Deliverable 6.2

Evaluation of possible management measures

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SUMMARY

The evaluation of potential management measures in the BENTHIS project is driven by the existing policy objectives. Therefore we briefly review the most relevant policy frameworks for the impact of fishing on the marine environment, i.e. Common Fisheries Policy and Marine Strategy Framework Directive. Because both policy frameworks have committed themselves to apply ecosystem-based management (EBM) to achieve a sustainable exploitation and conserve the environment we will be explicitly considering all three pillars of sustainability, i.e. ecological, economic and social, when selecting the indicators with which the potential management measures will be evaluated.

For the evaluation of potential management measures we distinguish between the governance part involving the incentives to be applied and the physical impact part evaluating the performance of the management measures to mitigate the actual impact of the fishing activities. This latter part is based on a number of case studies, some empirical, others based on computer simulations. These case studies are not intended to be comprehensive but provide the background to develop the framework for the evaluation of the BENTHIS management measures applying a comprehensive suite of BENTHIS indicators including ecological, economic and social indicators. While the economic and social indicators are adopted from existing frameworks, new ecological indicators needed to be developed in order to cover the provision of ecosystem services that need to be considered when developing EBM. Finally we identify the broad management measures that will be evaluated in each of the case studies.

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1 INTRODUCTION

Fisheries management in Europe falls entirely under the Common Fisheries Policy (CFP). The main goal of the Common Fisheries Policy (CFP) as of today is to ensure the sustainable development of fishing activities from an environmental, economic and social point of view. Two basic principles in the CFP are: 1) on one hand to protect and conserve living aquatic resources, 2) on the other hand contribute to efficient fishing activities within an economically viable and competitive fisheries industry. The Commission proposes common measures to make the CFP implementable (achieve the various principles and goals in the CFP), and the measures have to be passed by the Council of Fisheries Ministers. The implementation of the CFP, encompassing enforcement and control, is the responsibility of the member states.

However, even though fisheries management falls under the CFP, the measures taken may affect other policy frameworks and measures taken to achieve objectives of other frameworks may affect fisheries. Fisheries is the most important human activity affecting the marine ecosystem and therefore is any fisheries management measure likely to go beyond the commercial fish stocks and influence components or attributes of the ecosystem that are relevant for other policy frameworks, e.g. the Marine Strategy Framework Directive (MSFD). From the initial set of eleven qualitative descriptors of Good Environmental Status (GES) listed in the MSFD four descriptors were considered to be affected by fisheries and could be (partly) described by fisheries-related information such as from the Data Collection Framework (DCF): (D1) biodiversity, (D3) commercial fish and shellfish, (D4) food webs and (D6) sea-floor integrity (ICES 2014). The Habitat directive requires that "A coherent European ecological network of special areas of conservation shall be set up under the title Natura 2000". This network comprises natural habitat types and the aim is to maintain or, where appropriate, restore at a favourable conservation status in their natural range. While this directive is not specifically directed at fisheries the designation of a marine special area of conservation of specific habitat types will often involve specific measures to mitigate the impact of fishing on those habitat types such as the closure of this area for (some) fishing activities.

The CFP as well as other marine policy frameworks (i.e. MSFD) have committed themselves to apply ecosystem-based management (EBM) in order to achieve a sustainable exploitation. Many definitions of EBM exist (Curtin and Prellezo 2010; Larkin 1996), see (Arkema et al. 2006) for a review, and "they invariably share a number of common characteristics", such as "broadening stakeholder involvement" and dealing with "multiple simultaneous drivers or 'pressures' on ecosystems" (cf. (Murawski 2007). Here we use the scientific consensus statement on EBM, which defines EBM as "an integrated approach to management that considers entire ecosystems, including humans" (McLeod et al. 2005). Three characteristics pertaining to a holistic, integrated EBM aimed at sustainable exploitation render it a particularly complex process because this requires management objectives to include social, economic and ecological concerns.

The aim of this review of possible management measures is two-fold:

- To identify criteria for success or failure
- To identify the preferred indicators required for the evaluation of their performance

Having established the requirement of EBM this review includes criteria covering all three pillars of sustainability: ecological, economic and social and where possible involve indicators beyond the conventional indicators on fishing activity and state of fish stocks.

