Z, rather the just fishing mortality F. This would require greater input from multispecies methods into the advisory process. Fishers would probably have second claim to the fish, after the predators had been accounted for.

F1, F2, F3: Management strategy F is expected to have a positive effect on the foodweb and biodiversity descriptors, as the objective is to ensure enough herring as food for higher predators (large fish). The most likely overriding impact of management strategy F is a reduction in fishing effort, which is expected to have a positive effect for the descriptors commercial fish (2), biodiversity (1) and foodweb structure (3).

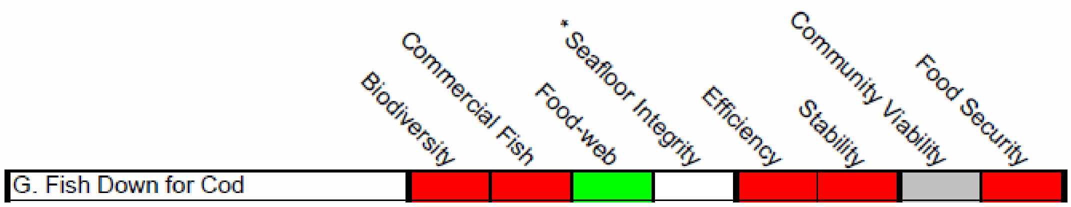
F4 – seafloor integrity: The impact of the herring pelagic fisheries on the seabed is low, because the likelihood of net damage acts as a disincentive to contact with the seabed.

F5, F6: Herring fisheries would probably have second claim to the herring, after the predators had been accounted for, hence, a loss major loss in efficiency but not necessarily stability is expected.

F7: Effects on community viability of management strategy F would depend on how well the current catching and processing sectors can deal with changes in landings.

F8: Putting top predators before the fisheries will result in less secure food. Also producing cheaper larger quantities of herring products is better for food security than higher priced less abundant cod products.

G. Fish down to allow cod to recover



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
G. Fish Down for Cod	🟥	🟥	🟩	⬜	🟥	🟥	▨	🟥

This scenario considers fishing down the herring population to such an extent that it is expected that there will be much lower predation by herring on cod eggs. The bio-manipulation approach is high risk, in that it assumes a direct causal link between the cod productivity and the abundance of herring; herring prey on cod eggs, thus with less herring, cod will recover. The strategy would have the rebuilding of the cod populations as the main objective, and in the short term would lead to great benefits to the herring fisheries in terms of yield, but in the medium term, it might result in another collapse of North Sea herring, with drastic effects on the herring fisheries. The naive simplistic linear thinking, and associated arrogance of this proposed strategy make it very unpalatable, but concepts like this are being considered in other regions. Sand eel and sprat may replace the role of herring so this approach has a high likelihood of failure.

G1, G2, G5, G6: If a management strategy involves depleting one stock to attempt to help another stock (herring verses cod), with a low risk of success this would negatively impact on biodiversity (1) and on the commercial stock (2) that is being fished down. In turn, this would also negatively impact on economic efficiency (5) and stability (6).

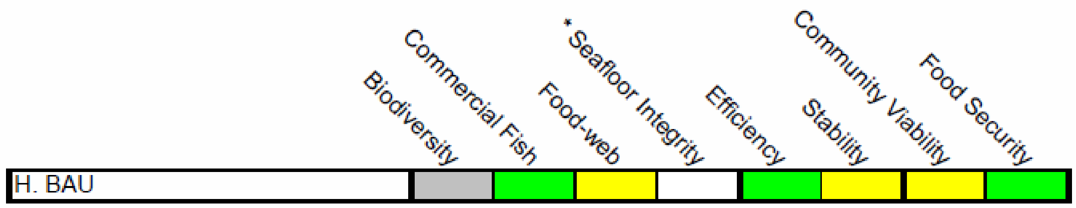
G3: Management strategy G aims at reducing the herring population at the benefit of the cod population, a larger fish than herring. The LFI would therefore increase.

G4: The impact of the herring pelagic fisheries on the seabed is low, because the likelihood of net damage acts as a disincentive to contact with the seabed.

G7 – community viability: It could be argued that this strategy will increase employment as cod fisheries require more labour than herring fisheries per tonne. However, it is unlikely that this approach would actually work, and if it fails more herring fishers would be jobless without the benefit of increased opportunities for cod fishers.

G8: Putting top predators before the fisheries will result in less secure food. Also producing cheaper larger quantities of herring products is better for food security than higher priced less abundant cod products.

H. No change in the current management approach



	Biodiversity	Commercial Fish	Food-web	*Seafloor Integrity	Efficiency	Stability	Community Viability	Food Security
H. BAU	▨	🟩	🟨	⬜	🟩	🟨	🟨	🟩

This scenario considers a continuation of the current fisheries management sticking to the existing management plan.

The existing management plan (or a slightly amended plan) should with time lead to a greater understanding of fishing at F_{MSY}. Theoretically the biomass of herring in the North Sea should increase. The fishing on the juveniles will continue to be restrained by the bycatch ceiling. Any increase in productivity of the stock (recruitment) to similar rates as the 1990s will lead to an increase in biomass and hopefully to a further recolonisation of abandoned spawning grounds (such as Dogger Bank). In the past the North Sea has supported approximately 4.5 million tonnes of mature herring. The last time herring was this abundant, Bluefin tuna was also present and supported a local fishery in the North Sea (Dickey-Collas *et al.*, 2010a).

H1 – biodiversity: Biodiversity may include phenotypic diversity and sub-stock structure. It is not probable that – but unknown whether –the current management plan will impact on this. It might be worth introducing a threat indicator for vulnerable species: How many species are decreasing over a period of time?

H2, H5, H6: The measurement baseline is the current status, so management under the current management plan is expected to improve the current status.

H3 - food web: As herring are not included in the calculation of the LFI, the large fish indicator (LFI) is not be influenced by the current management strategy.

H4 – seafloor integrity: The impact of the herring pelagic fisheries on the seabed is low, because the likelihood of net damage acts as a disincentive to contact with the seabed.

H7 – community viability: The current management plan does not include any employment objectives.

H8 – food security: The measurement baseline is the current status, so management under the current management plan is expected to improve the status quo. Producing cheap, large quantities of herring products is good for food security.

9.4. Annex D: The North Sea beam trawl fishery

The dominant demersal fishery in the North Sea targeting flatfish in the beam trawl fishery. The beam trawl derives its name from the beam supported by two shoes at either end of the trawl. The net is attached to the beam, shoes and ground rope, thus the mouth of the net is held open regardless of the speed at which it is towed. Shoes of the beam glide across the surface of the seabed and prevent the beam from sinking into soft substrata. Beam trawls are deployed with tickler chains to disturb or dig out the target species. The larger beam trawls can be fitted with more than 20 tickler chains and penetrate soft sands to a depth of more than 8 cm. Beam trawls with standard tickler chains tend to be fished over clean ground as on rougher grounds the net would soon fill with rocks. To be able to fish on rougher ground chain mats are added, along with a flip up gear fitted to the ground rope.

In the North Sea, two principal métiers are usually distinguished: “large vessels” with an engine power of 221 kW or more, and “eurocutters”, with an engine power <221 kW and a maximum length of 24 metres. The large vessels deploy two 12m beam trawls and are not allowed to fish inside the 12 mile coastal zone or the “plaice box”, whereas eurocutters deploy two 4.5m beam trawls and are allowed to fish inside those areas (Piet *et al.* 2007; Rijnsdorp *et al.* 2008).

This case study focuses on the beam trawl fisheries targeting sole and plaice. The distributions of these two stocks differ, with plaice being generally more widespread while sole is located primarily in the southern North Sea. Beam trawlers centred on the southern North Sea using mesh sizes of 80-89mm take the majority of the catches of plaice and sole and are much more important than other gear categories in terms of both weights and numbers removed (STECF 2008c). However, in terms of efficiency, the large beam trawls with a mesh size >100mm are most efficient in capturing plaice (**Error! Reference source not found.**). For the capture of sole the most efficient gears are trammel nets and gillnets followed by the beam trawl with a mesh size of 80-89mm fishing in the Eastern Channel (**Error! Reference source not found.**) (STECF 2008c).

Table 3.1.1: Top 10 most efficient gear categories for catching plaice. Ranking is based on the CPUE in 2007. Table modified from (STECF 2008c), which categorized the gears even further based on special condition specified in annex IIA to Council Reg. 40/2008.

Rank	Gear	Mesh size (mm)	Area	CPUE 2007
1	Beam trawl	>120	North Sea, Skagerrak	2038
2	Beam trawl	>120	North Sea, Skagerrak	1968
3	Beam trawl	100-120	North Sea, Skagerrak	1853
4	Beam trawl	100-120	North Sea, Skagerrak	1634
5	Beam trawl	100-120	North Sea, Skagerrak	1631
6	Gillnets	110-150	North Sea, Skagerrak, Eastern Channel	1512
7	Beam trawl	>120	North Sea, Skagerrak	1468
8	Trawls	100-120	North Sea, Skagerrak, Eastern Channel	1448
9	Beam trawl	80-89	North Sea, Skagerrak	1202

10	Trawls	100-120	North Sea, Skagerrak, Eastern Channel	1139

Table 3.1.2: Top 10 most efficient gear categories for catch sole. Ranking is based on the CPUE in 2007. Table modified from (STECF 2008c), which categorized the gears even further based on special condition specified in annex IIA to Council Reg. 40/2008.

Rank	Gear	Mesh size (mm)	Area	CPUE 2007
1	Trammel net		Eastern Channel	854
2	Gillnets	<110	North Sea, Skagerrak, Eastern Channel	830
3	Beam trawl	80-89	Eastern Channel	656
4	Trammel net		North Sea, Skagerrak	654
5	Beam trawl	80-89	North Sea, Skagerrak	352
6	Trawls	70-90	Skagerrak	185
7	Trammel net		North Sea, Skagerrak, Eastern Channel	142
7	Beam trawl	100-120	Eastern Channel	142
9	Gillnets	110-150	North Sea, Skagerrak, Eastern Channel	125
10	Trawls	70-90	North Sea, Skagerrak, Eastern Channel	118

Other species landed by the beam trawl are flatfish species e.g. turbot (*Psetta maxima*), brill (*Scophthalmus rhombus*), dab (*Limanda limanda*) and lemon sole (*Microstomus kitt*); Roundfish species e.g. cod, haddock, whiting, monkfish (*Lophius piscatorius*), tub gurnard (*Trigla lucerna*) and seabass (*Dicentrarchus labrax*); Skates and rays e.g. thornback ray (*Raja clavata*); Molluscs e.g. common whelk (*Buccinum undatum*) and Crabs e.g. edible crab (*Cancer pagurus*). Besides the landed species, a part of the catch is discarded. The discards consist of undersized caught fish, high-graded fish (can be landed, but are discarded because of low value or low TAC), and non-commercial fish and benthos species. The top ten discarded species in the beam trawl in the North Sea are presented in **Error! Reference source not found.** (STECF 2008a). Undersized plaice were estimated to make up 54% of weight and 82% of numbers in the Dutch 80-89mm beam trawl, for sole this was 23% to 29% in numbers and 10% to 13% in weight (van Helmond & van Overzee 2008).

Table 3.1.3: Top ten discarded species by country for the beam trawl in weight and numbers based on data reported by (STECF 2008a).

UK (n=12)		**Netherlands (n=28)**	**Belgium (n=18)**	**Germany (n= 15)**	
Weight	Numbers	Weight & numbers	Weight	Weight	Number
Plaice	Plaice	Dab	Plaice	Plaice	Dab
Dab	Dab	Plaice	Cod	Dab	Plaice
Sole	Sole	Scaldfish	Sole	Red starfish	Scaldfish
Lemon sole	Lemon sole	Solenette	Ray sp.	Whiting	Whiting
Cod	Common cuttlefish	Dragonet	Lemon sole	Gurnards	Gurnards
Common cuttlefish	Edible crab	Grey gurnard	Dab	Solenette	Sole
Haddock	Great Atlantic scallop	whiting	Brill	Cod	Cod
Thornback ray	Whiting	Sole	Turbot	Sole	Dragonet
Turbot	Thornback ray	Tub gurnard	Gurnards sp.	Dragonet	European flounder
Brill	Haddock	Sprat	Whiting	Starry ray	Tub gurnard

The beam trawl fishery in the North Sea has been dominated by the Dutch fleet but this has been decreasing recently. For example in January 2008, 23 Dutch trawl vessels were decommissioned. However, in some cases, reflagging vessels to other countries has partly compensated these reductions (ICES 2008). Approximately 85% of plaice landings in the UK (England and Scotland) are landed by Dutch vessels fishing on the UK register. The decrease in fleet size may have been partially compensated by slight increases in the technical efficiency of vessels. In the Dutch beam trawl fleet indications of an increase in technical efficiency of around 1.65% per year was found over the period 1990 – 2004 (Rijnsdorp *et al.* 2006). The beam trawl effort has spread out from the coastal and offshore areas of the southern North Sea, into coastal areas of Germany and Denmark and northern offshore areas of the Doggerbank and central North Sea since the 1970s, but effort was concentrated again in more southern offshore fishing areas in the 1990s. These changes in effort allocation reflect a change in targeting from sole to plaice in the 1970s, and back to sole during the 1990s (Rijnsdorp *et al.* 2008).

The direct economic value of the North Sea beam trawl fleets in 2006 is represented in **Error! Reference source not found.**. (STECF 2008b). In terms of total gross national product the beam trawl fisheries are not very important. However, fishing is one of the most important traditional industries around the North Sea and is vital to local economies. The high price of fuel and the relatively low biomass of sole jeopardize the survival of the large beam trawl fleet (Rijnsdorp *et al.* 2008). A number of vessels have already switched to other fishing methods such as 'twinrigging' (12 vessels) and 'snurrevaed' or 'fly-shooting' (5 vessels). Also of interest are technical developments, mainly to reduce fuel consumption, including pulse trawling (Van Marlen *et al.* 2006) and the use of sumwings (www.sumwing.nl). The prospects of the fleet are further threatened by the impacts of this fishery on the ecosystem. Because beam trawling has a high potential to cause collateral damage to other components of marine ecosystems, including fish and benthic invertebrate communities as well as seabed habitat, it has long been the focus of considerable scientific attention. Due to the impacts on the ecosystem, this fleet is in the line of fire of various NGO’s: Greenpeace describes beam trawling as “one of the most destructive forms of bottom trawling” and WWF says: “Bottom trawling is described as the most destructive of all fishing practices”.

Table 3.1.4: Total number of vessel, the value of the landings and the employment of the beam trawl fleet in 2006. The fishery by the beam trawl fleet is not exclusively based in the North Sea (STECF 2008b).

Country	Gear	Number of vessels	value of landings (mEuro)	employment (FTE)
Belgium	<24m.	49	18.86	178
	24-40m	53	69.15	352
Germany	<24m.	247	39.3	
Netherlands	<24m.	188	47.3	502
	24-40m.	42	36.1	210
	>40	84	139.2	525
UK	<24m.	60	6.4	109
	24-40m.	52	26.9	281
	>40	15	15.2	84
Denmark	<24m.	29	10	59
	24-40m.	6	7	31
Total		825	415.41	2331

9.5. Annex E: Management tools beam trawl fishery

This evaluation of current and historic management measures affecting the North Sea mix flatfish beam trawl fishery is designed to answer a list of questions on a selection of management measures. The main goal is to learn from the past to improve or fine-tune management tools that will be part of future operational Fisheries Ecosystem Plans (FEPs).

The available measures to evaluate differ by regional case study, but need to be specifications of the tools listed in WP3 (WP3, table 2.3) and still need to be relevant for future FEPs. Each measure is evaluated along the same lines. This basic framework first gives a description of the measures taken and the pressure it was supposed to reduce and if possible its goals that were set to be reached. This is followed by how it was implemented and how it was perceived by the stakeholders at that time. The evaluation questions that will be answered are:

- Did the measure succeed in reducing the anticipated pressure?
- How was this reduction measured (and evaluated)?
- Which Pressure indicators changed by the measure?
- If not: What was the cause? For example, was there a governance issue? Possible response indicators?
- Did this result in required State?
- If not: what was the cause?
- Which State indicators were influenced by the implementation?
- Finally: what are the lessons / best practice learned?
- What guidance can be given for implementation?

These evaluations are based on available literature on the specific measure and where possible on minor analysis on the subject. Lack of information will be the first indications for lessons that need to be learned.

TAC

Management Tool

TAC (total allowable catch) regulation is a fundamental regulatory tool in the Common Fisheries Policy. It is an output measure that sets the upper limit for the total catches of each commercial species, by region or stock.

The total catch is divided between each member state according to specific distribution formula, and it is then up to each member state to perform a further distribution on vessel types, gear types or according to other criteria.

Current TACs for the North Sea flatfish stock are set on the basis of landings and do not include discarded quantities.

History

TAC management was introduced in 1975 for the main commercial species in the North Sea and was extended in later years to include more species. For most of the species the TACs are set each year by the EU based on scientific advice by ICES.

This scientific process is based on multiple input data sources: scientific surveys, landing and catch statistics and discard information. There is considerable uncertainty caused by the availability and quality of the input data, as well as the capacity of the methodology generally used, e.g. virtual population analysis, to assess the status of the stocks. This undermines the credibility of the advice. The uncertainties are incorporated in the advice through the implementation of the precautionary approach, in which reference points are used to take account of the uncertainties in the assessment process.

The political process considers the ICES advice and sets the official TACs. Based on the most comprehensive set of data on the management process of 125 stocks for which ICES provided advice over the period 1987–2006, it was shown that for just 8% of the stocks, the official TAC equalled the scientific advice, and that in recent years the official TAC overshot scientific advice by >50%. Compliance levels appear to be reflected in the percentage of stocks for which landings exceeded the official TAC, decreasing from ~8 to 2% (Piet *et al.* 2010). For the mixed beam trawl target species plaice, F increased by 25% from 1983 (the introduction of the CFP) to 1995, for sole by 20%. In this respect, all attempts to constrain fishing mortality by TACs appear to have failed (Daan 1997). Later analyses show that plaice TAC and quota established have not always respected scientific recommendations, and in 2004 and 2005 the quotas were exceeded by catches. Also for sole the recommended TACs were not respected and they were exceeded prior to 2005 ((Villasante *et al.* 2011), **Error! Reference source not found.**).

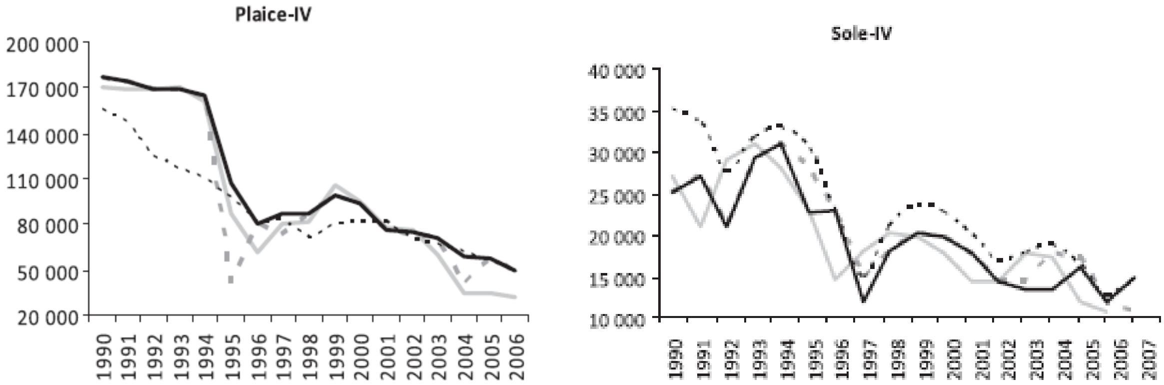


Figure 3.1.1: TAC of plaice and sole in the North Sea, Solid black line official TAC, solid grey line recommended TAC by ICES, dashed grey Proposed TAC by the EC and dashed black line Landings (Villasante *et al.* 2011).

In recent years, since 11 June 2007, a multiannual management plan for fisheries exploiting stocks of plaice and sole in the North Sea became active, that limited changes in the TAC between years. The objective of the management plan shall be attained by 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.

Objective

The objective of TAC measures is to control the amount of fish above the MLS that is caught in order to protect the stocks from collapsing. This is done by using different reference levels, a limit reference level and a precautionary reference level. In the latest advices also MSY reference levels are used. TAC is reduced when the SSB becomes near or below the precautionary level or when fishing mortality is above Fpa, to prevent SSB becoming near or below the limit reference level.

Pressure

The pressure managed is the fishing mortality (F) on the SSB of the target stocks. As an addition it potentially also reduces the F on other species and on the discard fraction.

Effect

The TAC measures over time controlled the biomass of the target species plaice and sole around the reference level (Bpa), with positive exceptions due to good yearclasses (**Error! Reference source not found.**). This is consistent with managers commonly treating Bpa as a target, despite frequent ICES admonitions not to (Piet & Rice 2004).

The fishing mortality on plaice following the introduction of TAC control has been above the reference point F_{pa} and even above F_{lim}. The SSB had been below B_{pa} for several years. However, the most recent assessments of this stock show F to be well below the reference levels and SSB is currently at its highest observed level. Similar trends have been observed for sole, where the SBB has been below B_{lim} in a couple of years. In recent years sole too has seen a decrease in F and an increase in SSB. The most recent assessments of these two stocks show that for the last two consecutive years both have been within safe biological limits (**Error! Reference source not found.**).

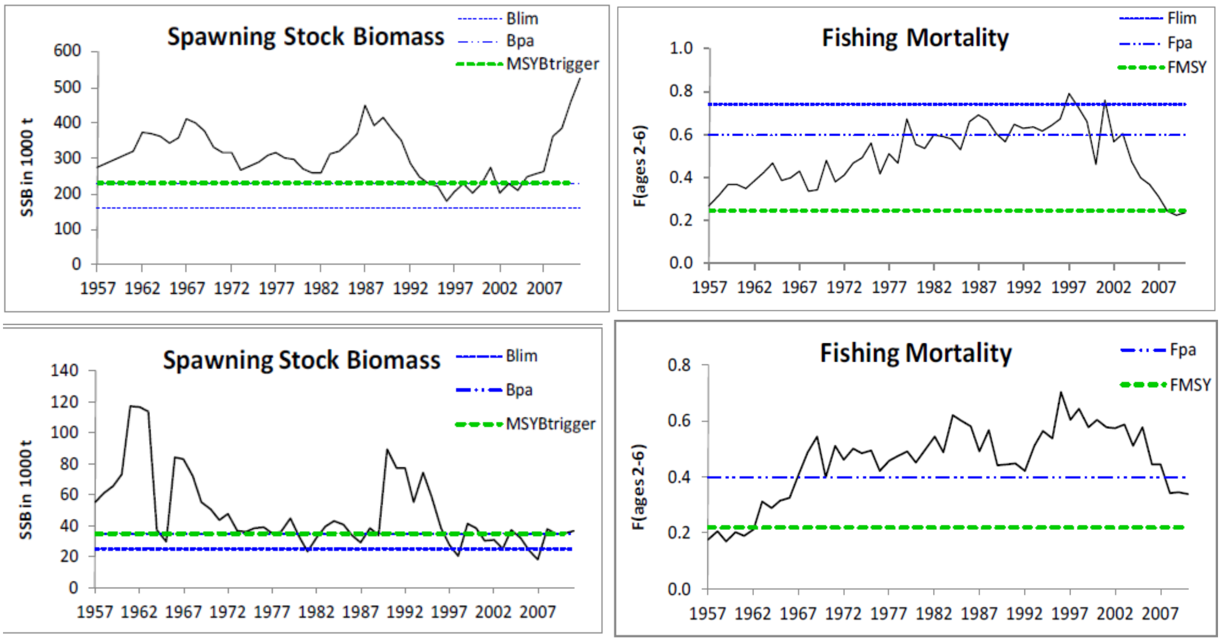


Figure 3.1.2: SSB and F of plaice (above) and sole (below) over the years, included the different reference levels (ICES 2011).

An effect of yearly changes in TAC is that fishermen are uncertain about next year's catch opportunities. Reducing the economic stability of the sector. Furthermore, setting the TAC, especially when large changes were necessary, causes discontent within the fisheries sector. From an industry perspective, such variations are undesirable because they disrupt market chains and result eventually in less profitability. Nor does arguing each year for enough quota improve the attractiveness of the sector. This has improved with the introduction of multiannual management plans introduced in 2007 (Council Regulation (EC) No 676/2007), which allow stability in TACs by restricting interannual variations and provide a predictable basis by which future TACs will be set. An ex-ante evaluation of the multiannual management plan shows that the plan is very likely to be precautionary but it is more difficult to assess whether it achieves the goals of long term yields and sustained healthy populations. This is essentially a question over whether the F targets specified for the two stocks are reasonable and whether in practice they can be achieved simultaneously (Miller & Poos 2010).

Lessons learned/guidance for implementation

An overview of reasons of the "failure" of TAC management as given by Daan (1997):

A TAC system may not be an appropriate tool to control fishing mortality, because it does not control catches but only landings. In a mixed multispecies fishery, the problem of discarding can only become worse.

Any management system essentially requires the basic support from the fishery, because there are so many ways to circumvent the regulations that enforcement is virtually impossible.

Non-compliance has the important effect that the quality of catch statistics entering the assessments deteriorates. Bias in catch statistics critically influences the quality of forecasts and thus the TAC advice.

It would seem inappropriate that at the very end of the procedure when the EC has put up a balanced proposal for the new TACs, the Council of Ministers takes the final decisions based on political lobbies and negotiations rather than on commitment to a well-defined policy.

Sincere doubts could occur about applying TACs to implement drastic changes in fishing effort from one year to the other or even gradual changes over a longer period, because such cuts have a direct bearing on the distribution of wealth within the society (Daan 1997).

Regarding Daan's first point, TAC limitations lead to over-quota discarding and/or high-grading. The first especially occurs in a mixed fishery if the quota for one of the species is reached while there is still quota for the others species. This does not reduce the F on the first species as these are just discarded. It may also lead to high-grading to land only the most valuable catch (see the next section). The TAC management neither has an incentive for reducing/limiting discards, as only the amount of landings are monitored. TAC management on its own is unlikely to lead to a reduction of F, it needs to be accompanied by other measures.

Area closure

Probably the best known example of an area closure affecting the flatfish beam trawl fishery is the implementation of the ‘plaice box’ (PB).

Management tool

The ‘plaice box’ (PB) is a technical fisheries management measure where an area in the south-eastern North Sea along the Dutch, German and Danish coast, is closed for trawl fisheries with vessels bigger than 221 kW for the conservation of plaice and other species.

History

The plaice box is a technical fisheries management measure where an area in the south-eastern North Sea along the Dutch, German and Danish coast, is closed for trawl fisheries with vessels bigger than 221 kW for the conservation of plaice and other species. It was established by the EU (Council Regulation EEC No. 4193/88) in 1989 to reduce the discarding of undersized plaice (*Pleuronectes platessa*) and thereby to enhance the recruitment to the fishery. At its establishment, it was decided that the ‘box’ should be active for the 2nd and 3rd quarter (1 April to 30 September) only, but in 1994 the plaice box regulation was extended to the 4th quarter. Since 1995, the Plaice Box has been closed year round.

The PB is closed for beam and otter trawlers exceeding 300hp (221kW) and no fishing inside the ‘‘box’’ is allowed within 12 miles of the coast by vessels exceeding 8 m overall using beam and otter trawls. Fishing by other vessels is permitted provided that they are:

– on an authorized list and their engine power does not exceed 300hp, even if fishing with beam trawls;

– not on a list but fishing for shrimp;

– not on a list but fishing with other trawls using 100 mm mesh, even if engine power exceeds 300 hp, provided catches of plaice and sole which exceed 5% by weight of the total catch on board were discarded immediately.

The PB was intended to cover the major distribution area of juveniles of the main commercial demersal fish species such as plaice, sole and, to a lesser extent, cod. However, for specific age-groups of other, non-target, species occurring in the PB a reduction of fishing mortality was expected as well. In contrast an increase in mortality of age groups outside the PB was expected as a result of the displacement of the fleets to them (Piet & Rijnsdorp 1998).

Over the years some evaluations of the plaice box have been performed. ICES has performed an evaluation on the effectiveness on the plaice box in 1994 (ICES 1994). In 2004, an assessment of the ecological effects in the plaice box was performed (Grift *et al.* 2004). And in 2010, IMARES has performed an evaluation of the effectiveness of the plaice box (Beare *et al.* 2010). This was done by an inventory of existing information and collecting new material. Different data (logbook data, VMS data, discarding data (observer trips), data from BTS (beam trawl survey) and SNS (sole net survey)) were used to construct patterns of landings and effort, and help to identify fine scale patterns in effort and discarding.

Objective

The implementation of the plaice box was expected to increase yield, recruitment and spawning stock biomass (SSB) (Grift *et al.* 2004; Beare *et al.* 2010) and protect undersized plaice from discarding. The expected gain from the plaice box was an increase of survival of each cohort of 35%, if closed all year. The closure was not predicted to produce significant changes in yield per recruit and biomass per recruit (ICES 1994).

Pressure

The pressure managed, is the fishing mortality (F) and total fishing effort in the main nursery area of plaice and some other fish species, and the number of discards. By closing the area, the intention was to reduce this pressure in the PB; the area where the juvenile plaice were concentrated and most vulnerable for becoming caught when still undersized.

Fishing effort and mortality

The plaice box has been effective in closing the area to fishing by large beam trawlers (ICES 1994). After complete closure of the box the fishing effort decreased to 23% of the pre-box levels (see **Error! Reference source not found.**) (Grift *et al.* 2004). Dutch logbook data showed that total fishing effort by beam trawlers inside the PB was even further reduced to 14% of the pre-box levels (Beare *et al.* 2010).

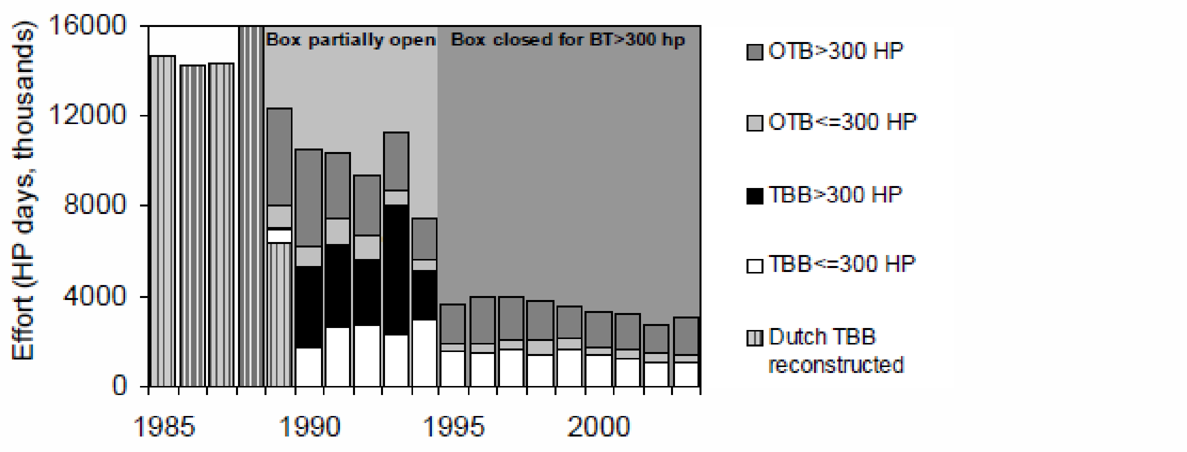


Figure 3.3.1. Total effort (HP days, thousands) of beam trawlers (TBB) and otter trawlers (OTB) in the Plaice Box. Data from Germany, Denmark, England and the Netherlands combined. The effeort in the years 1985-1989 represent data of the Dutch beam trawl fleet only, that was reconstructed. Total effort before 1989 was thus higher than presented here because data from beam trawlers of other countries and otter trawlers of all countries are lacking from that period. From Grift et al. (2004).

The PB has led to changes in the pattern of fishing with a significant increase in activity by vessels permitted to fish in the box (see **Error! Reference source not found.**). This factor has likely reduced the expected gains (35% increase survival for each cohort) from the box (ICES 1994). Beare et al. found that indeed the plaice box is still an important fishing area for the fleet of smaller vessels, mostly shrimp and mixed flatfish fisheries. Shrimpers are concentrated within the 12 nm zone, and the influence of the regulation of the PB is restricted to the area outside the 12 nm zone (Beare *et al.* 2010).

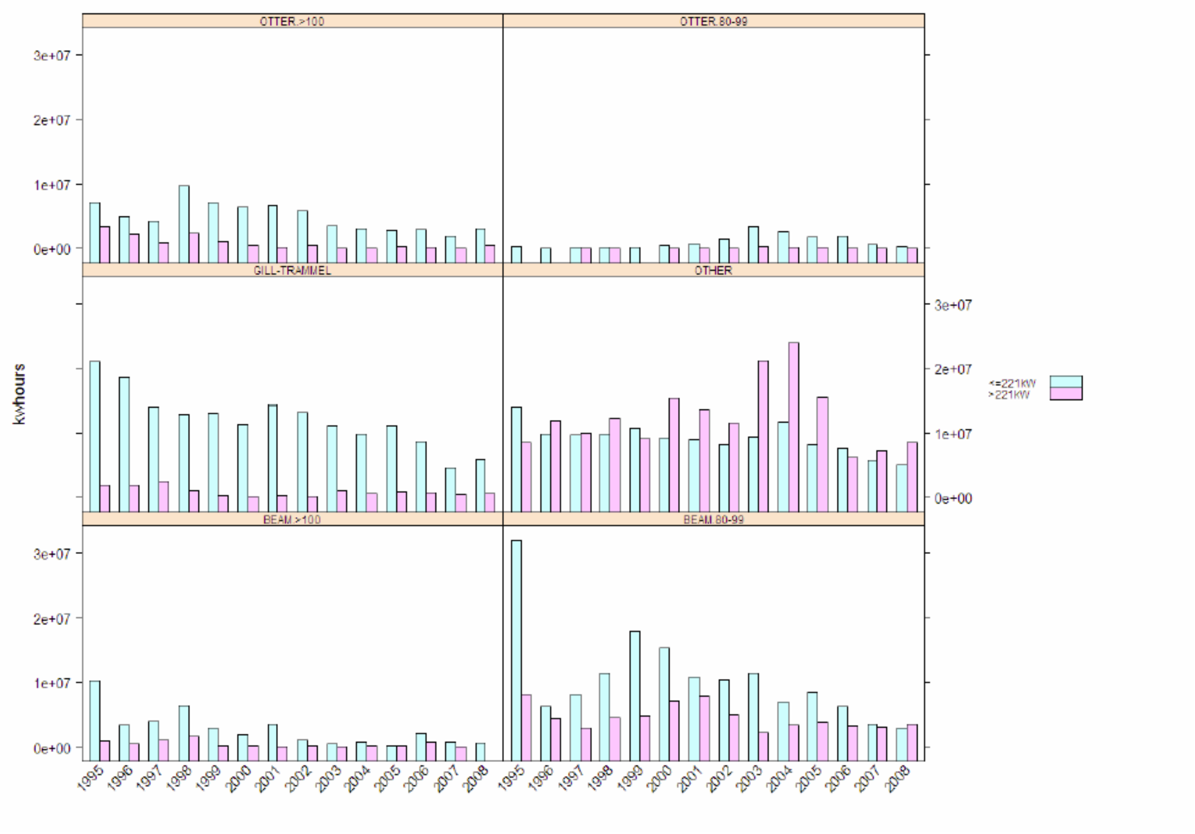


Figure 3.1.4. Total fishing effort (kWhours) inside the PB by metier between 1995 and 2008. Note: the shrimp fleet is excluded. (From Beare et al. 2010)

In the study of ICES (1994), the results from VPA and demersal fish surveys did not indicate a reduction in fishing mortality on the youngest age groups. Grift (Grift *et al.* 2004) indeed found that fishing mortality increased from 1970 up to a level of 0.65 in 1997, but after 1997 it sharply declined to 0.42 in 2001.

Discard mortality

Due to the shift in distribution of juvenile plaice to offshore areas outside the Plaice Box, they remained vulnerable to discarding in spite of the presence of the plaice box (Beare et al. 2010). However, it is impossible to state whether discard levels would have been higher or lower without the establishment of the Plaice Box because comparisons cannot be made (Röckmann *et al.* 2011). The percentage of plaice discards in the beam trawl fisheries increased inside and outside the box. The difference in discard percentages inside and outside the box is much smaller than in the period before the box (see **Error! Reference source not found.**.1.3) (Grift *et al.* 2004). The Plaice Box has not proven to have effectively reduced discarding of undersized target species (Röckmann *et al.* 2011).

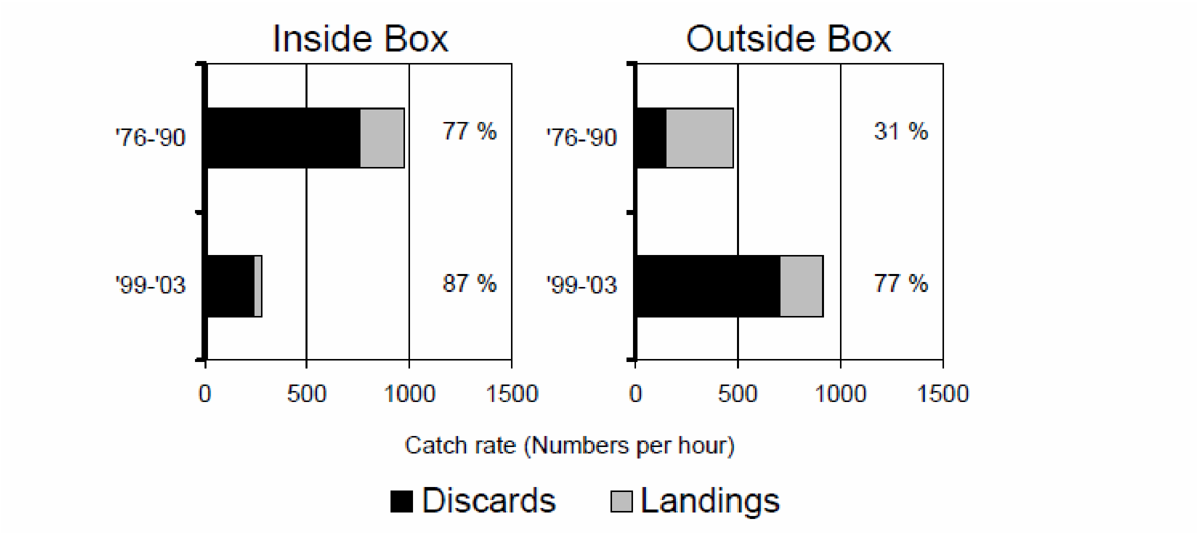


Figure 5.1.3. Catch rates of discards and landings in the Dutch beam trawl fleet in numbers per hour fished. The percentages are the percentages of the total catch that was discarded (van Keeken *et al.* 2004).

Effect

The state indicators were plaice abundance, spawning stock biomass (SSB) and yield.

Even though the plaice box resulted in a reduction in beam trawl fishing effort of 86% of the pre-box levels, the management goals for the plaice within the plaice box have not been achieved. Plaice stock biomass in the North Sea decreased (see **Error! Reference source not found.** and **Error! Reference source not found.**), plaice abundance within the PB is lower than in 1989 (see **Error! Reference source not found.**) and the proportion of undersized plaice to the marketable size plaice is still higher in the PB than outside (resulting in a higher discard rate in the PB) (Beare *et al.* 2010).

The evaluation of the PB by Grift *et al.* in 2004 concluded that total recruitment and consecutively spawning stock biomass and yield decreased since the PB was installed. Since the box was established in 1989, recruitment has shown a negative overall trend, and spawning stock biomass and total yield have decreased by 60%.

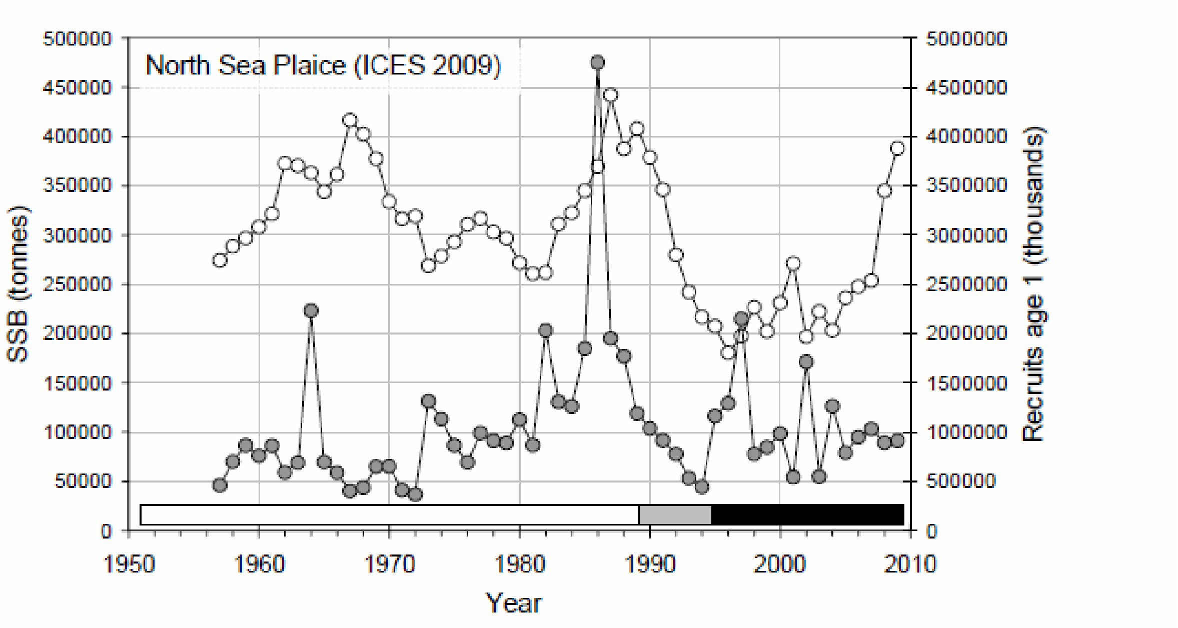


Figure 3.1.6. Spawning stock biomass (SSB, open markers) and recruitment of age-1 fish (grey markers) for North Sea plaice. The bars above the x-axis depict distinct implementation-phases of the plaice box: white bar = no plaice box; grey bar = plaice box closed to trawlers >300 hp for part of the year (since 1989); black bar = plaice box closed for these trawlers during the whole year (since 1995) (Beare *et al.* 2010).