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2 POLICY OBJECTIVES AND INDICATORS

2.1 Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD), often referred to as the Marine Directive, establishes a framework within which Member States must take the necessary measures to achieve or maintain good environmental status (GES) in the marine environment by the year 2020 at the latest.
GES will be assessed on the basis of eleven descriptors of good environmental status and their criteria set out in Annex I of the Directive 2008/56/EC (MSFD). Each descriptor/criterion is accompanied by a number of related indicators so as to make the descriptors/criteria operational and allow for assessment of ecological status.

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 climate conditions
Descriptor 2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem
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
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
Descriptor 5: Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters
Descriptor 6: 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
Descriptor 7: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems
Descriptor 8: Concentrations of contaminants are at levels not giving rise to pollution effects
Descriptor 9: Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards
Descriptor 10: Properties and quantities of marine litter do not cause harm to the coastal and marine environment
Descriptor 11: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

Member States are required to adopt marine strategies in order to achieve GES. These are plans of action which are to be delivered in several stages (Art. 5) and reviewed every six years. Marine strategies must apply an ecosystem-based approach to the management of human activities (see Art. 1(3)). While 'an ecosystem approach' was initially an ecological term which referred to natural ecosystem functioning, since the early 1990s this has been adopted as 'The Ecosystem Approach' which aims to place human society as a central part in the ecosystem (Atkins et al. 2011). At its most comprehensive, the concept of The Ecosystem Approach was defined by The Convention for Biological Diversity (CBD 2000) as: 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The application of The Ecosystem Approach will help to reach a balance of the three objectives of the Convention: conservation, sustainable use and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources'.

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The DPSIR (Drivers–Pressures–State–Impact–Response) framework has developed as a systems-based approach which captures key relationships between society and the environment, and is regarded as a philosophy for structuring and communicating policy-relevant research about the environment. As such the framework often serves as the basis when applying the ecosystem approach. The MSFD explicitly considers two aspects of this framework, i.e. state, pressures and impacts and as such can be used to provide the basis that drivers the decision-making, i.e. management measures.

Because the BENTHIS project only considers the driver fisheries we will only consider those state characteristics as well as pressure/impacts relevant for that driver.

2.1.1 Relevant state characteristics

For the relevant state characteristics we distinguish between biological features, at the level of the individual species, functional groups or habitat types.

The following characteristics with regard to biological features are identified:

- information on the structure of fish populations, including the abundance, distribution and age/size structure of the populations
- a description of the population dynamics, natural and actual range and status of species of marine mammals and reptiles occurring in the marine region or sub region
- a description of the population dynamics, natural and actual range and status of species of seabirds occurring in the marine region or sub region
- a description of the population dynamics, natural and actual range and status of other species occurring in the marine region or sub region which are the subject of EU legislation or international agreements
- an inventory of the temporal occurrence, abundance and spatial distribution of non-indigenous, exotic species or, where relevant, genetically distinct forms of native species, which are present in the marine region or sub region.

At the level of individual species, the following are relevant:

- species listed under EU Directives and international agreements;
- commercially exploited species (in relation to Descriptor 3);
- genetically distinct forms of indigenous species;
- non-indigenous species, particularly those which are invasive (note that these are addressed further, as a pressure, in section 4.2);
- species which are assessed to represent or contribute to the assessment of functional groups (selection of such species should be based upon agreed criteria).

Table 1. Relevant functional groups according to the MSFD.

Species group	Functional group
Birds	Intertidal benthic-feeding birds
	Inshore surface-feeding birds
	Inshore pelagic-feeding birds
	Inshore benthic-feeding birds
	Inshore herbivorous-feeding birds
	Offshore surface-feeding birds
	Offshore pelagic-feeding birds
	Ice-associated birds

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Mammals	Toothed whales
	Baleen whales
	Seals
	Ice-associated mammals
Reptiles	Turtles
Fish	Diadromous fish
	Coastal fish
	Pelagic fish
	Pelagic elasmobranchs
	Demersal fish
	Demeral elasmobranchs
	Deep-sea fish
	Deep-sea elasmobranchs
	Ice-associated fish
Cephalopods	Coastal/shelf pelagic cephalopods
	Deep-sea pelagic cephalopods

The criteria and indicators which are directly relevant for the assessment of the state of birds, mammals, reptiles, fish and cephalopods, plus listed species and those which have genetically distinct forms, are indicated in Table 2. The criteria and indicators provided in the Commission Decision on GES criteria for Descriptors 1 (biodiversity) and 3 (commercially exploited fish and shellfish) are particularly relevant for the assessment of the environmental state of these species groups. Several criteria and indicators for Descriptor 4 on food webs also concern species and functional groups and may therefore need also to be considered although, as mentioned earlier, their application is particularly relevant for assessment at the scale of ecosystems which we consider outside the remit of BENTIS and have therefore not considered.

Table 2. Relevant criteria and indicators with regard to biological features (individual species and functional groups) according to the MSFD

Biological features	Criteria	Indicators
At level of individual species	1.1 Species distribution	1.1.1 species distribution range
		1.1.2 species distributional pattern
		1.1.3 area covered by species
	1.2 Population size	1.2.1 population abundance
	1.3 Population condition	1.3.1 population demographics
		1.3.2 population genetic structure
	3.2 Reproductive capacity of the stock	3.2.1 spawning stock biomass
		3.2.2 biomass indices
	3.3 Population age and size	3.3.1 proportion of large fish

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	distribution	3.3.2 mean max. length
		3.3.3 fish length distribution
		3.3.4 size at first sexual maturation
At level of functional groups	1.6 Habitat condition	1.6.1 condition typical species
		1.6.2 relative abundance
		1.6.3 habitat condition

Table 1 of Annex III to the Directive contains an indicative list of the state characteristics related to the habitat types of the water column and seabed (see Table 3). As indicated in the Commission Decision on GES criteria, the term habitat addresses both the abiotic characteristics and the associated biological community, treating both elements together in the sense of the term biotope. Consequently, the section on habitat types is treated here together with their associated biological features, as follows:

- Water column habitats are combined with phytoplankton and zooplankton communities;
- Seabed habitats are combined with angiosperms, macro-algae and invertebrate bottom fauna, and associated vertebrate fauna.

Table 3. Characteristics with regard to habitat types and associated biological communities

Habitat types	• The predominant seabed and water column habitat type(s) with a description of the characteristic physical and chemical features, such as depth, water temperature regime, currents and other water movements, salinity, structure and substrata composition of the seabed, • Identification and mapping of special habitat types, especially those recognized or identified under EU legislation (the Habitats Directive and the Birds Directive) or international conventions as being of special scientific or biodiversity interest, • Habitats in areas which by virtue of their characteristics, location or strategic importance merit a particular reference. This may include areas subject to intense or specific pressures or areas which merit a specific protection regime.
Biological features	• A description of the biological communities associated with the predominant seabed and water column habitats. This would include information on the phytoplankton and zooplankton communities, including the species and seasonal and geographical variability, • Information on angiosperms, macro-algae and invertebrate bottom fauna, including species composition, biomass and annual/seasonal variability.

The criteria and indicators which are relevant for the assessment of the state of habitat types (predominant and special) are indicated in Table 4. The criteria and indicators laid down in the Commission Decision on GES criteria for Descriptor 1 (habitats) are directly relevant for the analysis of the current environmental status, as are most of those relating to Descriptor 6 on seafloor integrity.