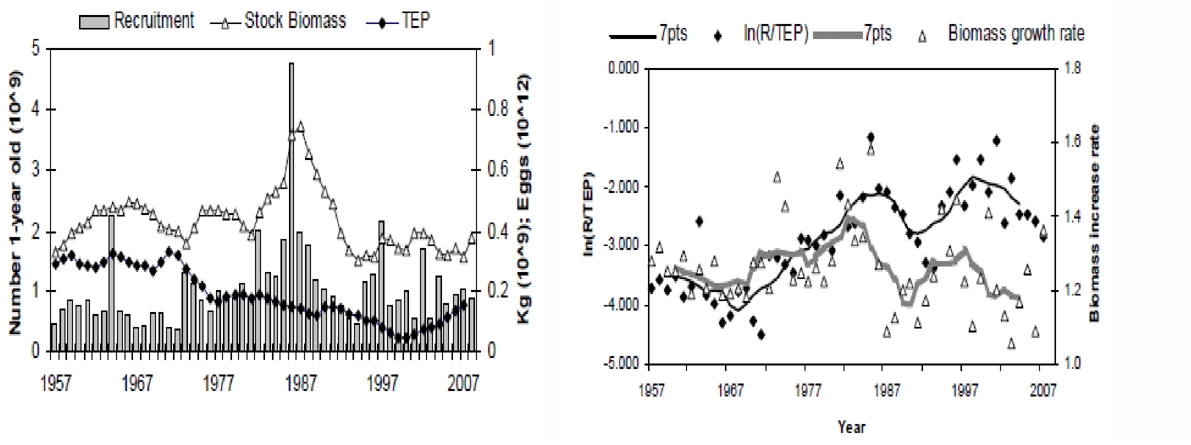


Figure 3.1.7. Population dynamics of North Sea plaice since 1950 showing the number of 1-year old recruits (10^9), stock biomass (10^9 kg) and total egg production (TEP (10^{12}) and the index of mortality (♦ loge(recruits.TEP-1)) of pre-recruits and the rate of biomass increase (Δ). The lines show the 7 years running mean (Beare *et al.* 2010).

Figure 3.1.8. BTS survey data 1987-2008. Abundance (log numbers caught per hour) of age 0-4 plaice in four areas: in-in = inside the PB inside 12 nm limit; in-out = inside PB outside 12 nm limit; out-in = outside PB but inside 12 nm limit and out-out = outside both PB and 12 nm limit (Beare *et al.* 2010).

Plaice abundance

Surveys results showed that immediately after the partial closure of the box (1989-91) the relative abundance of marketable plaice had increased compared to pre-box years (ICES 1994). The abundance of commercial fish within the marketable size-range of 25-40 cm increased when fishing effort was reduced (Piet & Rijnsdorp 1998). The relative abundance of under-sized age groups had also steadily increased since 1989 (ICES 1994). Recruitment increased because of a better survival of undersized plaice.

It was found that the relative abundance of older fish (>3 years old) increased in comparison to the juveniles in the PB (ICES 1994; Piet & Rijnsdorp 1998). This could be due to a reduction in marketable fish mortality caused by the reduction in fishing mortality, but also because the spatial distribution of juvenile plaice changed.

However in 2004, it was concluded that there was no direct evidence that the abundance of plaice had increased either in terms of recruitment, spawning stock biomass or yield (Grift *et al.* 2004), and later is was found that the abundance of both undersized and marketable plaice decreased and showed the same pattern inside and outside the box (Beare *et al.* 2010) see **Error! Reference source not found.** and **Error! Reference source not found.**).

Spatial distribution

There is clear evidence that the spatial distribution of juvenile plaice has changed ((Grift *et al.* 2004) see **Error! Reference source not found.** and **Error! Reference source not found.**). The change was clearest in 1-group plaice that moved to deeper areas further offshore (see **Error! Reference source not found.**). The growth rate of plaice decreased around 1980 after which it stabilized until recent years.

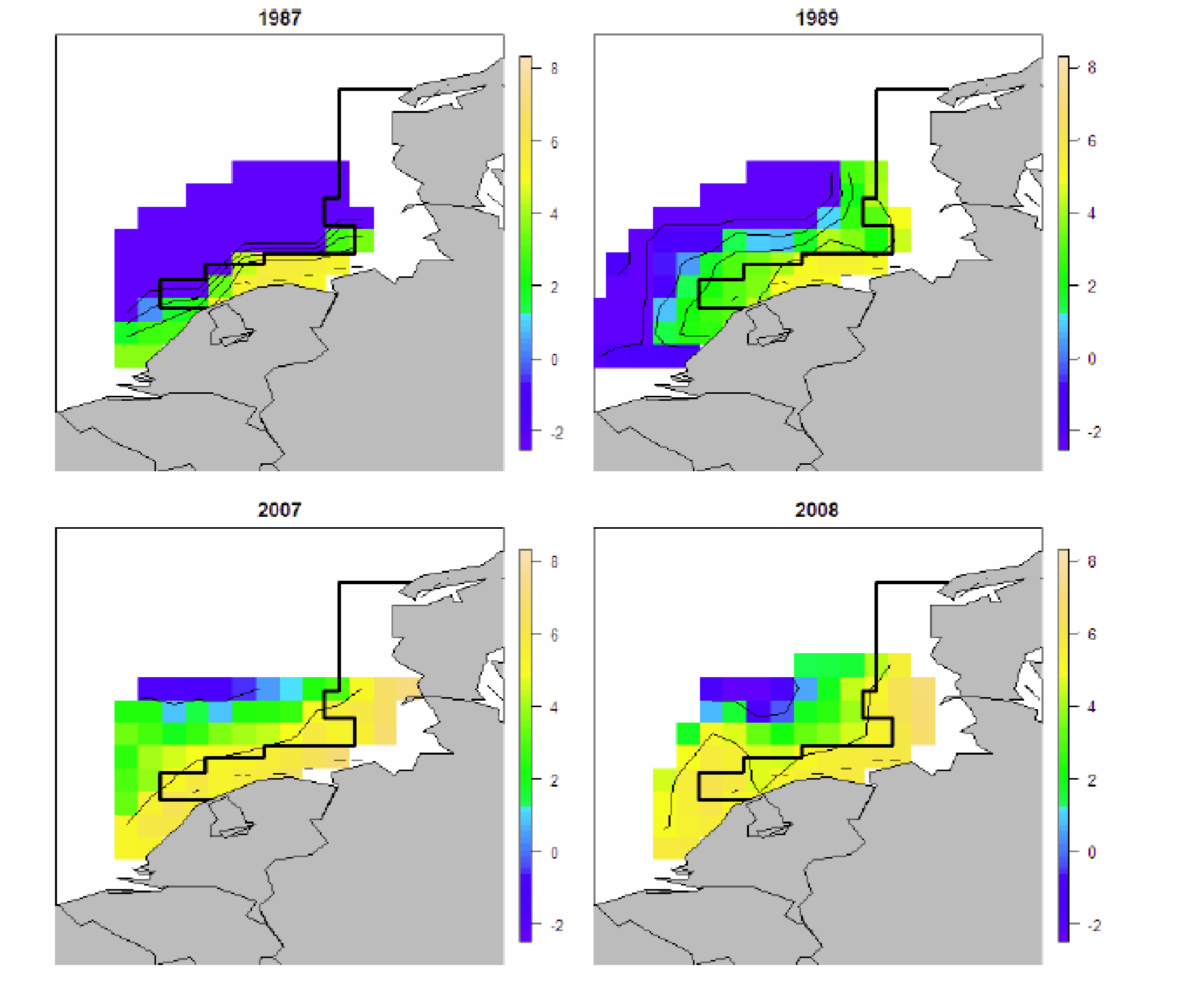


Figure 3.1.9. Spatial distribution of Age 0 plaice [log(noshr-1)] recorded during BTS ISIS surveys (quarter 3) in 1987, 1988, 2007 and 2008 (Beare *et al.* 2010).

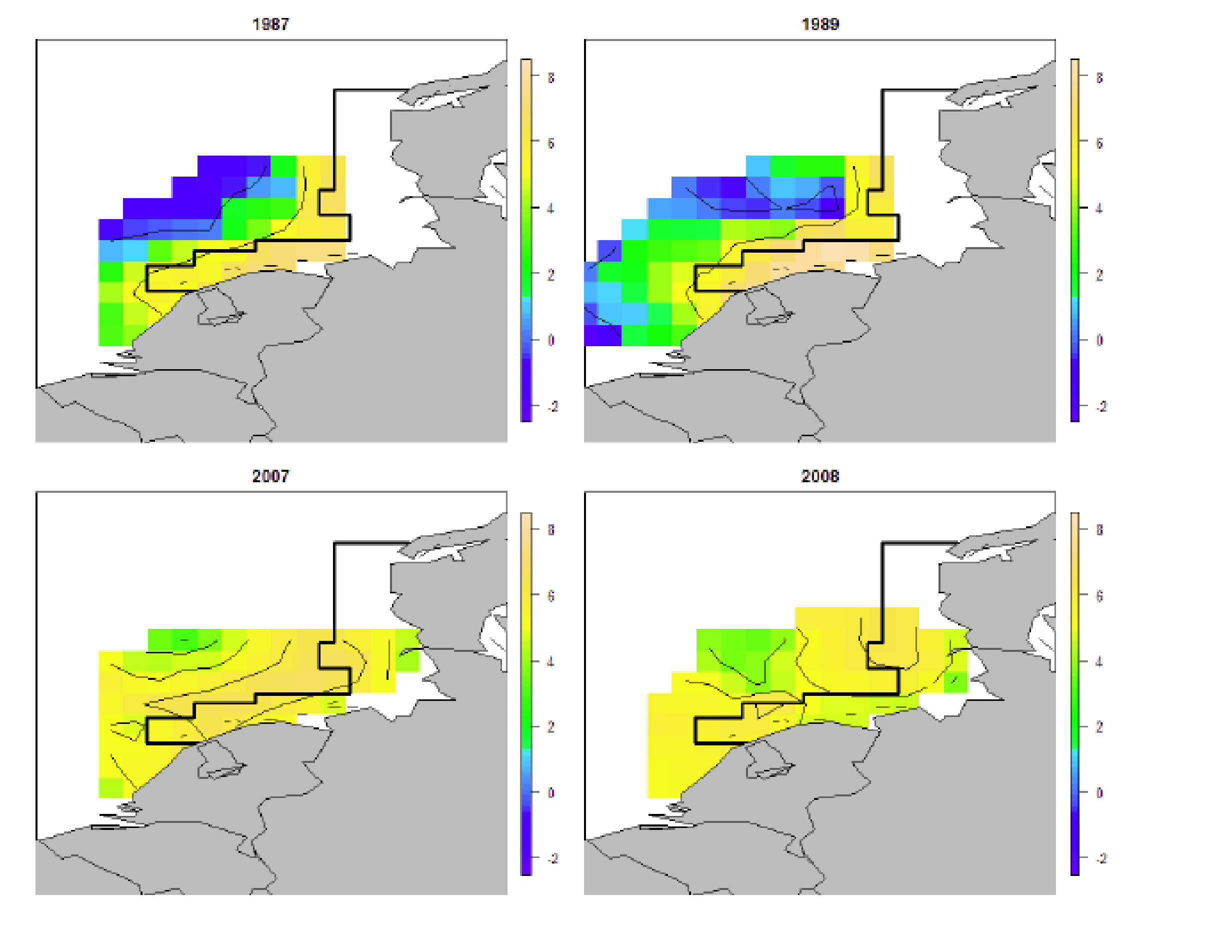


Figure 3.1.10. Spatial distribution of Age 1 plaice [log(noshr-1)] recorded during BTS ISIS surveys (quarter 3) in 1987, 1988, 2007 and 2008 (Beare *et al.* 2010).

The change in distribution of undersized plaice is likely due to a behavioural response to higher temperatures in combination with a decrease in macrobenthos (Beare *et al.* 2010). The water temperature in and around the box has increased by 0.5-1 degree Celsius, and nutrient concentrations have decreased between the early 1980's and early 1990's (Grift *et al.* 2004). Piet & Rijnsdorp(Piet & Rijnsdorp 1998) found an increase of species richness for the first few years after closure of the box. This, however, was concluded to be due to the influx of southerly species, not the result of the management measure.

The fishermen, however, hypothesize that fish move out of the PB because the reduction in bottom trawling leads to a reduction of food availability for the plaice, which prey on opportunistic benthos-species (Verweij & van Densen 2010). Ergo, fish follow the fishery.

According to Grift 2004 the observed trends do not provide clear support for the hypothesis of decreased food abundance as a result of the PB: 1) contemporary literature shows that there is no positive effect of bottom trawling on ecosystem productivity; 2) the decrease in growth rates was initiated before the establishment of the pb; the temporal trends in growth rate are not correlated with the trends in beam trawling effort and 3) similar trends in the abundance and spatial patterns of plaice were shown for areas outside the box, such as the Wadden Sea and the Dutch coastal zone south of the box (Grift *et al.* 2004). The evaluation of Beare et al. (Beare *et al.* 2010) concludes that the reduced effect of the PB is more likely due to changes in environment (i.e. behavioural response to higher temperatures in combination with a decrease in macrobenthos) and less likely due to a decrease in food within the PB due to the decrease in bottom trawling.

Lessons learned/guidance for implementation

First lesson is that due to environmental changes and/or a system that was apparently not fully understood the aims of the establishment of the box (i.e. improvement of the plaice stock through a reduction in discarding and thus F) was not achieved in spite of the fact that the measure did result in a reduction of effort inside the box. Much of the effort was displaced to areas just outside the box. The measure therefore resulted in a displacement of effort but not necessarily a reduction in effort. This did not result in a decreased juvenile mortality, probably because much of the younger place moved to offshore waters.

During the establishment of the plaice box clear objectives lacked and no clear criteria were phrased for evaluating its success, hindering ecological assessments (Beare *et al.* 2010). The implementation of reference areas is suggested. This could be done by using a checkerboard pattern of opened and closed areas. Also it was advised to manipulate the quantity of fishing effort exerted relative to the natural gradient of environmental influences.

Grift et al. (Grift *et al.* 2004), too, states that the lack of pre-established criteria and of experiments to address specific research questions make evaluation of the effectiveness of the PB difficult.

Verweij & Densen(Verweij & van Densen 2010) studied the differences in causal reasoning about processes between fishermen, policy makers, ENGO-staff, and scientists regarding the plaice box.

The problems that were found were that science and policy did not communicate on all possible outcomes in advance. Second, in the current debate on the functioning of the plaice box the focus is on developments in the stock size of plaice. But stock size is influenced by many factors simultaneously; both natural and human. The isolated effect of the plaice box alone can therefore not be separated from other factors influencing stock size. Other variables to monitor the effectiveness of the PB, for instance by measuring the survival and growth of undersize plaice inside the PB should have been put forward. Third, scientist add complexity to the debate on the effectiveness of the PB by responding to hypotheses of fishermen and ENGO-staff without articulating the basic reasoning behind closing a nursery ground for the fishery repeatedly.

Political acceptance is not a big issue, as area restrictions are common (see WP3).

Le Quesne(Le Quesne 2009) used a population model to examine if MPAs would also fail if they are properly implemented and/or enforced. Poaching and reduction in MPA size during the design process are both seen in existing MPAs. They found that the expected biomass and yield resulting from the establishment of an MPA are reduced as poaching occurs within the MPA or if the MPA is smaller than optimally desired, which indicates that MPAs as a tool for conservation and fisheries management are susceptible to many of the same problems that occur in classical fisheries management.

Seasonal closure

Management Tool

Seasonal closures affecting the North Sea Beam trawl fishery aren't used very often as a management tool. One of the main examples is based on the early years of the closure of the 'plaice box' (PB). The PB is a technical fisheries management measure where an area in the south-eastern North Sea along the Dutch, German and Danish coast, is closed for trawl fisheries with vessels bigger than 221 kW for the conservation of plaice and other species.

History

The plaice box became known as an area in the south-eastern North Sea along the Dutch, German and Danish coast. It was established by the EU (Council Regulation EEC No. 4193/88) in 1989 to reduce the discarding of undersized plaice (*Pleuronectes platessa*) (Pastoors *et al.* 2000) and thereby to enhance the recruitment to the fishery. At its establishment, it was decided that the 'box' should be active from 1 April to 30 September. During this period it was closed for beam and otter trawlers exceeding 300hp (221kW) and no fishing inside the ''box'' was allowed within 12 miles of the coast by vessels exceeding 8 m overall using beam and otter trawls. Fishing by other vessels was permitted provided that they were:

– on an authorized list and their engine power did not exceed 300hp, even if fishing with beam trawls;

– not on a list but fishing for shrimp;

– not on a list but fishing with other trawls using 100 mm mesh, even if engine power exceeds 300 hp, provided catches of plaice and sole which exceed 5% by weight of the total catch on board were discarded immediately.

The PB was intended to cover the major distribution area of juveniles of the main commercial demersal fish species such as plaice, sole and, to a lesser extent, cod. However, for specific age-groups of other, non-target, species occurring in the PB a reduction of fishing mortality was expected as well. In contrast an increase in mortality of age groups outside the PB was expected as a result of the displacement of the fleets to them (Piet & Rijnsdorp 1998).

In 1994 the plaice box regulation was extended to the 4th quarter and from 1995 onwards the area was closed all year round[6].

Over the years some evaluations of the plaice box have been performed. ICES has performed an evaluation on the effectiveness on the plaice box in 1994 (ICES 1994). In 2004, an assessment of the ecological effects in the plaice box was performed (Grift *et al.* 2004) and in 2010, an evaluation of the effectiveness of the plaice box was performed (Beare *et al.* 2010). This was done by an inventory of existing information and collecting new material.

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[6] Here, only the early years of the Plaice box during seasonal closure are discussed. The full closure is discussed in a previous section.

Objective

The first and main objective of closure was to reduce the discarding of undersized plaice in their main nursery area and thereby to enhance survival and latter recruitment to the fishery. Thus, the implementation of the plaice box was expected to increase yield, recruitment and spawning stock biomass (SSB) (Grift *et al.* 2004; Beare *et al.* 2010). In this sense, the objective was single species oriented and mainly focussing on the sustainability of exploitation of plaice and thereby the economical sustainability of the beam trawl fishery. The reduction of discarding was based on predictions by the ICES North Sea Flatfish Working Group (ICES, 1987). They predicted that, for a cohort of plaice, the proportion surviving could increase by about 25% if the Box was closed for all discarding fleets in the 2nd and 3rd quarter, and by almost 35% if the Box was closed all year round. In a similar way it was estimated for sole, it was concluded that the Plaice Box would generally enhance recruitment in Sole, but to a much lesser extent than in plaice (Rijnsdorp & Van Beek 1991).

Additionally, a reduction in fishing mortality of other species, e.g. sole and cod, but also non-target species was anticipated as a result of the measure.

Pressure

The pressure managed, is the fishing mortality (F) on plaice in their main nursery area and the fishing mortality on some other fish species by managing fishing effort. By seasonally closing the area, the intention was to reduce this pressure during the period the juvenile plaice were most vulnerable for becoming caught when still undersized.

The initial introduction by a partial closure of the Plaice Box had almost no effect on the effort of the vessels ≤ 300 HP whereas the effort of larger vessels, especially beam trawlers, decreased rapidly.

The total effort (in HP days at sea) from the international otter and beam trawl fleet decreased to 69 % of the pre-Box level ((Grift *et al.* 2004) see **Error! Reference source not found.** and **Error! Reference source not found.**).

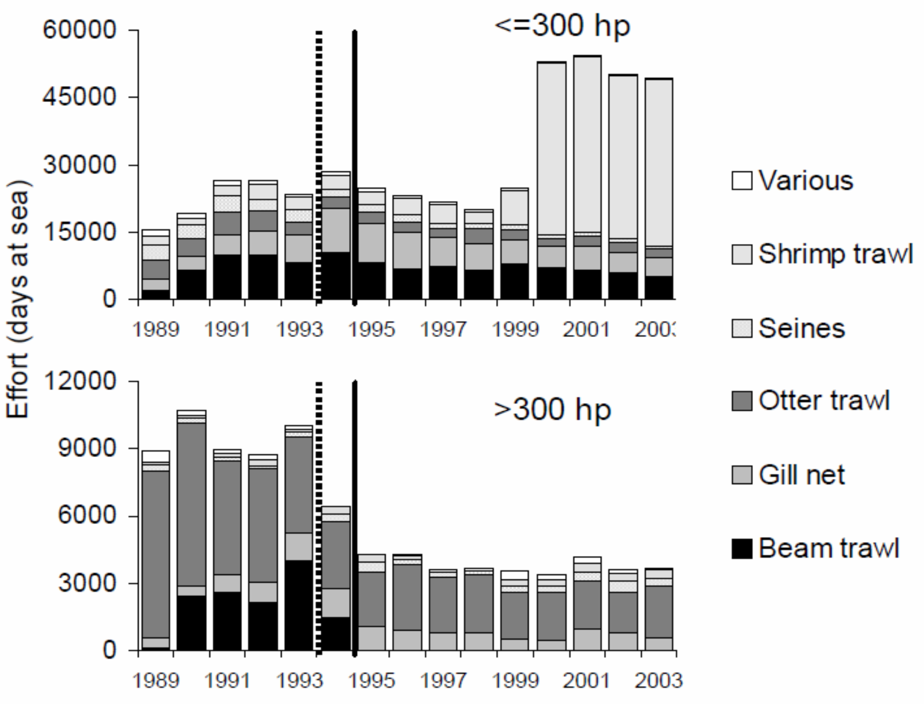


Figure 3.1.11. Trends in total effort inside the PB for all gear types for euro cutters (upper panel) and larger vessels (lower panel) (Grift *et al.* 2004).

The evaluation using micro-distribution plots of the Dutch beam trawl fleet effort showed that the plaice box has been effective in closing the area to fishing by large beam trawlers. However, it has led to changes in the pattern of fishing by different fleets.

Data from the Scientific & Technical Committee for Fisheries of the European Commission was used to estimate the effect of the box closure on the distribution of fleet effort. The pressure indicators were beam trawl fishing effort (kW hours at sea).

Annual effect of Dutch beam trawl effort inside the box increased slightly during 1990-1993. There was a large increase in effort by >300 HP vessels in 1990-1993 inside the box in the 4th quarter. The overall effort of the <300 HP vessels showed a doubling in effort inside the plaice box.

The seasonal closure of the box resulted in a large seasonal displacement of effort from the 2nd and 3rd quarter to the 1st and 4th quarter (see **Error! Reference source not found.** and **Error! Reference source not found.**) (ICES 1994).

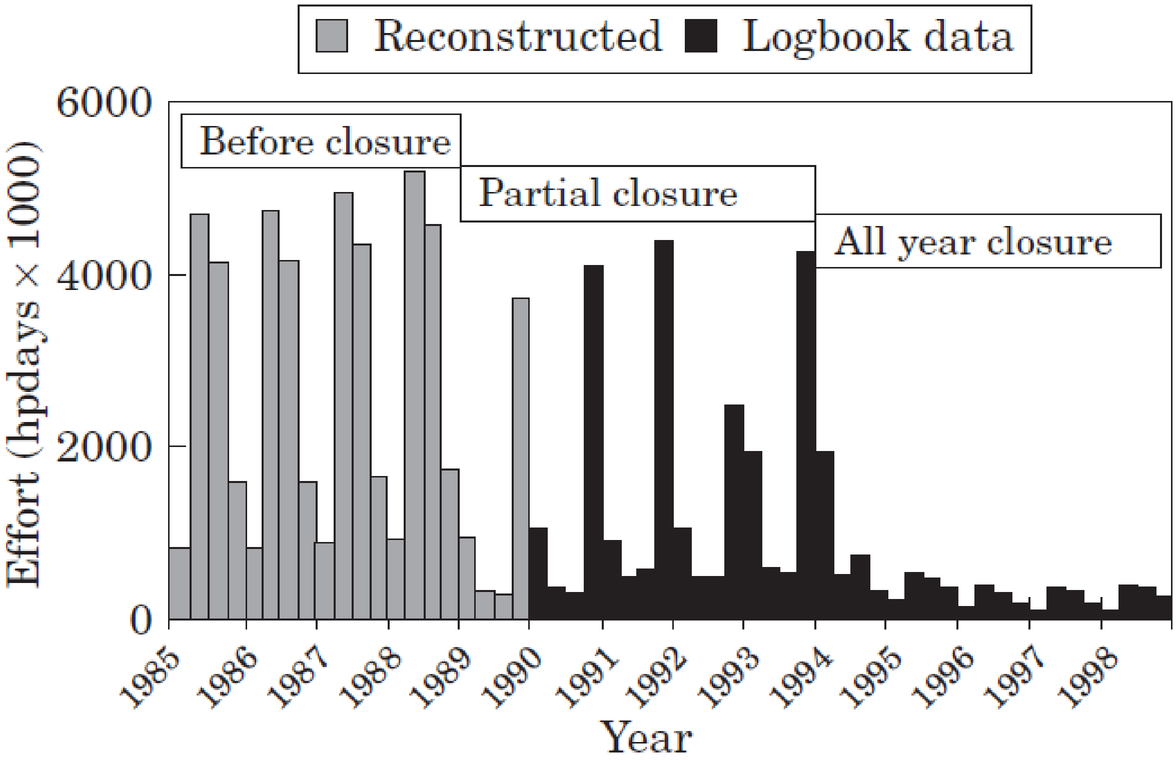


Figure 3.1.10. Fishing effort (HP days-at-sea) of the Dutch beam trawl fleet fishing in the plaice box by quarter, 1985–1998. Data for years before 1990 were reconstructed; thereafter logbook data are available (from Pastoors et al 2000).

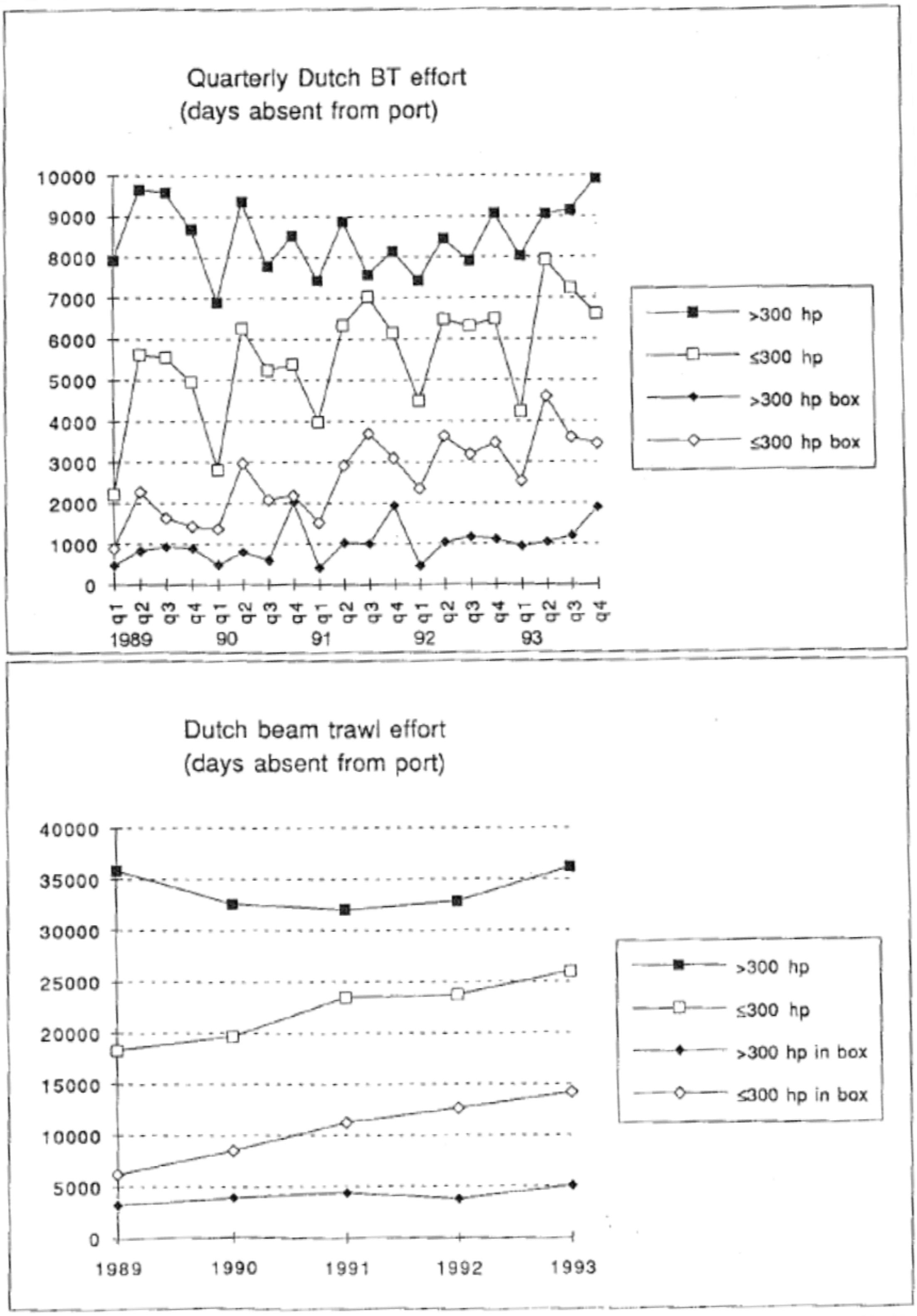


Figure 3.1.12. Trends in quarterly and annual effort by Dutch beam trawlers inside and outside the plaice box (ICES 1994).

In the study of ICES (1994), the results from VPA and demersal fish surveys did not indicate a reduction in fishing mortality on the youngest age groups. Grift et al. (Grift *et al.* 2004) indeed found that fishing mortality increased from 1970 up to a level of 0.65 in 1997, but after 1997 (2 years after the full closure of the box) it sharply declined to 0.42 in 2001. Landings gradually increased over 1957 to 1989, going along with an increase in fishing mortality, but have subsequently decreased, reflecting the decrease in the stock size over the same period. Fishing mortality reached a maximum in 1997, after which some decrease was observed (Grift *et al.* 2004).

Effect

The relevant state indicators were the amount of bycatch/discarding and plaice recruitment and spawning stock biomass.

Survey data showed no clear indication that a reduced fishing mortality on the younger age groups was achieved. Growth rate of plaice is negatively correlated with density. It was hypothesised that a reduction of the discard mortality by a reduced fishing effort on pre-recruit plaice may result in a reduced growth and hence a prolonged time over which discard mortality may operate. A model was run to estimate the potential effect of a decrease in growth rate on the effect of the plaice box. The model showed that the reduction in the rate of discarding is not completely counteracted by an increase in the time period over which discard mortality takes place.

The assessment of Grift et al. (2004) indicates that recruitment shows little variability, apart from some strong year classes (see **Error! Reference source not found.**). There are some indications of a general reduction in recruitment since the early 1990s, although such a trend might also be apparent if, for instance, there was an increase in numbers discarded, or misreporting of landings.

Spawning stock biomass varied around 300 thousand tonnes until 1989. After 1989 SSB declined sharply to below B_{lim}(200 thousand tonnes) where it has since remained (see **Error! Reference source not found.** and **Error! Reference source not found.**). This decrease reflects increasing fishing pressure and an absence of strong year-classes. Even the relatively strong 1996 year-class did not return the stock to above B_{lim}.

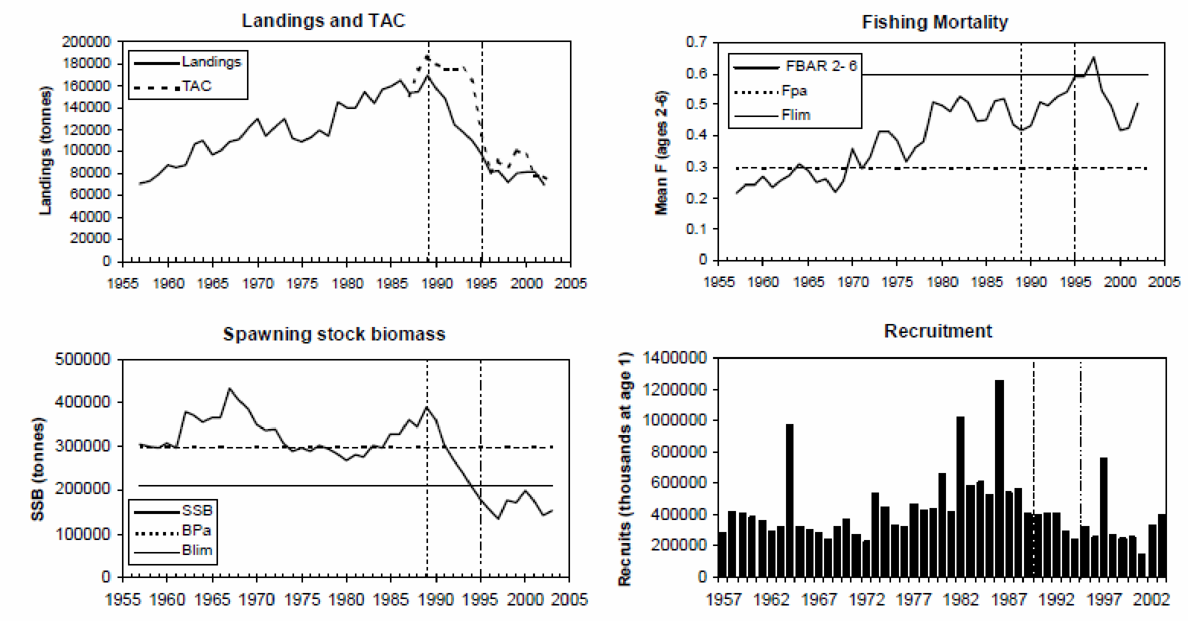


Figure 3.1.13. Long-term trends in landings, fishing mortality, spawning stock biomass and recruitment for North Sea plaice. The figures also indicate the precautionary reference points where relevant, as well as the years 1989 (when the plaice box was introduced for two quarters of the year) and 1995 (when the PB was extended to cover all four quarters). Stock trends adapted from (ICES 2004). Bpa= precautionary SSB.

Lessons learned/guidance for implementation

The seasonal closure of the box resulted in a temporal displacement of effort from the 2nd and 3rd quarter before the closure to the 1st and 4th quarter after the partial closure. A Working Group, evaluating the Plaice Box using the same methodology as used in 1987, concluded that the exemption fishery by small vessels and the increased fishing intensity during the 4th quarter reduced the positive effect of a 2nd and 3rd quarter closure from 25% to 11% (ICES, 1994). A simulation was run to predict the gain of closing the box fully to all fishing for the whole year, which would lead to a 32% improvement in recruitment. Extension of the current closure of the plaice box to a whole year would lead to an enhancement of 14% in plaice recruitment (ICES 1994). Spawning stock biomass was predicted to benefit from a complete closure of the PB by 36% (ICES 1994). The main reason for such a large predicted increase is the reduction in the discarding and killing of young fish; 83% of plaice caught in the PB were discarded (Horwood *et al.* 1998). Based on the evaluation of ICES (1994), the EU adapted the regulation and extended the PB to the 4th quarter in 1994 and the whole year from 1995 onwards.

This resulted in a decrease in aggregated effort in the PB, but discarding of undersized plaice in the fishery (up to 90% by number) is still a concern. According to Kjaersgaard and Frost there has been no improvement in stock status since the establishment of the PB. According to Kjaersgaard and Frost some believe the PB to be a management compromise, where the continued activity inside the box by vessels of >300 hp jeopardizes the success of the whole MPA (Kjærsgaard & Frost 2008).

Beare et al. refers to observations that were made by the EU including that during the establishment of the plaice box clear objectives lacked and no clear criteria were formed for evaluating its success, hindering ecological assessments. Also Kjaersgaard and Frost (Kjærsgaard & Frost 2008) concludes that it is important that managers state their objectives clearly and specify relevant indicators to measure the success of the regulation, as well as how it should be monitored, before an MPA is established. The PB balances different interests. The objectives included a wish to protect juveniles and to improve stock but also to maintain activity within the different fleet segments. Grift et al. (Grift *et al.* 2004) evaluated the PB biologically but no clear conclusion was drawn and an indicator of success was requested.

Kjaersgaard and Frost (Kjærsgaard & Frost 2008) used a model to study the economic and biological consequences of establishing a MPA. It was found that to maximize overall profit, the flatfish fishery should be conducted by a limited number of large beam trawlers fishing outside the PB. These are specialised in the flatfish fishery and therefore depend on the stock being healthy to operate profitable. This would mean that continued activity within most fleet segments (and nations) would have to be sacrificed.

The model suggest that if access to the PB had been banned entirely, the existing number of vessels in 1990 fishing outside the box could be profitable and that the stocks would be above Bpa. However, this would not be possible if fishing in the PB was permitted.

Sustainable stock levels could be attained by reducing the number of vessels in all fleet segments. Overall profit would be positive, except for Dutch beam trawlers (excluding >300 hp operating outside the box) (Kjærsgaard & Frost 2008).

Political acceptability is good, as seasonal restrictions are common. Seasonal restrictions may have ecological effectiveness when implemented in order to protect specific parts of a life-cycle. This may also secure this protection dynamically, hence both ecological and dynamic effectiveness is good (see WP3).

Subsidies: Decommissioning

Management Tool

Providing subsidies for decommissioning of vessels. This tool has been used in various ways to manage the effort of the North Sea beam trawl fleet over the years.

History

Following the early 1960s, when the technique of fishing with a double beam trawl developed, the effort and capacity of the beam trawl fleet increased rapidly. In less than 10 years, the otter trawl fleet was replaced by a highly specialised beam trawling fleet (Rijnsdorp *et al.* 2008). After a temporary decline in the mid-1970s, numbers peaked again around 1985.

In 1982 the EC Common Fisheries Policy (CFP) became effective. The CFP among others comprised of a programme on fleet structure: the Multi Annual Guidance Plans (MAGPs). Member States were left completely free in filling in the content of the first MAGP that ran for 4 years, but in subsequent MAGPs they were required to bring their target fleet size in line with the available fishing opportunities. In the Netherlands, a licensing system was introduced in 1985 requiring every boat fishing for species under quota to have a licence stating its main engine power. From the outset the licences were transferable under certain conditions. Other boats in the fishery register could also apply for a licence and many owners did so (De Wilde 2006). The fleet was frozen at the situation as per 28 December 1984; boats on order at that time were also entitled to a licence. An astonishing number of outstanding orders was reported up to 150 000 hp, nearly 30 % of the existing fleet. Only a limited number of these orders could be described as genuine, i.e. boats that were actually being built as a replacement for an existing boat or to expand the company that ordered it (De Wilde 2006).

The Dutch government felt legally obliged to include this “paper” capacity when in following years during the third MAGP the Dutch beam trawling fleet had to be reduced by 15%. In order to bring the fleet in line with the available fishing opportunities. With a rather simple calculation, it was shown that the cutter fleet was not economically sustainable at its present size and the available quotas (De Wilde 2006). The Dutch fishing fleet, however, never reached the successive reduction targets and was eventually threatened with heavy fines and reductions of fishing opportunities. The Dutch Government convinced the European Commission that a false start was made with the first MAGP and was allowed a redress, bringing the fleet largely in line with the (revised) targets.

During these first periods of reducing the capacity of the beam trawl, partially by decommissioning, the fleet was constantly under pressure to reduce its capacity. As the financial results of the fishing firms were often fairly good following the fall in fuel prices by the end of ’85, it was virtually impossible to push them out (De Wilde 2006). Only when owners were under heavy economic pressure were they prepared to decommission their boats. Quite a few chose either to apply for the decommissioning scheme that accompanied the measures or to re-flag their boats to the United Kingdom, Germany, or Belgium, selling their hp-licences and ITQs on the market (Frost *et al.* 1995). By the end of the second MAGP period in December 1992, the size of the active cutter fleet was reduced from more than 600 to about 475 and the aggregate power from 430 MW to 360 MW. A notable restructuring of the fleet took place, as the reduction of capacity was not evenly distributed over the size classes. Particularly the middle-sized boats between 300 hp and 1500 hp were leaving the fleet. At the other end, the number of >1500 hp boats continued to increase slightly by the addition of new 2000 hp boats. The costs of the Dutch decommissioning program of 1987-1994 was 127 million ECU (Frost *et al.* 1995).

Following this early period of decommissioning various rounds took place from 1994 until 2008 (**Error! Reference source not found.**). Since 1994 the total number of boats reduced from 432 to 311 (28%), while the capacity reduced by 46% (Algemene Rekenkamer 2008). As an example in 2002, 25 were decommissioned, however there were still unused or reserved licences available, and hence new investments in capacity could take place (Taal *et al.* 2002). However, in 2002 eight big beamers applied for the decommissioning programme. For the first time in all those years of fleet reduction, boats of the largest size, that were still active in the flatfish fishery were actually decommissioned (De Wilde 2006). In one of the last round in 2008, 23 boats were decommissioned, of which 20 were of the large category (Taal *et al.* 2008).

Table 3.1.5: Results decommissioning in the Netherlands since 2004 (Algemene Rekenkamer 2008).

	Number of vessels	Total KW	Total tonnage	total amount Euro
Values in 1994	432	310,585	137,470	
Decision on Capacity change 1994	5	4,589	1,035	1,843,459
Decision on Capacity change 1996	26	23,676	5,617	10,767,988
Measure Capacity reduction 2001	12	11,897	2,814	7,422,716
Measure Capacity reduction 2002	25	30,666	7,462	19,510,000
Measure Capacity reduction roundfish 2003	1	736	146	494,698
Measure Capacity reduction fisheries 2005	29	35,798	8,982	26,578,592
total up to 2005	98	107,362	26,056	66,617,453
Measure LNV-subsidies 2008	23	35,748	9,971	27,491,736
total up to 2008	121	143,110	36,027	94,109,189
Values in 2008	311	167,475	98,443	
Reduction in Fleet capacity (%)	28%	46%	26%	94,109,189

Objective

The objective of the MAGPs was to reduce the fleet capacity in order to bring it in line with the available fishing opportunities. The objectives were European wide, but the targets were set for each country individually and in the fourth MAGP even for individual fleet segments.

The overall goal (EC N° 4028/86) is "to establish a viable fishing fleet in line with the economic and social needs of the regions concerned and the foreseeable catch potential in the medium term", including the "situation of the fleet and the fishing capacity".

The objective for the Dutch decommissioning program that followed later was to reduce the fleet capacity of the Dutch fleet to bring it in agreement with the reduced quota for sole and plaice. The intention was to make the fisheries sector in a reduced form economically sustainable. This decommissioning was accompanied by other management tools.

The overall objective was thus focussed on the economic and social pillars rather than on the biological pillar.

Pressure

The objective was to improve the efficiency/profitability in the economic pillar. However, by reducing the number of vessels the level of exploitation (Effort, F) was expected to improve to more sustainable levels. This could then result in a decrease of the % unfished area. The latter, however, was never phrased as an objective of the measure.