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Table 4: Relevant criteria and indicators with regard to habitat types and associated biological communities according to the MSFD

<table>
<tr><th>Component</th><th>Criteria</th><th>Indicators</th></tr>
<tr><td rowspan="12">Predominant seabed and water column habitat types, including their biological communities (phytoplankton, zooplankton, angiosperms, macroalgae, bottom fauna):
• Littoral rock and biogenic reef,
• Littoral sediment,
• Shallow sublittoral rock and biogenic reef,
• Shallow sublittoral coarse sediment,
• Shallow sublittoral sand,
• Shallow sublittoral mud,
• Shallow sublittoral mixed sediment,
• Shelf sublittoral rock and biogenic reef,
• Shelf sublittoral coarse sediment,
• Shelf sublittoral sand,
• Shelf sublittoral mud,
• Shelf sublittoral mixed sediment,
• Upper bathyal rock and biogenic reef,
• Upper bathyal sediment,
• Lower bathyal rock and biogenic reef,
• Lower bathyal sediment,
• Abyssal rock and biogenic reef,
• Abyssal sediment

Special habitat types, especially those under EU legislation and international conventions</td><td rowspan="2">1.4 Habitat distribution</td><td>1.4.1 habitat distributional range</td></tr>
<tr><td>1.4.2 habitat distributional pattern</td></tr>
<tr><td rowspan="2">1.5 Habitat extent</td><td>1.5.1 habitat area</td></tr>
<tr><td>1.5.2 habitat volume</td></tr>
<tr><td rowspan="3">1.6 Habitat condition</td><td>1.6.1 condition typical species</td></tr>
<tr><td>1.6.2 relative abundance</td></tr>
<tr><td>1.6.3 habitat condition</td></tr>
<tr><td rowspan="5">6.2 Condition of benthic community</td><td>6.1.1 biogenic substrata</td></tr>
<tr><td>6.2.1 presence sensitive species</td></tr>
<tr><td>6.2.2 multi-metric indexes</td></tr>
<tr><td>6.2.3 proportion biomass of individuals above size</td></tr>
<tr><td>6.2.4 size spectrum of benthic community</td></tr>
</table>

2.1.2 Relevant pressures and impacts

The main pressures through which the fishing sector impacts the ecosystem according to the MSFD is biological disturbance, more specifically the extraction of species, and physical damage, i.e. Smothering, Changes in siltation, Abrasion. Therefore only those pressures are considered relevant in this report.

Regarding the extraction of targeted species, the criterion and the associated indicators, under Descriptor 3 on commercially exploited fish and shellfish, is about the level of pressure and associated indicators related to the impacts of fishing on the state of fish stocks:

3.1 Level of pressure of the fishing activity

- *Fishing mortality (3.1.1)*
- *Ratio between catch and biomass index (3.1.2)*

3.2 Reproductive capacity of the stock

- *Spawning Stock Biomass (SSB) (3.2.1)*
- *Biomass indices (3.2.2)*

3.3 Population age and size distribution

- *Proportion of fish larger than the mean size of first sexual maturation (3.3.1)*

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- *Mean maximum length across all species found in research vessel surveys (3.3.2)*
- *95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)*
- *Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)*

The distinction between, on the one hand, the criteria and indicators directly relevant and, on the other hand, indirect linkages to other criteria and indicators, needs to be considered carefully in the case of biological disturbance. This is because it requires an understanding of the resulting effects on biological features ("biological"), although it addresses by definition a form of impact ("disturbance"). Therefore, as a general rule, biological disturbance arising from the extraction of species (target and not-target) is expected to have an indirect effect on the state of all relevant biodiversity components (i.e. at the level of species, habitats and ecosystems) and relate to the criteria and indicators for Descriptors 1, 3, 4 and where appropriate 6.

If pressures from human activities create such a severe impact as to result in physical damage (or even physical loss), it is necessary to identify the extent of seabed and the particular habitats affected or lost. These changes should be assessed by applying the GES criteria and indicators specified in the Commission Decision on GES criteria under Descriptor 6 on sea-floor integrity:

6.1 Physical damage, having regard to substrate characteristics

- *Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)*
- *Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)*

6.2 Condition of benthic community

- *Presence of particularly sensitive and/or tolerant species (6.2.1)*
- *Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)*
- *Proportion of biomass or number of individuals above some specified length/size (6.2.3) Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)*

Some of the indicators mentioned above, particularly indicator 6.1.1 (biogenic substrate), and the indicators listed under criterion 6.2 on the condition of benthic community, can also be categorised as state indicators. Therefore, they are in principle directly relevant also to the description of state. However, this state characterisation only becomes really meaningful once it is combined with a description of the impact, which is captured by other directly related indicators, such as the extent of seabed affected (pressure indicator 6.1.2) or the shifts in biological composition of communities addressed by several of the indicators above.

2.2 Common Fisheries Policy

The revised CFP is now centred around multiannual plans in order to achieve their management objectives which aim to contribute to the sustainable exploitation of the stocks and to the protection of the marine ecosystems concerned. To that end a multiannual plan should include quantifiable indicators for periodic monitoring and assessment of progress in achieving the targets of the multiannual plan, i.e. quantifiable targets such as fishing mortality rates and/or spawning stock biomass and clear time-frames to reach the quantifiable targets.

More specifically the objectives include:

1. *The CFP shall ensure that fishing and aquaculture activities are environmentally sustainable in the long-term and are managed in a way that is consistent with the objectives of achieving economic, social and employment benefits, and of contributing to the availability of food supplies.*
2. *The CFP shall apply the precautionary approach to fisheries management, and shall aim to ensure that exploitation of living marine biological resources restores and maintains populations of harvested species above levels which can produce the maximum sustainable yield. In order to reach the objective of progressively restoring and maintaining populations of fish stocks above biomass levels capable of*

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producing maximum sustainable yield, the maximum sustainable yield exploitation rate shall be achieved by 2015 where possible and, on a progressive, incremental basis at the latest by 2020 for all stocks.

3. *The CFP shall implement the ecosystem-based approach to fisheries management so as to ensure that negative impacts of fishing activities on the marine ecosystem are minimised, and shall endeavour to ensure that aquaculture and fisheries activities avoid the degradation of the marine environment.*

In order to support scientific advice regarding the (previous revision of the) CFP a multiannual program was initiated, the Data Collection Framework (DCF), which includes possible indicators for the economic, social and employment benefits (Objective 1) as well as the implementation of an ecosystem-based approach to fisheries management (Objective 3). The proposed indicators for objective 2 are fishing mortality rates and/or spawning stock biomass.

2.2.1 Economic indicators

The potential economic indicators for objective 1 (see table 5) come from Appendix VI and can be calculated per fleet segment or metier.

Fleet segment: a group of vessels with the same length class (LOA) and predominant fishing gear during the year, according to the Appendix III. Vessels may have different fishing activities during the reference period, but might be classified in only one fleet segment.

Metier: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern.

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Table 5. List of Economic variables according to DCF

Group	Variables
Income	Gross value of landings
	Income from leasing out quota or other fishing rights
	Direct subsidies
	Other income
Personnel costs	Wages and salaries of crew
	Imputed value of unpaid labour
Energy costs	Energy costs
Repair and maintenance costs	Repair and maintenance costs
Other operational costs	Variable costs
	Non-variable costs
	Lease/rental payments for quota or other fishing rights
Capital costs	Annual depreciation
Capital value	Value of physical capital: depreciated replacement value
	Value of physical capital: depreciated historical value
	Value of quota and other fishing rights
Investments	Investments in physical capital
Financial position	Debt/asset ratio
Employment	Engaged crew
	FTE National
	FTE harmonised
Fleet	Number
	Mean LOA
	Mean vessel's tonnage
	Mean vessel's power
	Mean age
Effort	Days at sea
	Energy consumption
Number of fishing enterprises/units	Number of fishing enterprises/units
Production value per species	Value of landings per species
	Average price per species

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2.2.2 Social indicators

As part of the CFP reform (2014) a special document was written on the social dimension of the fishing industry (and aquaculture). Here we provide a summary of this document with a focus on the fishing industry.

Employment trends are negative, in line with the evolution of most primary sectors in the EU - since 2002 the employment declined by 31% in the catching segment and by 16% in aquaculture. In processing employment decreased only by 6.5% since this industry increasingly relies on imports from various MS or from third countries.