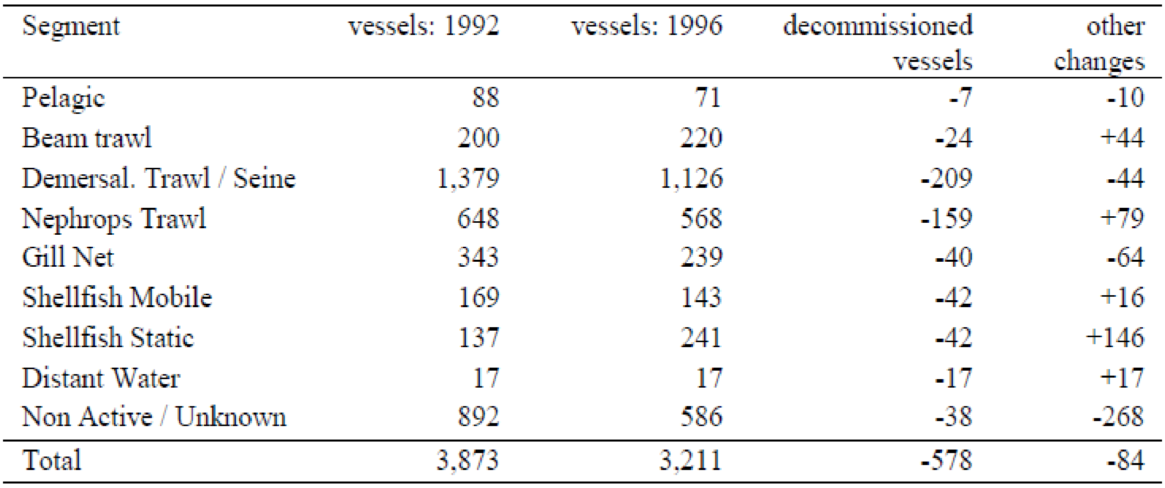
Effect

Economic sustainability

According to Algemene Rekenkamer (2008), is it unclear which effects the decommissioning rounds since 1994 had on the economic sustainability of the sector. They also concluded that the reduction of the fleet did not directly lead to an increased profit for individual fisherman, because in the Dutch case the fishing rights and quota were kept by the fishermen that decommissioned their boat. They could rent their rights and quota and thus still take part of the share without going to sea.

The effect of the decommissioning program should thus come from reduced fixed costs for the whole fleet (Frost *et al.* 1995), because the same fishing activity is performed with less boats. According to the study by Frost et al. (1995), the early decommissioning programs in the Netherlands and Denmark were successful from a financial point of view. In the Dutch case the structural increase in economic rent was estimated at about 40 mil. Euro per year. The decommissioning program in the UK was successful in the sense that it significantly reduced the potential fishing capacity in the fleet and led to a rapid increase in the demand for licences and track records for those remaining. This has considerably enhanced the capital worth of individual assets (Banks 1998). However, it failed to reduce the capacity in in those areas requiring immediate reduction i.e. the pelagic, beam trawl and the whitefish trawl sectors (**Error! Reference source not found.**).

Table 3.1.6: Reductions in the number of vessels in the fleet by segment in the UK case, 1992 to 1996 (Banks 1998).



Segment	vessels: 1992	vessels: 1996	decommissioned vessels	other changes
Pelagic	88	71	-7	-10
Beam trawl	200	220	-24	+44
Demersal. Trawl / Seine	1,379	1,126	-209	-44
Nephrops Trawl	648	568	-159	+79
Gill Net	343	239	-40	-64
Shellfish Mobile	169	143	-42	+16
Shellfish Static	137	241	-42	+146
Distant Water	17	17	-17	+17
Non Active / Unknown	892	586	-38	-268
Total	3,873	3,211	-578	-84

Source: MAFF

Sustainability of exploitation

It seems logical that decommissioning would result in reduced effort, and thus a reduction in F, leading to an improvement for the sustainability of exploitation. As long as it is actual capacity/effort and not only capacity on paper that is decommissioned.

However, it depends very much on other legislation that is in place at the time. If all fishing boats were already fishing at their maximum, decommissioning would reduce effort. However, if others can take over because they are not limited by their amount of days-at-sea or due to technological improvements, it will not lead to the expected reduction effort.

Overall decommissioning tended to result in older, less-efficient boats being removed, creating a modern, efficient fleet, essentially failing to reduce capacity and hence reduce F (Tidd *et al.* 2011). For example, a reduction in capacity of 19% of the least active eurocutters results in a reduction of just over 1% of effort in days at sea (Piet *et al.* 2007). The efficiency of the remaining fleet is likely to increase (Rijnsdorp *et al.* 2006), resulting in an increased fishing mortality of the target stocks in spite of a reduction in terms of fleet capacity and fishing effort in days-at-sea (Piet *et al.* 2007) (see figure 3.1.13). This may also be caused by the re-flagging to other Member States fishing on the same stock, while these licenses remained available for possible new boats in the Netherlands (Rijnsdorp *et al.* 2008). Furthermore, in the North Sea beam trawl case, the quota for the targeted fish stayed the same and thus the pressure on these species stayed similar.

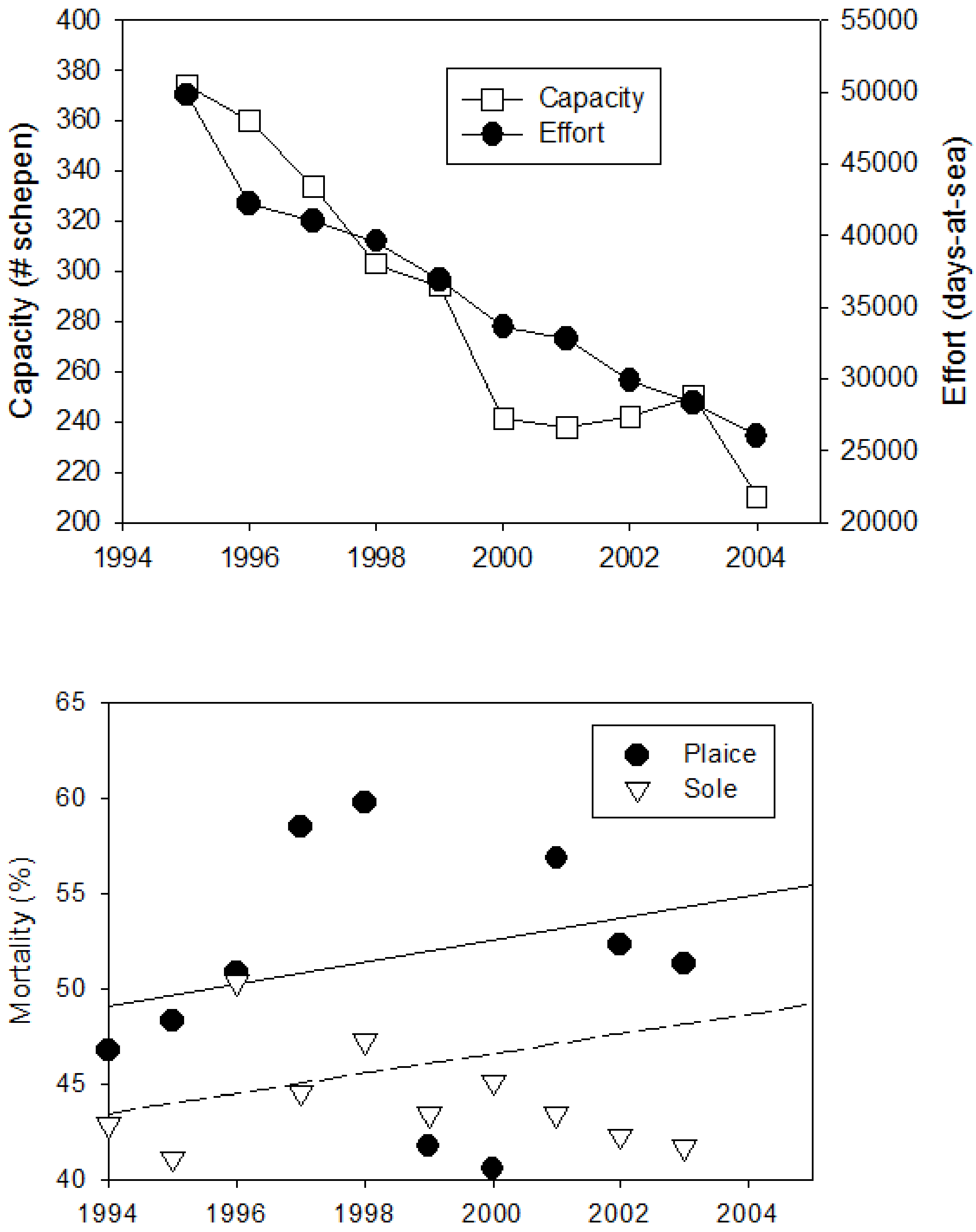


Figure 3.1.13. Fleet capacity and fishing effort of the Dutch beam trawl fleet (upper graph) in relation to the Fishing mortality of the main target species (lower graph). Based on Piet et al. (2007).

Percentage Unfished area

The area of seafloor that is trawled is expected to decrease when vessels are decommissioned. Whether this actually occurs is never assessed and the reduction is probably not linear as part of the reduction may be countered by other boats not limited in their days-at-sea, or an increase in fishing speed. The actual reduction in impact may be further reduced because the most fished areas are trawled less frequently as opposed to areas not being fished.

Lessons learned/guidance for implementation

An important reason for the limited effect of decommissioning is the dependency of this management tool on other legislation. For this tool to be at least partially effective, there needs to be a clear effort and capacity registration in place. This was not the case not only by the "paper" capacity which was introduced in the Netherlands, but also by unclear definitions of gross tonnage and engine power in different regions and countries (Hatcher 1998). The funds of the decommissioning could therefore be invested in new vessels (if licences allowed) or in larger vessels. This not only occurred in the Netherlands, but also in the UK (Banks 1998) and Denmark (Frost *et al.* 1995). Once the capacity of the fleet has been cut back, changes need to be made to the management system so that a situation of overcapacity does not arise once again.

In voluntary decommissioning programs, the vessels applying first for decommissioning are those that were generally associated with operating on the margins with low quota entitlement. Often being the oldest vessels near the end of their economic life (with a low debt). In the UK decommissioning program (1992-1996), most vessels leaving the sector had around half the catch rates and the days at sea of those that remained (Banks 1998). In this way the UK decommissioning program mainly reduced the potential fishing capacity in the fleet, similar to the Dutch "paper" capacity.

Another legislation that limited the economic effect of the decommissioning program, was the distribution of the quota. In the Netherlands, fishermen decommissioning their vessel kept their rights on the quota, which they could sell or rent for high prices. Therefore wealth was still distributed over the same amount of people, which was not an improvement of the economic sustainability of the sector. Additionally, the amount of available quota stayed similar and in this way the decommissioning programs had little to no effects on the level of exploitation. This was clearly reflected in the estimates of fishing mortality but not in the measures of capacity or effort thus showing that the appropriate indicators need to be applied to assess the effect of a measure.

A risk of introducing decommissioning programs, especially gradual programs rather than rapid decommissioning, is that it may actually exacerbate the overcapacity problem by reducing the perceived risk of investment and by injecting more capital into the industry (Hatcher 1998). Further risks are that it distorts the market, by increasing the price for vessels and decreasing the price of spare parts (Frost *et al.* 1995).

As international experience has shown, decommissioning programs can often be more effectively replaced by a system of transferable fishing rights. This may either apply to quotas, or to days-at-sea combined with the overall fishing entitlement, such as the licence (Hatcher 1998). In the case of transferable fishing rights, the race for fish is removed, allowing individuals to catch a set quantity and allowing investment and production strategies to be internally driven by market forces (Tidd *et al.* 2011).

Mesh size

Management Tool

Regulations on mesh size can describe the size and shape of the meshes used in the net. For almost all fisheries mesh size regulations are in place. For the beam trawl fishery in the EU there is an overall mesh size regulation in place that defines a minimum mesh size. More specific in the North Sea, there is an additional mesh size regulation in place that defines a different minimum mesh size for different areas.

History

Regulations on mesh size (Table 3.1.8) are already very old. As early as 1605 mesh size regulations were introduced in the sea fisheries (Burd 1986). In 1934 a Special Meeting of ICES recommended that all member countries would adopt the regulations in force in the UK at that time, meaning all trawls and seines should have about 75mm stretched mesh in the codend. In 1946 a Convention was decided upon that the minimum mesh size in trawls or seines should be 80mm in at least the North Sea area (Burd 1986). In 1992 these regulations were further tightened, the mesh size was increased to 100mm with a derogation of 80 mm for the sole fishery south of 55°N. During the late 1990s, maximum twine diameter and maximum codend circumference were regulated in some key fisheries, and the mesh size in North Sea demersal roundfish fisheries was increased to 120 mm. However, many trawl fisheries were still allowed to use a smaller mesh size because of derogations (Suuronen & Sardà 2007). One of these is the beam trawl fishery for sole which, since 2000, was allowed to use 80mm south of 55°N west of 5°E and south of 56°N east of 5°E (Rijnsdorp *et al.* 2008). While the latest regulation (EC No 2056/2001) states: “Mesh size regulations from January 2002 applying to beam trawls prohibit the use of any mesh size between 32 to 119 mm in the greater North Sea, north of 56° N. However, it is permitted to use a mesh size range 100 to 119 mm within the area enclosed by the east coast of the UK between 55° N and 56° N and by straight lines sequentially joining the following geographical coordinates: a point on the east coast of the UK at 55° N, 55° N 05° E, 56° N 05° E, a point on the east coast of the UK at 56° N, provided that the catches taken within this area with such a fishing gear and retained on board consist of no more than 5% cod. In the southern North Sea, it is permitted to fish for sole south of 56° N with 80-99 mm meshes in the cod end, provided that at least 40% of the catch is sole, and no more than 5% of the catch is composed of cod, haddock and saithe” (ICES 2008).

Table 3.1.7. Technical characteristics of the Dutch commercial beam trawl fisheries based on observations collected in four periods (Rijnsdorp *et al.* 2008).

	1967–1970			1976–1983 [a]			1989–1990 [a]			2002–2006 [a]		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Engine power (hp)	350	250	510	1262	600	2700	2884	1800	4446	2147	1800	4500
Towing speed (knots)	3.7	3.0	5.5	5.6	4.5	6.5	6.3	6.0	7.5	6.1	5.3	6.8
Beam width (m)	9	8	10	11	9	16	12	12	12	12	12	12
# ticklers from shoes	6	4	12	10	6	20	12	11	13	8	5	10
# ticklers from ground rope	3	0	8	7	3	12	9	8	11	11	6	16
Mesh size (mm)	71	62	75	78	68	110	89	80	100	84	80	98
# observations	14			45			6			22		

[a] Only vessels >300 hp.

Objective

The main objective of mesh size regulations is stated in the title of the EU regulation (EC No 850/98): the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. It is specifically focussed on the protection of juveniles to improve fishery resources. The additional regulation of 2001 adds the specific recovery of the cod stocks in the North Sea and to the west of Scotland. The objective is thus both economic as well as ecological.

Pressure

The pressure managed, is the fishing mortality (F) on small (juvenile) fish of target stocks. However, this should also result in a reduced by-catch of other small fish as well as benthos.

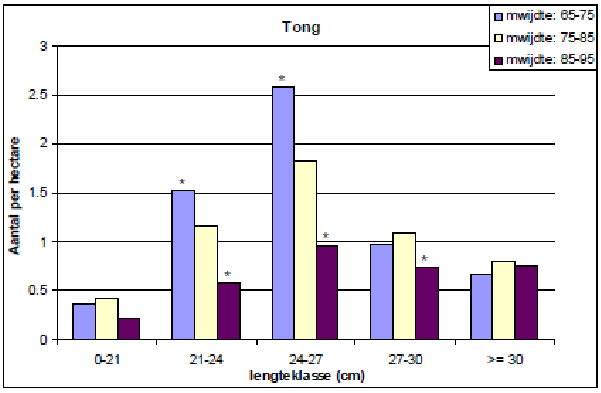
In the case of the mixed beam trawl fisheries the increase in mesh size in the northern area is specifically intended to decrease the F on undersized plaice. As the minimum landing size of plaice is much larger than the 50% retention length of 80mm mesh size, it corresponds better to the larger 100 mm mesh sizes mandatory in the northern area.

Effect

It seems logical that increasing the mesh size automatically means a decrease in F on smaller fish, increasing their change of survival to contribute to the later population and thus a positive effect on the state indicators abundance and SSB is expected.

However, this isn’t as simple as it seems, the same amount of fish and benthos enters the net and is thus disturbed. At the speed fishing takes place the fish is forced through the meshes and potentially damaged, reducing their fitness and potential survival. Besides that, during a haul the meshes in the codend become masked by the catch, scruff or other debris (Burd 1986), reducing the escapement of juvenile fish. This especially occurs when the hauls are longer, as in the North Sea beam trawl fishery hauls are about 1.5 to 2 hours (Quirijns & Hintzen 2007). In experiments fishing for sole with mesh size of 75 and 90mm, it was shown that owing to debris caught on “dirty” grounds the mean size of the sole caught decreased by 2-3cm compared to clear catches (Burd 1986). In the case of the 90mm mesh net this was equivalent of the sizes caught in a 80mm net.

Experiments with Dutch beam trawlers fishing with 70, 80 and 90mm mesh size for sole show that increasing mesh sizes from 80 to 90 mm would lead to a decrease in catches of about 50% of undersized sole and a loss of 32-47% of marketable sole (24-30 cm) (**Error! Reference source not found.**14). The amount of plaice discards was not lower than in the 80 mm. With 70 mm, significant amounts of marketable plaice were lost, and apparently more plaice discards were caught. Catches of sole from 21-27 cm were higher in 70 mm compared to 80 mm. For other sole size categories there are no significant differences between 70 and 80 mm (Quirijns & Hintzen 2007).



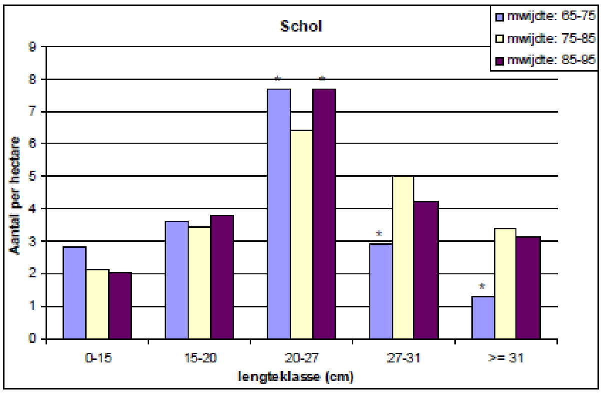
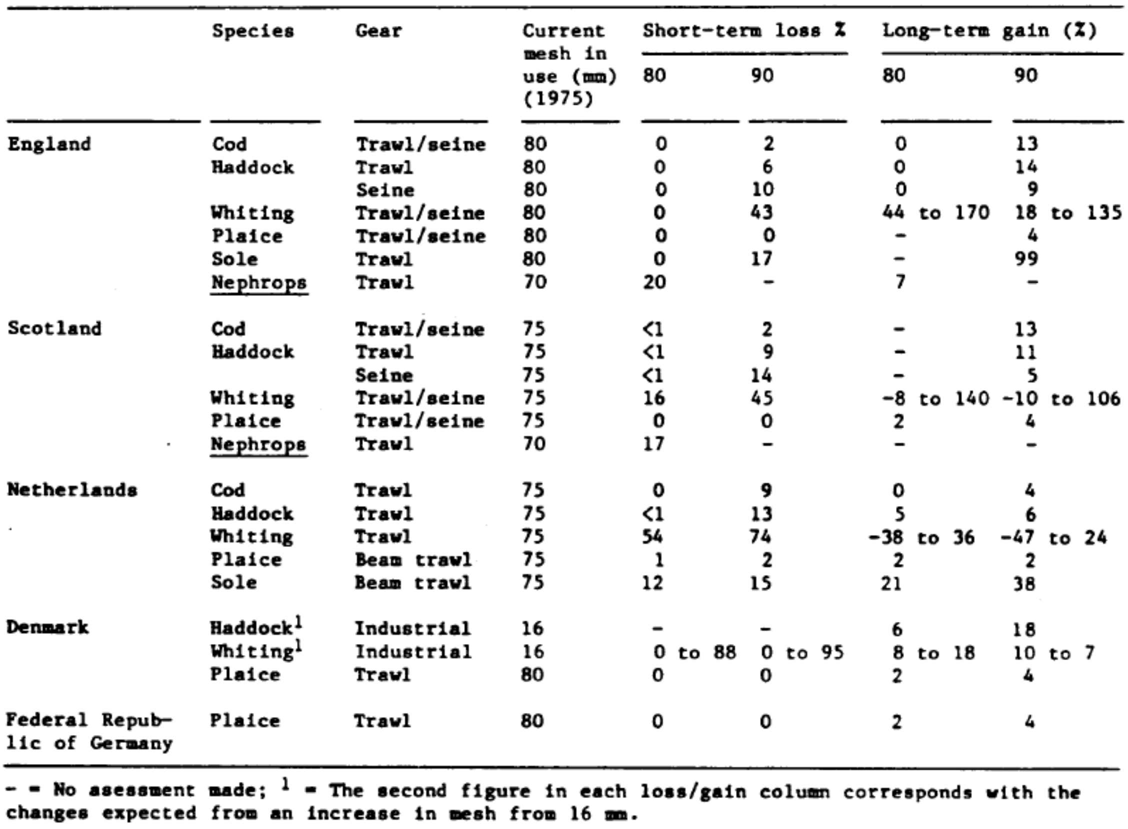


Figure 3.1.144: Differences in absolute numbers of sole and plaice per hectare using 70 (blue), 80 (yellow) and 90 (purple) mm mesh size.

This shows a clear problem of mesh-size regulations affecting the mixed North Sea beam trawl fisheries. Each target species has its specific minimum landing size (MLS) that may not be in line with the size selectivity of the prescribed mesh size. The minimum mesh size (MMS) permitted in the southern North Sea beam trawl fishery for sole and plaice is 80 mm. The MLS of sole (24 cm) corresponds roughly to the 50% retention length at such a mesh size, but the gear retains plaice considerably smaller than its MLS of 27 cm, resulting in high discard rates. However, a simple increase in mesh size to reduce discarding of plaice would result in considerable short-term losses of marketable sole (Graham *et al.* 2007). Sole at the MLS tend to have the greatest market value of all size grades. The regional separation in mesh size regulation, 80 mm in the south and 100/120mm in the north, is driven by this. The larger mesh size in the north has no effect on the catches of sole, as it is no target species in this area and this mesh size fits better to the MLS of plaice which is the target species in the north.