In addition to the decline in employment (particularly in the catching sector), the CFP reform Impact Assessment identified as a key problem a low attractiveness of the catching sector, particularly for new generations of fishermen. A recent study of 24 coastal communities shows that fleets have increasing difficulties to complete crews with local, well qualified people and have to resort to foreigners or –in small scale fleets- to continue working even beyond the legal retirement age *(indicator 1: level of education, indicator 2: nationality of the crew members).*

That lack of attractiveness is the result of relatively low wages (compared with jobs ashore) combined with hard working conditions and safety concerns *(indicator 3: number of injuries/accidents, indicator 4: working hours per day/week, and indicator 5: level of wages in both catching sector and processing).* In addition, the number of jobs depending on the fisheries sector is declining in the majority of coastal areas which puts some of them at risk of not being viable in the future.

The simulations conducted in the CFP Reform Impact Assessment show that in the absence of the CFP reform, the decline of employment in the catching segment will continue at a steady pace of 1 - 2% per year *(indicator 6: trend in employment rates)*. Quality of employment, in terms of wages and safety, will remain low. Such an evolution will have severe negative impacts on the viability of most vulnerable coastal communities.

WHAT ARE THE SOCIAL OBJECTIVES OF THE REFORMED CFP?

Social sustainability is one of the core CFP objectives and the reformed CFP aims at achieving the following mid and long-term social objectives for the fishing industry:

- reversing the decline in employment in the fisheries sector, particularly in catching;
- increasing the attractiveness of the fisheries sector and turning it into a source of high quality jobs;
- ensuring the viability of coastal communities by promoting economic growth and jobs;
- facilitating the transition to a sustainable fishing;

All tools of the new CFP would need to contribute to achieving these objectives; however the main tool of the new CFP in this respect is the new European Maritime and Fisheries Fund (EMFF). Compared to the European Fisheries Fund (EFF), the EMFF brings about a fundamental change of approach to public funding to the fisheries sector through a focus on collective actions and on the viability of coastal areas rather than fleet subsidies benefitting mostly vessel owners. Therefore, the EMFF proposes to eliminate most of the current fleet measures and instead use this part of the funding for achieving economic viability of the fleets and aquaculture sector (innovation, value added and marketing) and for the promotion of the development and diversification of areas depending on fishing *(indicator 7: level of funding focusing on innovation, value added, marketing, and development of areas depending on fishing)*.

HOW TO REVERSE THE DECLINE OF EMPLOYMENT IN THE FISHERIES SECTOR?

Achieving environmental sustainability as quickly as possible is a precondition for social sustainability. The simulations in the CFP reform Impact Assessment show that once MSY levels are achieved, TACs will go up; the overall increase being at least 20% by 2020. Such a significant increase has a potential to create new jobs in the catching sector, as shown by the fact that, according to the simulations, employment per vessel increases already after 2017. This is also in line with experience of countries such as New Zealand, where the use of management instruments allowing for the transition to sustainable fishing, very similar to those proposed by CFP reform, ultimately resulted in increases in catches and, consequently, in employing more capital and manpower in the fleets.

It is also in line with the EU's own experience as 13 EU stocks are already at MSY level and some others will reach it in one or two years. That has allowed for TAC increases for 2012 (e.g. herring in Celtic Sea, cod in Irish

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Sea, anglerfish in the South West Atlantic and North Sea Herring to mention only a few). It is precisely these TAC increases that help to maintain employment in the sector and represent a significant source of additional income for fishermen. As examples, these increases may represent an additional income of €10 million for herring fishermen in the Celtic Sea, an additional €13 million for cod fishermen in the Irish Sea or €12 million more income for anglerfish fishermen in the West Atlantic. The biggest increase will be felt by the herring fishermen in the North Sea whose income may double to €212 million following the sustainable management of this stock towards MSY 2015.

However, the problem associated to MSY objectives is the hard transition period, where additional short-term job losses are to be expected in EU fleets dependent on overfished stocks and showing overcapacity, which characterises the majority of EU stocks. Support will be available under the new EMFF to help fishermen navigate the transition period to environmental sustainability. However, the above data are clear proof that the economic reward for the short-term difficulties is well worth the effort and what is more, the additional economic wealth will have a positive impact on all coastal areas in the EU.

Increased catches would also create additional employment in processing *(indicator 8: employment rates in processing)*. In that respect, estimations show that at least 4,500 additional jobs will be created in processing, mostly in fisheries-dependent coastal areas.

HOW TO INCREASE THE ATTRACTIVENESS OF THE FISHERIES SECTOR?

Improving the attractiveness, particularly of the catching sector, requires actions intended, on one hand, to increase income and wages, and, on the other, to improve working conditions, training and safety. Fishing on sustainable stocks would also increase income and wages: simulations done for the Impact Assessment of the CFP reform show that the average wages under the reformed CFP will nearly double in comparison to what would happen in the absence of reform.

The following measures under the EMFF aim at reducing fishing costs or increasing income:

- Measures to facilitate the transition to environmentally sustainable CFP: the purchase of selective gears *(indicator 9: number of selective gears)*, investment in equipment allowing storing discards on board *(indicator 10: investment in equipment for storage of dicards on board),* and investments on the necessary port facilities to land unwanted catches, *(indicator 11: number of investments done in port facilities to land unwanted catches)* etc;
- support to marketing and business development intended to improve income through more involvement in selling and marketing their products. Support to product quality, labelling and certification, and to the development of new markets *(indicator 12: amount by the industry spend on marketing, indicator 13: funding available for improving product quality and certification)*;
- better market organisation through the reinforced support to Producers Organisations and through promotion of collective projects carried by fisheries organisations; and
- focus on innovation in order to promote new ideas and products across the value chain.
- support to new activities carried by fishermen which might complement their income (involvement in NATURA 2000 management, litter collection).

The EMFF will be also an important tool for improving working conditions, training and safety. In that respect, it will support:

- safety and health measures, including both on board modernisation and individual safety equipment and contributing to better working conditions; *(indicator 14: safety and health measures taken on board)*
- professional advice and training eligible to spouses of fishers and helping them to run family's fisheries business; and *(indicator 15: availability of professional advice and training to spouses of fishers).*
- vocational training, re-qualification and life-long learning *(indicator 16: availability of vocational training for fishers)*

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All these actions should significantly improve the attractiveness of jobs, particularly of the catching sector. They need however, to be given priority by Member States in the EMFF Operational Programmes. CFP reform tools give Member States a significant margin of manoeuvre to define and achieve social objectives with the only condition that national preferences do not jeopardise the potential of the CFP reform to achieve environmental sustainability in the short term.
A quick ratification by MS of two important Conventions concerning fishermen, i.e. the ILO Convention C 188 on work in fishing and the IMO Convention on Standards of Training, Certification and Watchkeeping for fishing vessel personnel will be important to further enhance the attractiveness of the sector.

HOW TO ENSURE THE LONG TERM VIABILITY OF COASTAL COMMUNITIES?
The EMFF focuses on people, particularly small scale fishermen and on coastal areas depending on fishing. The focus on small scale fishermen is achieved by the inclusion of dedicated measures (such as business advisory services), *(indicator 17: availability of business advisory services to small scale fishers)* by a higher aid intensity and by the creation of the link between the financial allocation and the share of these fleets. Beyond the EMFF, the new CFP would maintain the current access limitations in the 12 nautical miles waters and existing provisions in relation to control, such as the derogation to the vessel monitoring system equipment.
Regarding coastal communities, the EMFF builds on the success of the current Axis 4 of the EFF with increased funding options for sustainable development of fisheries areas, optional co-ordination of EMFF with local funding strands available under ERDF and EARDF, and with more funding available overall.
Integrated local development strategies should become a tool for coastal areas to promote new employment opportunities, within and beyond the fisheries sector. The potential for this economic diversification is broad and includes job creation in the dynamically expanding new maritime sectors, such as pesca-tourism and valorisation of fisheries cultural heritage. At the same time, they can support the increase of the contribution of fisheries and aquaculture activities to local economies through actions aiming at increasing their value.
The EMFF also includes, for the first time, an IMP pillar, managed centrally. Its implementation will help to explore new possibilities of growth and jobs the maritime economy and coastal regions. Member States can also take additional measures under EFF, by directing more towards Axis 4 as a way to speed up the process of job creation which in many coastal areas has already started.
Finally, closer co-ordination of EU funding – through Common Strategic Framework, Partnerships Contracts and Community-led Local Development – opens up new possibilities for creation of jobs in fisheries dependent areas. For example, European Social Fund can be used for re-training and getting new skills for fishermen while projects aiming at urban re-generation funded under ERDF can directly benefit coastal communities.