The objective of the mesh size regulation however was not only focussed on the reduction of F of the smaller fishes but on increasing the economic prospect of the fisheries. That should mean that the reduction in small fish leads to increases in larger quota and catches in later years. In **Error! Reference source not found.**, estimations are shown of the expected losses and gains after the increase of the mesh size from 75mm in 1975 to 80 or 90mm (Burd 1986). For the Dutch beam trawl fisheries, it was expected that there was a large loss on the short time for catches of sole. The short-term losses for plaice were smaller. The long-term gain however was much more positive for sole. The expected short term loses, however, are difficult to accept for the fishermen. This complicates finding support from the fishermen for such regulations as they have to pay their bills in a short-term rather than gaining more money in the long-term (Catchpole *et al.* 2005).

Table 3.1.9. Effects of mesh size changes from current levels to 80 an 90 mm in the North Sea (Burd 1986).



	Species	Gear	Current mesh in use (mm) (1975)	Short-term loss %		Long-term gain (%)	
				80	90	80	90
England	Cod	Trawl/seine	80	0	2	0	13
	Haddock	Trawl	80	0	6	0	14
		Seine	80	0	10	0	9
	Whiting	Trawl/seine	80	0	43	44 to 170	18 to 135
	Plaice	Trawl/seine	80	0	0	-	4
	Sole	Trawl	80	0	17	-	99
	Nephrops	Trawl	70	20	-	7	-
Scotland	Cod	Trawl/seine	75	<1	2	-	13
	Haddock	Trawl	75	<1	9	-	11
		Seine	75	<1	14	-	5
	Whiting	Trawl/seine	75	16	45	-8 to 140	-10 to 106
	Plaice	Trawl/seine	75	0	0	2	4
	Nephrops	Trawl	70	17	-	-	-
Netherlands	Cod	Trawl	75	0	9	0	4
	Haddock	Trawl	75	<1	13	5	6
	Whiting	Trawl	75	54	74	-38 to 36	-47 to 24
	Plaice	Beam trawl	75	1	2	2	2
	Sole	Beam trawl	75	12	15	21	38
Denmark	Haddock[1]	Industrial	16	-	-	6	18
	Whiting[1]	Industrial	16	0 to 88	0 to 95	8 to 18	10 to 7
	Plaice	Trawl	80	0	0	2	4
Federal Republic of Germany	Plaice	Trawl	80	0	0	2	4

- = No asessment made; [1] = The second figure in each loss/gain column corresponds with the changes expected from an increase in mesh from 16 mm.

The estimates in **Error! Reference source not found.** were however made at forehand. These are not the actual losses or gains caused by the regulation of the mesh sizes. We haven't found any actual results on the state indicators abundance or SSB of plaice or sole that are linked to mesh size regulations into place. It will also be very difficult to make these analysis, as many other measures came into place at a similar moment. The evaluation of the effect of the mesh size regulation on the conservation of fishery resources thus stays based on the expectations.

Other indicators that could be affected by mesh size regulation than the objectives of the regulation are those focussing on mortality of other than the target species. Based on analysis of the discard data of the fleet of England and Wales, showed a positive effect of the regulation on the total discards of other fish (**Error! Reference source not found.**) (P < 0.01). It showed a reduction from 83% by number for mesh sizes <90mm to 60% by number for the two larger mesh size categories (Enever *et al.* 2009).

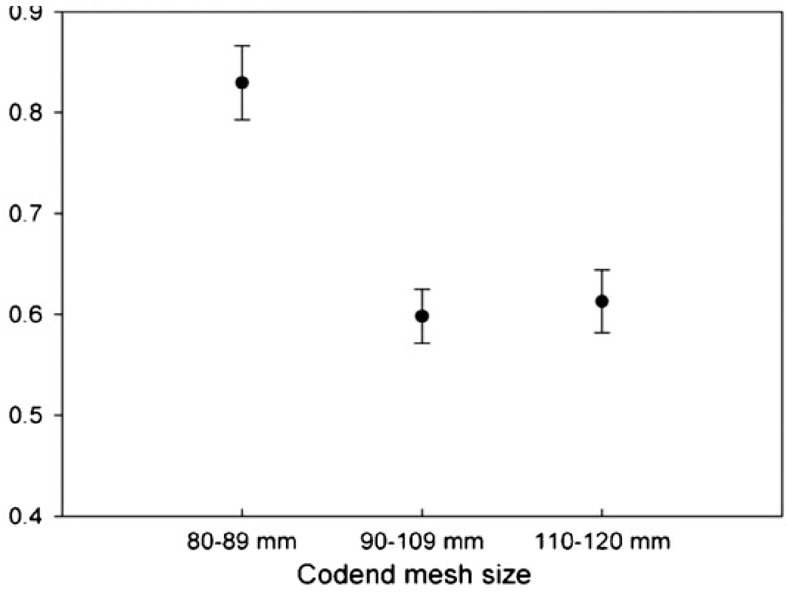


Figure 3.1.15: Proportion of catch discarded (all finfish numbers combined) by English and Welsh registered beam trawlers in the North Sea between 1999 and 2006 (Enever *et al.* 2009).

Lessons learned/guidance for implementation

Overall mesh size regulations seem logic to implement in order to reduce F on smaller fish. However it has to be supported by other regulation like those on minimum landing size, which is rather complicated in mixed fisheries for different species with different MLS. In the mixed fisheries, no single mesh size suits all species caught, and any change may favour one species at the expense of another (Suuronen & Sardà 2007). Overall it seems that in general the mesh size regulations had a much smaller effect than envisaged (CEC 2001).

Furthermore, it is a measure that needs the support of the fishermen, as it is costly and difficult to control and in many circumstances easy to circumvent. The drive of the fishermen is to catch as much as possible, a phenomenon labelled ‘big bag syndrome’ (Catchpole *et al.* 2005). Rather having a full net than clean nets with the same amount of fish that can be landed. Circumvention of the regulation occurred for example in the roundfish trawls, where a 100mm mesh roundfish trawl constructed of 6mm double twine, legal until 1999, was shown to be no more selective than a 90mm net constructed of the 4mm twine used prior to 1990 (Catchpole *et al.* 2005). In the beam trawl it is known that often fishing with a bag with smaller mesh size in the coded occurred to circumvent the regulation. However, this was difficult to adjust when the boat was controlled. Easier to get rid off when a control boat occurs on the radar are cords used to tie the meshes to each other. When the trawl is pulled with enough power these break and disappear before the net comes above water. Although fishermen were aware of the risks of being fined, as well as the negative effects on the fish stocks, they used these methods because the others did as well and the nets of these others were reported to be much more filled (thus not the actual landings being larger) (personal observation). The adherence to technical measures can be low if suitable incentives are not in place (Enever *et al.* 2009). Graham et al. (2007) noted that reduced fishing opportunities acted as a disincentive to North Sea fishers to use trawls with larger mesh. In contrast to this, gear-based technical measures attract more support from the industry than alternative measures that reduce fishing opportunities (closed areas, restricted fishing time) (Catchpole *et al.* 2005).

High-grading ban

Management Tool

High-grading is the practice of discarding low-value small fish above the minimum landing size in order to fill the quota with higher-value big fish. High-grading may result from quota management that restricts the fishery for one species but allows the fishery for another species to continue (Polet et al. 2010). The high-grading ban has been introduced in 2009 and includes all species subject to quota in all ICES zones.

NB High-grading rarely happens with sole, as sole is a species where some sizes have a higher value than larger fishes.

History

In 1987 Norway introduced a discarding ban on cod and haddock, and in 1988 another six species were banned from discarding (Diamond and Beukers-Stewart, 2011). The discard ban, including a high-grading ban, is part of a larger comprehensive package, e.g. technical measures, real time closures, quotas and regulations on bycatch, all with the purpose to assist the fishermen avoiding situations where fish may be discarded (Community, 2009).

To prevent a situation where Norwegian ships would discard their catches outside Norwegian waters, the European Community agreed to implement a high-grading ban, along with some other fisheries measures in 2008 (Community, 2009).

In January 2009 the high-grading ban was described in the EC Council Regulation No 43/2009 as; *"Any species subject to quota caught during fishing operations in the North Sea and Skagerrak shall be brought aboard the vessel and subsequently landed unless this would be contrary to obligations provided for in the provisions laid down in Community fisheries legislation establishing technical, control and conservation measures, and in particular the present Regulation and Regulations (EC) No 2371/2002, (EEC) No 2847/93 and (EC) No 850/98 and their implementing rules. Member States shall endeavour to take similar measures to those referred in point 5b.1 in the Eastern Channel."*

In November 2009 the prohibition of high-grading was extended to all ICES zones (EU Council Regulation no. 1288/2009).

Objective

The high-grading ban has the objective to create an incentive for the fishermen to fish in areas where the ratio between more and less valuable fish is lowest. High-grading is also a practice that affects discards. Discarding of fish is a major waste of resources as well as a loss of potential income and is negative towards the rebuilding of fish stocks. Furthermore, discarding implies that some catches are not recorded, possibly influencing catch and effort data with the result that the scientific basis for the management decisions is weakened (Community, 2009). Discard data can be estimated, and landings are known, but the high-graded part of the catch is unknown. Thus, the high-grading ban is also a measure to ensure that knowledge on the catch becomes more complete.

Pressure

The pressure indicators are fishing mortality (F) and number of discards caused by high-grading. These indicators are difficult to monitor for the high-grading ban. Next to that, fishermen might be reluctant to discard/high-grade in presence of observers.

Diamond and Beukers-Stewart (2011) assessed the effectiveness of the discard-ban in Norway. He found that after the introduction of the discard ban on cod, herring, haddock and saithe, the Norwegian and Russian fleets started landing larger proportions of small fish and smaller proportions of large fish than the EU fleet. This was followed by substantial stock recovery rates in the Northeast Arctic. Now, most present-day North Sea stocks have higher SSBs and lower F than the pre-discard ban Northeast Arctic stocks (Figure 3.1.18), with similar proportions of juveniles present in both areas.

This could indicate that a discard ban in general could lead to a reduction in F. As high-grading is a form of discarding the implementation of the high-grading ban could have, to a lesser extent, the same effect.

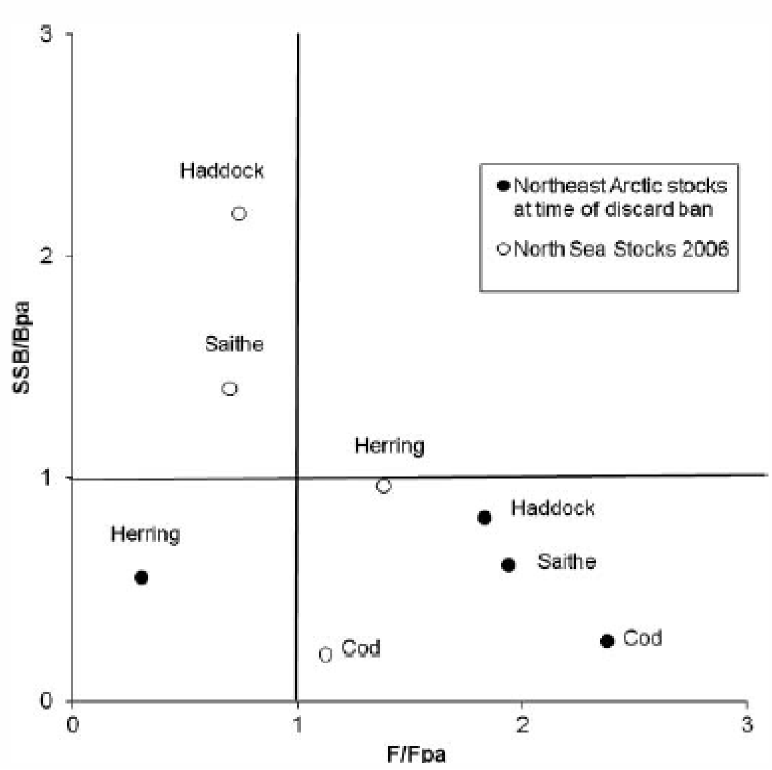


Figure 3.1.18. Normalised SSB (SSB/B_{PA}) against normalized fishing mortality (F/F_{PA}) for Northeast Arctic cod and haddock in 1987, Northeast Arctic saithe and herring 1988 (before discard ban), and North Sea cod, haddock, saithe, and herring in 2006 (from Diamond and Beukers-Stewart (2011).

Effect

It has been suggested that for the beam trawl fleet high-grading may specifically occur at the beginning of the year when catch rates of plaice are high and comprise of less valuable fish, and at the end of the year when catch rates increase owing to the recruitment of a new year class or quota become exhausted. A dynamic state variable model by Poos et al. (2006) of effort allocation and high grading in the Dutch flatfish fishery under a TAC system showed that a reduction in the individual quotum for plaice (ITQ) was compensated for by re-allocation of effort from an area with a high abundance for plaice and a low abundance of sole, towards fishing grounds with a higher abundance of sole and a lower abundance of plaice (Figure 3.1.19). When the ITQ for plaice was decreased further, the fleet could only continue fishing by discarding an increasing part of the plaice catch until the fishery had to stop completely because fishing was no longer profitable (Rijnsdorp et al., 2007). (Rijnsdorp *et al.* 2007) (Rijnsdorp et al. 2007)

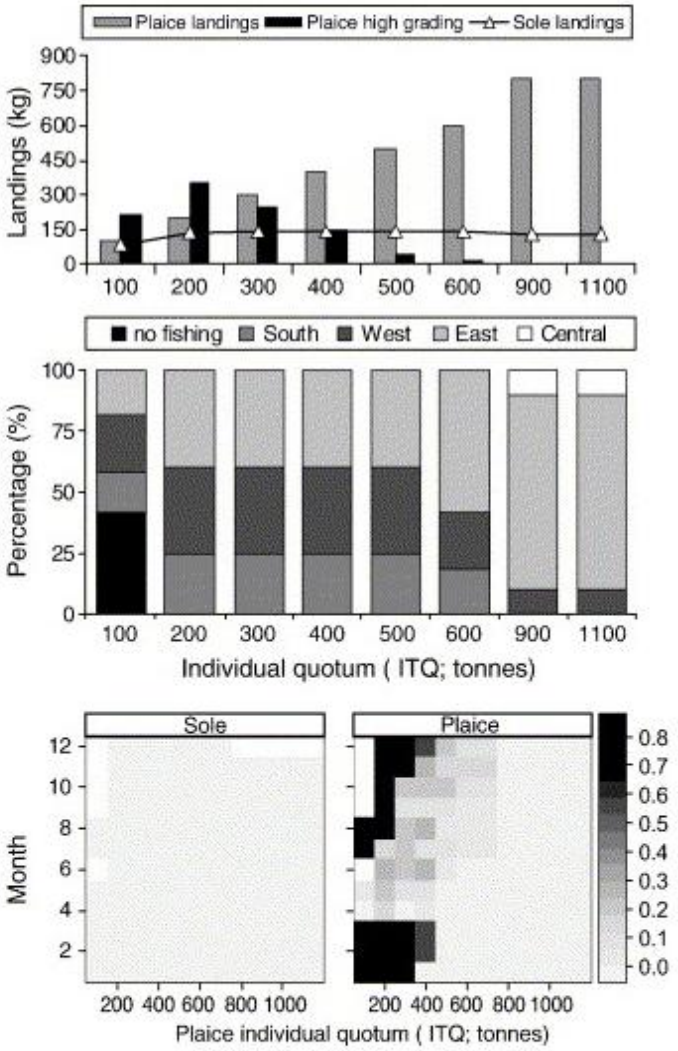


Figure 3.1.19. Sole and plaice landings (top), effort allocation over 4 fishing grounds with various abundance of sole and plaice (middle), and the proportion of the catch that is high graded by month (bottom) of the Dutch beam trawl fleet fishing under various levels of ITQ for plaice.. From Poos et al. (2006).

Spawning Stock Biomass

An indication was found that the discard ban in Norway has resulted in higher SSB and lower F than before the discard ban. Figure 3.1.20 shows the temporal trends in the normalized SSB for the Northeast Arctic and North Sea stocks of cod, haddock, saithe and herring. Post-discard ban the normalized SSB of the Northeast Arctic stocks (Figure 3.1.20 A) increased at a rate of 18% per year. The normalized SSB of the North Sea stocks (Figure 3.1.20 B) began to increase at a rate of 3% per year after implementation of CFP(Diamond & Beukers-Stewart 2011)(Diamond and Beukers-Stewart, 2011).

Thus, allowing fishermen to land everything does not appear to have increased pressure on the fish stocks. Combined with a system of real-time area closures the discard ban appeared to have generated an incentive for fishermen to install gear modifications and fish more selectively. This is likely to have contributed to the relatively fast stock recovery rates experienced in the Northeast Arctic(Diamond & Beukers-Stewart 2011)(Diamond and Beukers-Stewart, 2011).

The results of this study could indicate that a discard ban in general could lead to an increase in SSB.

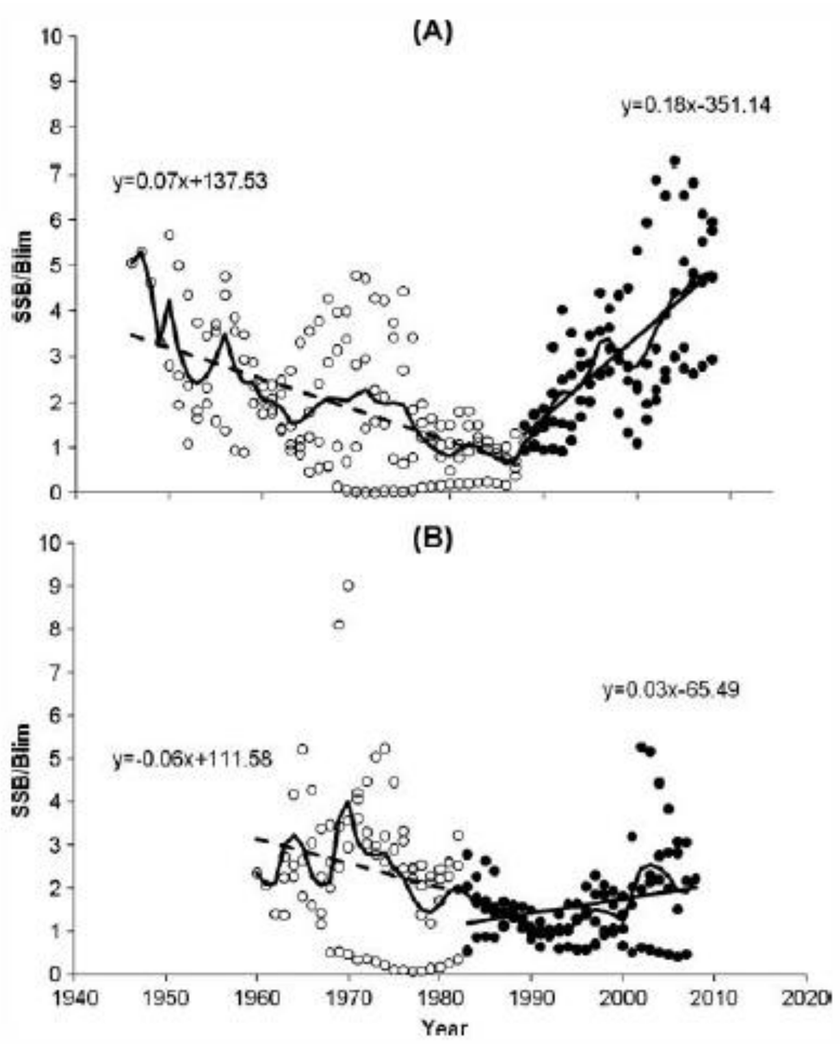


Figure 3.1.20 . Normalised SSB (/B_{lim}) for: (A) the Northeast Arctic and (B) the North Sea stocks of cod, haddock, saithe, and herring by year. The undulating lines represent the mean values by year, and the straight lines are the linear regressions (parameters are given in each panel). The open circles/dashed lines are the pre-discard ban (a) CFP (b) and the closed circles/solid lines represent the subsequent period. From Diamond and Beukers-Stewart (2011).

Fisher behaviour

Gillis et al. (1995) have developed a simulation model to determine how regulations on trips by management agencies may influence discarding behavior at sea. High grading was predicted to be highest when there is a high probability of the catch exceeding the trip quotas as well as when effort limits are high and trip quotas are low.

The model showed that a combination of large trip landing limits and intermediate trip effort limits best satisfied the multiple goals typically used by management agencies.

A theoretical model describing the high-grading behavior of fishers and an empirical model as a testing strategy for high-grading and to estimate the discarded amount of each grade was developed. This model was applied to Icelandic cod fishery data which is quota regulated. They found that high-grading occurred in both long-line and net vessels, but that discard rates were considerably larger for the net vessels. However, the discard rates were small. Results suggested that that the ban on discards in Iceland has effectively dealt with high-grading. Also, they found that progressive punishments and monitoring schemes effectively reduce the quantity discarded (Kristofersson and Rickertsen, 2005).

Tests of which input prices affect discarding identifies the oil price for both vessel types, but the quota price only for net vessels. This may be taken to suggest that the lower discard rates of the long-line vessels are partly due to better capacity use and therefore fewer quota-induced discards. The theoretical model of high-grading behavior by fishers shows that ITQs (individual transferable quotas) may provide incentives for high-grading but only as long as there is free hold capacity. If hold capacity is binding, the quota price does not induce discarding (Kristofersson and Rickertsen, 2005).

Although the high-grading ban is in place since 2009 it is believed that the ban is relatively unknown among fishermen. Over-quota discarding is still allowed, leaving space for high-grading. Enforcement of the rule is difficult and costly, as proving a vessel has been involved in high-grading can only be done by observation or video images.

Economic

The study by Diamond and Beukers-Stewart (2011) showed that after introduction of the discard ban in Norway, the economic costs to the fishing industry were at first relatively high with fishermen experiencing catches comprised of great proportions of small fish with lower values and lower CPUE. However, the period for which the fishing sector remained unprofitable lasted for just four years. Today the Norwegian and Barents Sea fisheries are some of the most prosperous in the world. The SSB for Northeast Arctic cod is now near its record high and the 2010 TAC amounted to 607,000 tonnes (ICES, 2010).

Introducing a discard ban in the North sea might also lead to an increase in SSB. The economic reliance on fisheries in the North Sea is also smaller, and the short-term negative impacts on the industry of a discard ban are likely to be significantly less than that experienced by Norway in the late 1990s.

Lessons learned/guidance for implementation

There is a lack of information on the effects of a high-grading ban. Although there are some studies on the behavior of fishermen, quantitative data are scarce and often limited to general discarding.

Monitoring and research on the implementation and effectiveness of the high-grading ban is difficult to execute. Due to the remoteness of a vessel at sea there is a low chance of being observed discarding. This makes it difficult to prove that a vessel has been involved in illegal discarding. Apart from that there are six different countries involved in the fisheries in the North Sea which means six different legal systems, complicating hard methods of enforcement(Diamond & Beukers-Stewart

2011)(Diamond and Beukers-Stewart, 2011). However, new developments to monitor fishing activity, such as remote electronic monitoring systems (e.g., on-board CCTV), are showing great promise.

The method of Kristofferson is suggested an accurate and useful alternative to existing methods for estimating discards, as the results were consistent with the existing estimates. The availability of the type of data used in this study is increasing as more fish markets employ electronic sales systems. The cost of estimation associated with this method is small, and it can be performed routinely by statistical agencies to help resource managers choose the level of monitoring in response to changes in estimated high-grading, thus increasing the effectiveness of monitoring.

The results indicate that resource managers should focus monitoring attention on net fishing vessels rather than long-line vessels, or more generally on highly seasonal fisheries where hold capacity is only limited for short periods(Kristofersson and Rickertsen, 2005) (Kristofersson & Rickertsen 2005).

If high-grading results from quota management that restricts the fishery for one species but allows the fishery for another species to continue, a reduction in fishing effort is deemed to contribute to lesser high-grading and to a reduced risk that the fisheries management gets trapped in a spiralling downward mechanism by under-estimating catches, under-estimating stock sizes, assigning TACs that are too low and thus promoting high-grading (Polet, 2010).

9.6. Annex F: Management Strategy Evaluations beam trawl fishery

Management Strategy A: TAC management for maximum sustainable yield (MSY)

This management scenario was evaluated using a full feedback stochastic projection model (Miller and Poos, 2010). In this simulation model observations from the 'true' simulated populations of sole and plaice are used in assessment models to produce a 'perceived' view of the stocks. There are uncertainties/error in observations from the true population (catch and indices of abundance) included in the process. The biological dynamics include random variability in recruitment and weights at age. In addition to the biology, the fisheries system is modelled with simple fleet dynamic rules for three different beam trawls fleets, with different gears and selectivities, targeting the two species. While it could be possible to look at the results in terms of economic consequences, no economic feedback was incorporated into the feedback management loop in the simulations.

The analyses were carried out using the FLR package (FLCore v3.0; Kell et al. 2007), a collection of data types and methods written in the R language (v2.8.1; R Development Core Team 2008) as part of the EU EFIMAS-COMMIT-FISBOAT project cluster. All code, data and additional sources for checking, validating and evaluation are freely available upon request. Full details of the biological evaluation, including a full description of simulation methodology and complete results are documented in Miller and Poos (2010) and Simmonds et al. (2010).

To ensure the robustness of conclusions drawn from the model, a number of biological scenarios were tested to determine whether or not the results of the evaluation were sensitive to the assumptions of initial starting condition and underlying stock productivity (stock recruit function). Under these alternative biological scenarios the long term trends in stock development and TAC did not show any significant differences that would invalidate the use of the 'base case' (best available knowledge) scenario to assessment management options.

The potential effects of MSY-based TAC management was evaluated by examining management scenarios containing alternative fishing mortality (F) targets for each stock. In particular, four potential Fmsy targets were considered:

1. Base Case (black in plots): current flatfish management plan F target values i.e. plaice = 0.3, sole = 0.2.
2. Fmsy (red in plots): best estimate of Fmsy. Plaice = 0.23, sole = 0.2.
3. ICES (green in plots): Current ICES Fmsy values for these stocks i.e. plaice = 0.2, sole = 0.22
4. F = 0.25 for both stocks (blue in plots).

For the plaice stock, alternative F targets examined over the range from 0.2 to 0.3 all lead to similar long term TAC values because the equilibrium yield vs F curve is flat-topped for this stock (Table C.1). However, below F=0.2, at for example 0.15, there is a long term reduction in catch. In all cases the risk of the stock falling outside of safe biological limits is negligible. However for sole, alternative F target values in the range 0.15 to 0.35 result in both short term and long term differences in TAC. An F target of 0.15 produces lower TAC in both the short and long term, while a F target of 0.3 provides higher short term TACs, slowly becoming more similar to the long term TACs from F targets in the 0.2-0.25 range. There is a short term difference between 0.2 and 0.25, though in the long term this is less substantial (0.25 slightly higher). The equilibrium yield vs F curve for sole suggests that Fmsy could well be greater than 0.3 for this stock, however the simulations show that the risk of falling outside of safe biological limits reaches an unacceptable level for F values in this range.

Table C.1. Plaice and sole average yields (over the time period considered) and risks of falling outside of safe biological limits under different targets Fs in the multi-annual plan. (For scenarios that were run with less than 100 iterations (rows in bold), it is not possible to adequately estimate the risk to the stock, so NA values are given.)

PLAICE

F	Yield ST (2011-2015)	Yield MT (2016-2025)	Risk to stock ST (2011-2020)	Risk to stock MT (2016-2025)	Risk to stock LT (2021-2030)
0.15	**69357**	**97825**	**NA**	**NA**	**NA**
0.2	**73307**	**112434**	**NA**	**NA**	**NA**
0.22	*	*	*	*	*
0.23	79190	124038	0	0	0
0.25	82168	124938	0	0	0
0.3	93044	130710	0	0	0
0.35	*	*	*	*	*

* = Not run for this stock.

SOLE

F	Yield ST (2011-2015)	Yield MT (2016-2025)	Risk to stock ST (2011-2020)	Risk to stock MT (2016-2025)	Risk to stock LT (2021-2030)
0.15	**14365**	**15904**	**NA**	**NA**	**NA**
0.2	14512	17687	0.1	0.05	0.02
0.22	14531	18215	0.1	0.05	0.02
0.23	*	*	*	*	*
0.25	14615	19151	0.1	0.06	0.06
0.3	14645	20236	0.14	0.14	0.19
0.35	**15886**	**20568**	**NA**	**NA**	**NA**

* = Not run for this stock.

To consider the likely impacts of mixed fishery dynamics on the success of MSY-based TAC management, three scenarios of fishing effort were examined in a further analysis (Figure C.1). These scenarios consider potential reactions to the TAC of one of the stocks being caught before the TAC for the other has been caught. In this case the fishery will either stop (Least_Eff: i.e. the mixed fishery is limited by the least effort required), continue while avoiding catching the other by some technical or spatial changes in fleet behaviour (Both_Eff: i.e. catches of stocks considered independent, both TACs caught) or continue to fish until the TAC of both stocks is caught, discarding the overquota catch caught for the other stock (MostSOL_Eff: i.e. effort only limited by the most demanding TAC). In the situation that there is a big discrepancy between the TACs of the two stocks, plaice can be caught cleanly by spatial changes or technical restrictions. There are areas where plaice is present but not sole (e.g. further north in the North Sea). Also, changing gear used can prevent large overquota catches of sole while still landing plaice (e.g. shift from 80mm to 100mm mesh size). Considering these mitigating factors, the final scenario considers that fishing will continue until all sole is caught, but extra effort to catch plaice beyond this will not impact on the sole stock.

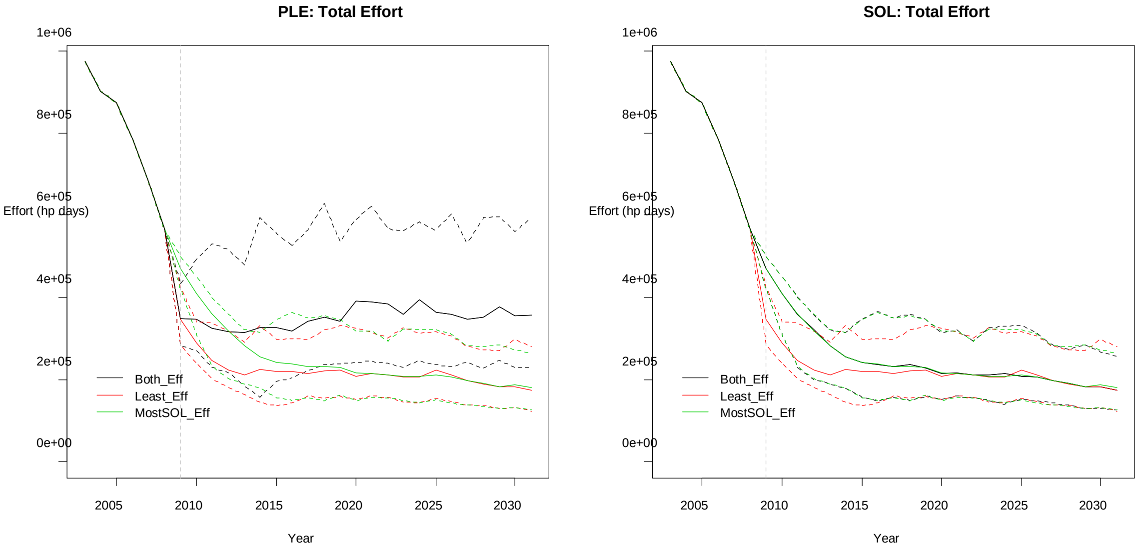


Figure C.1. Total effort for plaice (left) and sole (right) under different mixed fishery scenarios, following the current management plan. Time series comprise recorded values prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

The general pattern of effort shows a short term decrease levelling off in the longer term. Initially more effort is required to land the sole TAC than the plaice TAC but this reverses as sole F decreases and plaice F increases to move towards the management plan targets. For plaice, the increase in F together with a recovering stock leads to more rapid increases in TAC than for the sole stock. Because plaice TACs increase more rapidly than those of sole, in the long run the TAC of plaice requires more effort to land. This is a more tractable and favourable situation for the mixed fishery to be in because overquota of sole can be more easily avoided than that of plaice.

Further results are presented in the appropriate sections below:

Ecological descriptors

A.1: It is not possible to assess the impact on ecosystem biodiversity with this model. The reduction in effort should in theory reduce the pressure on the ecosystem.

A.2: Results show that the SSB of both stocks increases (Figure C. 2). The Fmsy basis of the scenarios ensures that the fishing mortality levels are maintained at a reasonable level. The general pattern of stock development of plaice under the various management scenarios evaluated was an increasing trend in SSB in the short term (roughly 5 years) followed by a levelling off of median SSB. Alternative F targets in the 0.15 to 0.3 range lead to the stock stabilising at different levels of SSB, all above Bpa and precautionary with regards to the limit reference points in the short and long term. The sole stock also shows a general pattern of increase under the scenarios examined, although this increase is slower initially and it takes longer for the stock to stabilise at a higher level (roughly 10 years). Although the sole stock is currently believed to be slightly above Bpa, F remains high and this has implications on stock growth in the short term. There is a small risk of poor incoming recruitment leading to the stock dropping below Blim.

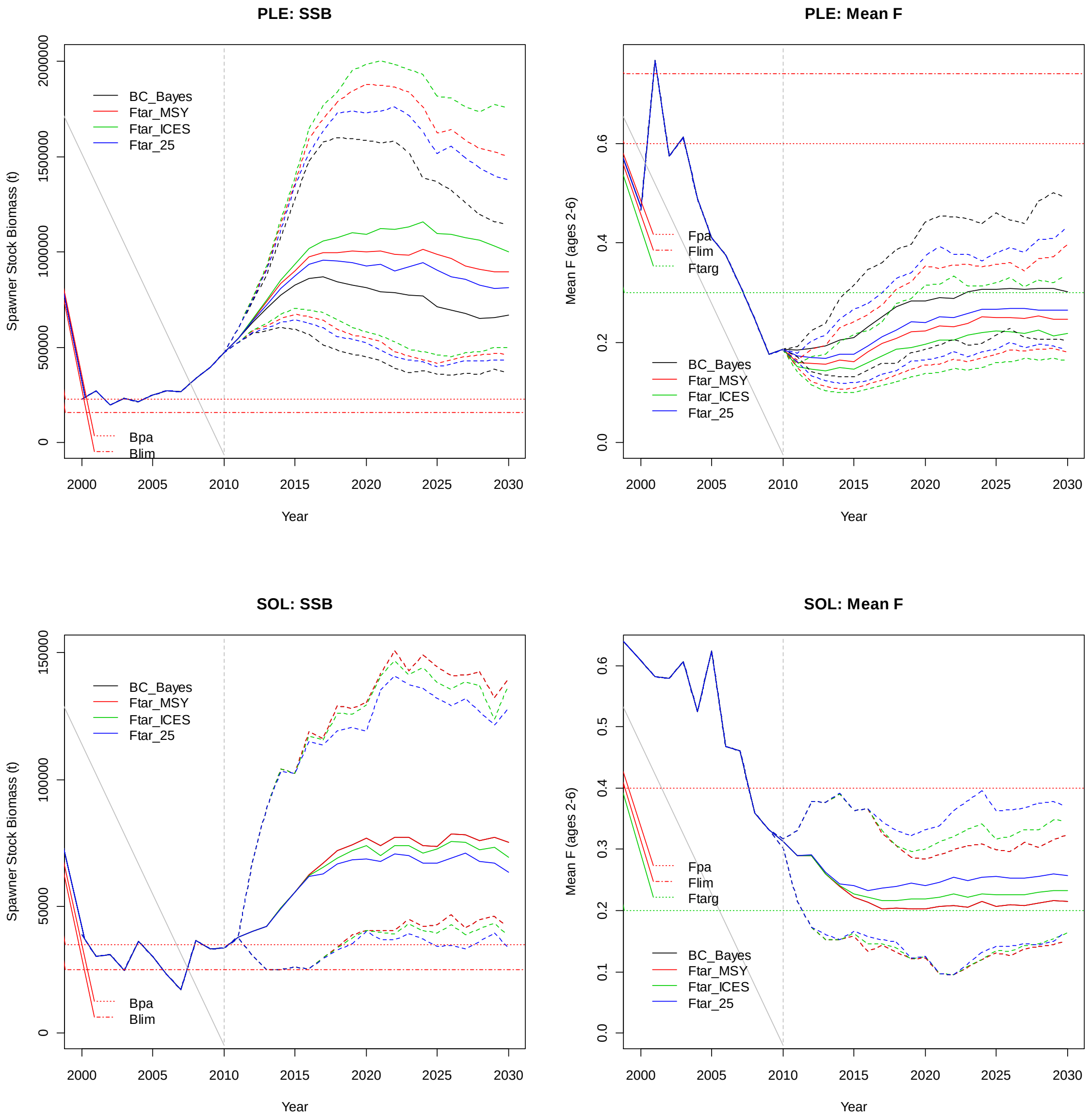


Figure C.2. Stock development for the North Sea plaice (top) and sole (bottom) stocks under alternative F targets scenarios: stock size (SSB, left) and fishing mortality exerted on the stock (F, right). Time series comprise historical TAC changes prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

Further, over the range of F targets evaluated, all showed a short term decrease in the discards proportion of plaice, levelling off at a lower level in the region of 20-30% discards.

A.3: While it is not possible to predict future trends in the LFI of food web dynamics with this model, expected changes in the plaice and sole stocks can be predicted. Over the short term, the mean weighted age of both stocks (Figure C.3) is expected to increase as the survival of older fish improves. The mean age of sole continues to increase for the duration of the time series while that of plaice starts to decrease slightly in the longer term, stabilising to a degree at a value higher than the current level. From this it could be concluded that the average length of flatfish is likely to increase under MSY management, potentially improving the LFI.

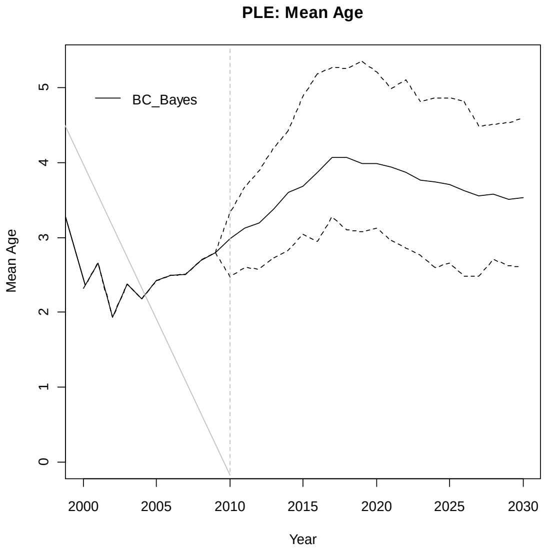


Figure C.3. Mean weighted age of the North Sea plaice (left) and sole (right) stocks under alternative F targets scenarios. Time series comprise historical TAC changes prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

A.4: The decrease in effort required to land the TACs should reduce the seafloor damage exerted by the beam trawl fleet, improving seafloor integrity.

Economic descriptors

A.5: Economic efficiency, though not directly assessed in this model, is likely to increase or at very least remain stable. TACs for both stocks are forecast to increase before levelling off as sustainable yield is maximised (Figure C.4). The direct effect of this on profits is likely to be complicated by market forces. However, the reduction in effort required to land these high TACs in the long term will reduce operation costs, making for a more efficient fishery.

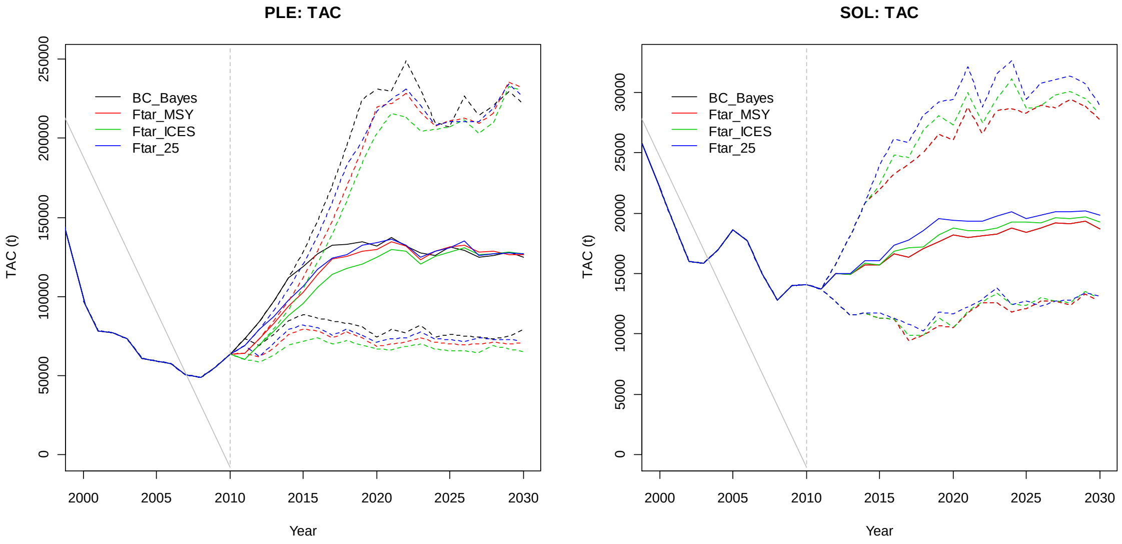


Figure C.4. TAC development for the North Sea plaice (left) and sole (right) stocks under alternative F targets scenarios. Time series comprise historical TACs prior to 2011, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

A.6: Stability of the fishery should increase with time. Even sustainable stocks will have fluctuation in TAC over time according to incoming year class strengths. However, with the two targeted stocks ‘stabilising’ around a higher SSB, the stocks should be able to handle periodic recruitment failures more successfully, allowing for a more consistent fishery. Current management limits TAC changes to a maximum of 15% from year to year and it is likely such restriction would remain in place even under MSY-based TAC management. Model forecasts show that for both sole and plaice the median annual variation in TAC should reduce over time (Figure C.5), though each year in at least 5% of the replicates the 15% TAC change limit is encountered.

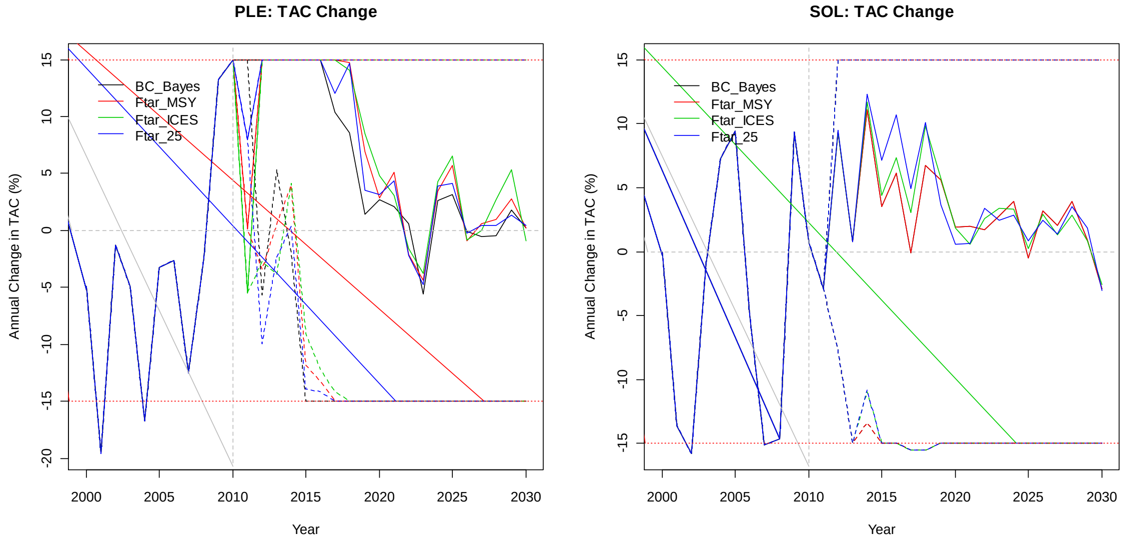


Figure C.5. Annual variation in TAC for the North Sea plaice (left) and sole (right) stocks under alternative F targets scenarios. Time series comprise historical TAC changes prior to 2011, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

Social descriptors

A.7: Higher average annual landings and reduced operating costs should lead to a more profitable fishery. Also, a sustainably managed fishery is more likely to remain viable in the long term. Model results show that the percentage chance of falling out of safe biological limits is much lower at Fmsy than in higher Fs that have been observed in the past. These factors should combine to increase community viability.

A.8: A more sustainable fishery, with higher average annual landings, should improve food security.

A.9: Job attractiveness was not assessed by this model.

Management Strategy B: Effort control

In order to evaluate the different management scenarios for the North Sea (NS), a model was developed to calculate the impact of fishing on the North Sea fish community. This model, presented in WP5, was essentially a combination of two existing models: one simulating the fish community (SIBmo) and the other simulating the removal of fish by different fisheries (DIMCOM). Further details can be found in WP5.

As the intention of this management scenario would be to assess effort reductions not linked to TAC levels, the GES scenario examined by this model is considered . Under this scenario, if the LFI is below 0.3 then the effort of all the beam- and otter trawls is decreased by 10%. If the LFI increases above 0.3 again, then effort is allowed to increase.

Several indicators are direct outputs from the model; for other indicators it was necessary to make (often very crude) assumptions and devise proxies based on different weightings that were applied to the model output. A business as usual (BAU) scenario was also modelled. The potential benefits of effort management relative to this can be gleaned from a comparison between the two. The GES scenario outperforms BAU for six of the nine indicators in the management strategy matrix, fairing only slightly worse in economic stability and a lot worse in food security. Biodiversity was not assessed. Full results are available in WP5 of this project.

Ecological descriptors

B.1: Biodiversity was not assessed in this model.

B.2: Results indicate that SSB of commercially interesting stocks is likely to increase under effort management, accompanied by a decrease in F. This impact depends to a large degree on the associated TACs.

B.3: This strategy is driven to respond to the LFI and, though it fluctuates around this level in response to incoming yearclasses, performance with regards to this indicator is good.

B.4: Reducing effort is likely to decrease seafloor disturbance, promoting seafloor integrity.

Economic descriptors

B.5: Economic efficiency (profit) is not forecast to deviate notably from the current level, despite outperforming the BAU approach.

B.6: Profit is forecast to remain stable under this management strategy. A reduction in operating costs that would be associated with decreasing effort should allow for greater economic stability as well.

Social descriptors

B.7: This management strategy, by restricting the amount of time or vessels that can participate in the fishery, is likely to lead to a decrease in employment and therefore community viability.

B.8: Yield under this approach decreases slightly, and is substantially lower than that from the BAU approach. As a result food security is compromised.

B.9: A slight increase in job attractiveness is anticipated, though this is sensitive to assumptions made in the generating of this indicator.

Management Strategy C: Restrictions in Mesh Size

This management strategy was evaluated using the DIMCOM model as described in (Piet *et al.* 2009) which estimates the direct effects only. The scenario and technical details are described in (Polet *et* *al.* 2010). The scenario includes other fisheries then the mixed beam trawl as well, because it is likely that if these mesh size regulations are implemented, they will be enforced for other fisheries as well. Effects of the implementation likely are different for the different metiers, and implementing a mesh size change only in one of the metiers will like have a different result as presented here.

The model as used in Polet et al. 2010 does not incorporate the Size based model (SIBMO) as used in WP 5 (Piet *et al.* 2011). This limits its use in long-term evaluation of the regulation in relation to foodweb interactions. The DIMCOM alone only shows the direct effect of implementing the regulation compared to the situation in 2006 (reference year in Polet et al. 2010). For long-term (10 year) forecasts an extended approach as described in (Catchpole *et al.* 2007) was used (Polet *et al.* 2010).

The results as described in Polet et al (2010) were:

A reduction in landings for sole, plaice and all other species of 14%, 4% and 9% respectively. This leads to an overall loss in revenue of 10%, i.e. from 297,222 k€ to 268,335 k€ (Keeping the effort in days-at-sea the same, if it is compensated by longer fishing it will lead to an increase of fishing effort). The 140mm and 100mm fisheries lose most landings whereas the 90mm fishery looses sole but increases its plaice catch. In general profitability decreases but stays positive for the larger vessels, not for the smaller segment.

The immediate total estimated number of discards for sole, plaice, cod, haddock and whiting is reduced with 32% and the sole and plaice discard numbers are reduced with 31%.

The SSB of sole, plaice, cod whiting and haddock is expected to increase with 19%, 44%, 10%, 8% and 9% respectively - ten years after the introduction of the new mesh sizes.

The yield of the stock, in terms of landings, increases for all five species and especially for plaice, with 35%. The plaice yield substantially drops in the first couple of years but is followed by large year on year increases. Sole shows a similar pattern to the baseline projection in the first few years but then increases and overtakes to give a substantial increase in yield. Cod also follows the baseline projection, in the short term there is no considerable loss in yield but increases in the latter years of the projection. As expected a delay in capture at age benefits the stock in that spawning stock biomass will increase along with future catch rates for all species relative to the baseline forecast

Ecological descriptors

C.1: The “Conservation Status of Fish” (CSF) would not directly be affected by a change in mesh size. However, the increase in SSB of cod, one of the species listed as threatened or declining, shows that in the long term expectations the increase in mesh size could have a positive effect on the CSF indicator.

C.2: Changes in mesh size are intended to decrease F on the smaller length classes, and will thus have a positive effect on the commercial fish indicators. This is also seen in the increase in the SSB of the target species plaice and sole, but also in the increase of the others commercial species as cod, whiting and haddock.

C.3: A mesh size change does not change the catchability of large fish, it only reduces the catchability of smaller fish. The shift in selectivity occurs below the 40cm limit, reducing the amount of small fish (small according to the LFI) being caught. Negatively affecting the LFI in the short term expectation, especially because more large fish will be caught to fill the TAC, when days-at-sea are not restricting. The long term expectation is rather positive as it is likely that the survival of more small, juvenile fish will lead to more fish growing large. But with a foodweb context, more small fish means more food available for larger fish.

C.4: A change in mesh size will not lead to changes in the percentage seafloor being trawled by the gears. Changes in the percentage seafloor being trawled will only occur if the change in mesh size leads to changes in behaviour e.g. fishing in other areas. No changes in behaviour can be taken into account in the model.

Economic descriptors

C.5: The changes in meshes lead to a short term decrease of 10% in revenue over all fleet segments. The profitability decreases but stays positive for the larger vessels, not for the smaller metiers. However, the increases as shown in SSB will probably lead to an increased CPUE, likely having a positive effect on the efficiency in the long term, depending on the market prices and fuel costs.

C6: Increases in SSB, and thus likely increases in quota, should be positive for the stability.

Social descriptors

C7: This management strategy, if positive for efficiency and stability, is likely to be positive for community viability.

C.8: Yield under this approach is likely to decrease in the short term but increase on the long term, as a result it will have a positive effect on food security in the long term.

C.9: A change is mesh size is not expected to have an effect on the job attractiveness. If the ‘big bag syndrome’ plays a role in job attractiveness it could decrease due to anticipated smaller catches (smaller bags). This could be balanced out by smaller catches, with fewer discards, meaning smaller bags that are easier to handle and require less work.

Management Strategy D: Spatial Closures – temporary closure to fishing of areas utilised by the primary fishery stocks for spawning

This management scenario was evaluated quantitatively by Rijnsdorp et al. (2011) using a spatially and temporally explicit model of four target species (sole, plaice, turbot and brill) and two bycatch species (cod, rays). The fishery examined was the North Sea mixed flatfish fishery (primarily beam trawlers). The model examined the consequences of spawning closures for the dynamics of exploited species, the fishery and the ecosystem effects of the fishery. Specifically: (i) revenue to the fisheries; (ii) biomass of the target species; (iii) bycatch of undersized flatfish; (iv) bycatch of cod and rays; (v) fisheries-induced evolution; and (vi) trawling impact on the benthos.

The model has a weekly temporal resolution in terms of landings, discards and population dynamics. Seasonal and spatial variations in age-specific catchability are estimated for the major target species (sole, plaice, turbot and brill) and used to calculate the exploitation pattern for different management scenarios (Murawski 1984; Rijnsdorp and Pastoors, 1995; Piet et al., 2007). Derived indicators are calculated on a per recruit basis and represent the equilibrium conditions assuming constant growth and fishery characteristics.

Three spawning closure scenarios for the main target species were considered: plaice (scenario 2), sole (scenario 3) and plaice and sole combined (scenario 4). These were compared to a baseline scenario reflecting the effort distribution observed in the period 2003-2007 (scenario 1) is order to assess the effectiveness of these measures. In addition to this two possibilities of effort reallocation to other fishing areas or other seasons were considered for each scenario. Schedule A considered spatial reallocation, with fishing effort reallocated within the same week over the rectangles still open to the fisheries. Schedule B considered temporal reallocation, with fishing effort reallocated to other seasons in the same area. Displaced fishing effort was distributed over the open rectangles in proportion to the effort exerted in those rectangles.

A summary of the main results is presented in Table C.2. Full details of the modelling procedure and comprehensive results can be found in Rijnsdorp et al. (2011). It should be noted that spawning area closures are a complimentary management measure. Further analyses using the model assuming that fishing effort at an Fmsy level are similar to those presented here, indicating that the additional benefits, and drawbacks, of spawning area closures are maintained across of range of different fishing pressure levels.

Table C.2. Change (%) in the response indicators for six spawning closure scenario's relative to the baseline at status quo fishing mortality ($F_{2003\text{-}2007}$). From Rijnsdorp et al. (2011).

Response indicators		**Scenario**					
		2A	2B	3A	3B	4A	4B
Revenue	Plaice	3.7%	7.6%	-0.2%	-1.5%	3.4%	5.5%
	Sole	-0.5%	0.3%	0.2%	1.6%	-0.3%	2.9%
	Turbot	3.9%	-1.5%	-2.4%	-2.1%	1.4%	-3.9%
	Brill	3.3%	8.1%	-0.3%	-1.3%	2.9%	6.8%
	Flatfish	1.3%	2.7%	-0.2%	0.3%	1.1%	3.2%
Landings	Plaice	1.2%	0.3%	-0.4%	-0.9%	0.8%	-0.9%
	Sole	-0.1%	-0.1%	0.1%	0.4%	0.0%	0.6%
	Turbot	2.8%	0.3%	-1.1%	-1.2%	1.6%	-1.2%
	Brill	2.4%	4.8%	-0.3%	-0.7%	2.0%	4.3%
	Flatfish	1.0%	0.3%	-0.4%	-0.7%	0.7%	-0.5%
Discards	Plaice	-0.6%	-2.5%	0.4%	0.0%	-0.1%	-2.8%
	Sole	0.5%	0.2%	0.0%	-0.2%	0.4%	0.0%
	Turbot	-0.6%	-0.1%	0.3%	0.3%	-0.3%	0.2%
	Brill	-0.4%	-1.1%	0.2%	0.2%	-0.2%	-1.0%
	Flatfish	-0.5%	-2.1%	0.4%	0.0%	0.0%	-2.3%
SSB	Plaice	16.1%	26.2%	-5.6%	-6.4%	8.9%	18.1%
	Sole	-2.7%	-1.0%	0.5%	2.5%	-2.3%	2.5%
	Turbot	8.9%	-1.1%	-5.8%	-4.9%	2.4%	-6.4%
	Brill	4.1%	16.8%	-3.7%	-2.4%	0.7%	16.0%

Fmean	Plaice	-6.7%	-9.3%	3.0%	3.3%	-3.8%	-6.3%
	Sole	2.5%	2.6%	-0.4%	-2.1%	2.0%	-0.2%
	Turbot	-3.7%	2.3%	3.8%	2.9%	0.1%	5.8%
	Brill	5.4%	-4.6%	4.9%	1.6%	10.4%	-4.6%
	Cod	-10.4%	-30.5%	2.8%	3.2%	-7.6%	-29.8%
Bycatch	Rays	-22.2%	-16.8%	18.9%	12.2%	-7.5%	-8.4%
Trawling impact	Benthos	10.9%	9.7%	-1.5%	-2.4%	10.7%	7.7%
Fisheries-induced evolution	Plaice*	-25.1%	-43.0%	10.7%	8.9%	-14.8%	-38.2%
	Sole*	-0.4%	2.0%	-0.7%	-3.3%	1.2%	-3.6%

*Baseline slope in fisheries-induced evolution is towards a decrease in maturation length in plaice (-0.0138 cm^{-1}) and sole (-0.0322 cm^{-1})

The greatest impact was found for scenario 2, plaice spawning ground closures. While the effort reallocation schedule can affect the magnitude of the observed changes, the selection of scenario rarely changed the direction in which an indicator moved (i.e. from a positive to a negative change). For simplicity, further discussion with regards to the likely impact on the 9 indicators considered in the management strategy evaluation matrix will focus on scenario 2B.

Ecological descriptors

D.1: Broader ecosystem biodiversity was not evaluated in this analysis. However, it is anticipated that such measures would lead to a reduction in bycatch of rays, and presumably other incidentally caught species.

D.2: Spawning area closures have the potential to promote the sustainability of commercial fish stocks (shellfish not examined). The plaice spawning ground scenario leads to a large increase in the SSB of plaice (26%) as well as smaller increases for the other species, with a minor decrease in sole SSB. There are also notable reductions in F on cod and plaice, with smaller effects on the F of other species.

D.3: The impact on the food web, as measured by the LFI, was not assessed in this analysis. However, results indicate that for the species examined, the pattern of fishing mortality at age is likely to be altered. A reduction in the fishing mortality on the oldest age groups (up to 22% decrease) and an increase on the youngest age groups (between 15 and 25%) is expected. This, combined with the observed reduction in overall F on plaice and cod and lesser changes in the F experience by the other species, is likely to lead to an increased LFI due to increase survival of older fish.

D.4: While the benthos in the spawning areas themselves may experience a temporary relief from fishing activity, given the effort reallocation schemes considered, the overall trawling impact indicator increases by 10% due to the re-allocation of fishing effort to previously less intensively trawled fishing areas. This strategy is therefore unlikely to improve seafloor integrity.

Economic descriptors

D.5: Revenue is expected to increase for all species except turbot, indicating an increase in economic efficiency of the fishery. The decrease in turbot revenue is because turbot is not a targeted stock and is primarily caught as bycatch, which is expected to decrease.

D.6: Given the equilibrium nature of the model used in this analysis, inter-annual stability of the fishery was not directly assessed. Seasonal closures may impact on intra-annual stability directly, though this effect is likely to be small. However, by protecting the spawning component of the stock, the likelihood of recruitment failure and poor year classes should be reduced

Social descriptors

D.7: An increase in profitability and reduction in overall F likely to mean more stable, sustainable stocks. A more sustainable resource is likely to enhance community viability.

D.8: More sustainable stocks, with a slight increase in landings, should impact positively on food security, though this impact is likely to be minimal.

D.9: Social factors were not directly assessed in this evaluation. As an added regulation on top of other management restrictions, potentially increasing the distances fishermen need to steam in order to find productive fishing grounds, it could be assumed that this could decrease job attractiveness. Whether this will be balanced out by the potential benefits is unsure.

Management Strategy E: Managing on the basis of catch quotas rather than landings quotas

Catch quota management was evaluated qualitatively. Quantitative modelling of this scenario is difficult given that the likely outcomes will depend to a large degree on the fishery is able to adjust its behaviour to adapt to this regulation. Fishers are able to avoid undersized fish in a number of ways, from changing gears to changing fishing location. It is hard to predict how effective these measures will be and the effectiveness will also depend on the population structure of the targeted stocks (i.e. yearclass strengths).

Ecological descriptors

E.1: More targeting of commercially interesting species of marketable size may reduce bycatch of other species (e.g. using larger mesh for plaice). Reduced discarding may impact on seabird populations and other scavengers. However, both of these effects are unlikely to be significant so the overall impact on ecosystem biodiversity should be minimal.

E.2: The potential protection of incoming year-classes that would be afforded by reducing discard rates could make the fishery more sustainable and potentially even boost the productivity of commercial fish stocks.

E.3: Under CQM the selectivity of the fishery likely to target larger fish unless markets are developed for small size class fish. It would remain illegal to land fish under MLS so the increasing proportion of larger fish in the catch is likely to decrease the food web LFI.

E.4: Should fishers be able to effectively discard their discard proportion, overall fishing effort could decline. Under CQM fishing has to cease once the TAC has been taken. This also applies in the case of mixed fisheries where one stock may becoming limiting before the TACs of the other stocks have been caught. Additionally, by targeting mainly large fish, the overall area exploited is likely to reduce, with potentially sensitive coastal areas being less heavily exploited.

Economic descriptors

E.5: The impact of this measure on economic efficiency depends to a large degree on how the fishers are able to adapt to it. In the short term as fishermen adapt to the new changes efficiency is likely to decrease. In the longer term, as the fishery becomes more able to effectively target marketable fish, this should increase as the fishery becomes more sustainable.

E.6: Interannual variations in TAC are unlikely to be of a different level compared to the current system of landings quotas. Potentially a more sustainable population should have fewer poor year classes, increase stability to a degree. The overall impact on economic stability should be negligible.

Social descriptors

E.7: It is not expected that CQM would impact notably on community viability.

E.8: If CQM does successfully increase the sustainability of the main target fish stocks, food security should improve.

E.9: CQM is likely to reduce job attractiveness for fishers. More unwanted fish will need to be landed and opportunities may seem reduced. Also, participating in a fully documented fishery will require extra effort from the fishers participating (and this will probably need to be in front of a CCTV camera) e.g. catch per haul needs to be weighed, log book registrations of under-sized plaice should be made (to be checked with video footage) etc. Previous pilot studies noted that before the fishers committed to the project their main concerns were related to the ethical (privacy) issues about being monitored, and the crews' reaction to this. However it was found that in a short time the crew accepted the video monitoring and did not find it problematic or disruptive for their normal working procedures (Dalskov and Kindt-Larsen, 2009).

Management Strategy F: Marine Protected Areas

This management strategy was assessed qualitatively utilising best available knowledge. MPAs are about to be introduced in the North Sea as part of the Natura 2000 framework mostly to conserve habitats or bird species according to the Habitats and Birds directive. The North Sea beam trawl fishery may be impacted by MPAs if areas are closed to all fishing. The bio-economic impacts of the establishments of MPAs depend on the degree of overlap between fish distributions and MPAs, and whether there are spill-over effects from the MPA areas to the non-MPA areas.

MPAs without accompanying fishing effort restrictions are likely to merely result in the redistribution of 'ecosystem pressure'. The MPAs themselves will see obvious direct benefits, but surrounding areas may see negative impacts as a result of the redirected pressure.

Ecological descriptors

F.1: Any effects on biodiversity would depend on the size of the MPAs, on the degree of overlap with fish distribution and on spill-over effects. From a general biodiversity perspective, such a measure is expected to be beneficial, in particular if the MPA areas cover habitats for sensitive species, e.g. rays.

F.2: Again, the effects on the commercially exploited stocks depends on the size of the MPAs, the degree of overlap with fish distribution, spill-over effects and the efficiency of fishing effort redistribution to other fished areas. It is thought that the impact here is likely to be small due to the small proportion of the fished area likely to be protected by MPAs.

F.3: From a general foodweb perspective, such a measure is expected to be beneficial. However, the impact of MPAs through their restrictions on the flatfish fishery itself is likely to be minimal.

F.4: From a general seafloor perspective, such a measure is expected to be beneficial, in particular if the MPA areas coincide with sensitive habitats for sensitive benthic species. As was shown in the spawning closures evaluation, depending on the reallocation of effort, areas outside of the MPAs could potentially see increased impact. However, the implementation of MPAs will result in previously fished habitats that are not fished anymore while the surrounding area will most likely already be fished with reallocation only causing an increase in frequency. This together with the fact that the first trawling impact causes most harm implies that unless the fishery reallocates to previously un-fished areas the net effect on seafloor integrity should be positive.

Economic descriptors

F.5: The establishment of an MPA increases the fishing effort required to catch the TAC, as the fleets would have to fish outside the MPAs. Particularly if MPAs are established in productive fishing areas, this would reduce the profitability of the fisheries. In addition fishers may need to increase steaming time to cross the MPA areas thereby increasing their cost.

F.6: The introduction of MPAs is unlikely to have a notable effect on economic stability, which is already high for this fishery.

Social descriptors

F.7: Similarly, community viability is difficult to assess due to numerous factors.

F.8: As with the impact on commercial fish stocks, the impact of MPAs on food security is assumed to be low.

F.9: In general, introducing more conservation measures, and in particular area closures, is expected to decrease job attractiveness.

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