2.2.3 Environmental indicators involving the wider ecosystem impacts

Information collected under the Data Collection Framework (DCF) can support assessments of environmental status and fishing impacts on GES beyond just Descriptor 3. Appendix XIII of (EC 2008a) specifies 10 environmental indicators of the 'effects of fisheries on the marine ecosystem' (hereafter referred to as 'the DCF indicators'). The ability of the DCF indicators to be operationally applied for MSFD assessments of GES descriptors *other* than Descriptor 3 is discussed below. A summary of the potential relationship between MSFD criteria and DCF indicators is presented in table xx. Prior to discussion of the application of the DCF indicators it should be noted that the DCF indicators were proposed to integrate general environmental considerations into fisheries management, rather than the specific requirements of the MSFD, and were only specified with provisional reference levels or for use with reference trends, rather than specific reference levels. Only DCF indicator 7 is considered specifically relevant for BENTHIS.

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Table 6. Relationship between the DCF indicators and MSFD criteria for GES.

	Indicator	Criteria	Fixed calculation method	Reference level
1	Conservation status of fish species	1.2.1	Modifications proposed	Proposed
2	Proportion of large fish	1.7.1, 4.2.1	Regionally specified	Proposed in regions
3	Mean maximum length of fish	1.7.1		No
4	Size at maturation of exploited fish species	3.3.4	Modifications proposed (see section 8.1.4)	No
5	Distribution of fishing activities			
6	Aggregation of fishing activities			
7	Areas not impacted by mobile bottom gears	1.6, 6.1.2	Options proposed	No
8	Discarding rates of commercially exploited species			
9	Discarding rates in relation to landed value			
10	Fuel efficiency of fish capture			

2.3 OSPAR

The OSPAR Convention is the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. Work under the Convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Union. The Intersessional Correspondence Group on the Coordination of Biodiversity Assessment and Monitoring (ICG-COBAM) has agreed on a common list of indicators of which those related to fish and benthic habitats may be relevant for BENTHIS:

Fish

- Population abundance/biomass of a suite of selected species. The population abundance/ biomass indicator measures the size of the catchable proportion of fish populations by survey. The indicator can either be weight based, which gives a measure of biomass, or numbers based which gives a measure of abundance. Biomass and abundance indices are in most cases relative and require surveys to be conducted at regular intervals (eg annually), in the same area, in the same season and with a standard gear. The indicators are sensitive to fishing, but also to environmental conditions. There are currently extensive surveys conducted across the OSPAR region to measure the abundance/biomass of commercial fish. Some of these surveys such as demersal fish trawl surveys also provide abundance and biomass on non-commercial fish species. There are however certain functional groups and subregions that are not adequately covered by current monitoring programmes.
- OSPAR EcoQO for proportion of large fish (LFI). The proportion of large fish indictor (LFI) is a size based indicator to measure the proportion of large fish by weight in the assemblage, reflecting the size structure and life history composition of the fish community. Size based indicators are considered suitable to measure the effects of fishing on the fishing community as they are responsive to fishing impacts. The LFI takes no account of species identity but rather that of individual size and provides a measure of the relative composition in terms of size of individuals making up the community. The LFI was developed as an OSPAR EcoQO for fish community structure in relation to the impacts of fishing (Greenstreet et al. 2011). Data for this indicator comes from scientific fisheries surveys which sample the whole fish community and the methods require that surveys are conducted at regular intervals (annually) in the same area with a standard gear. Targets are set according to the principle that the fish community is moving towards

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recovery from fishing. The LFI is part of the indicator suite that member states have to report on under the data collection framework directive to evaluate the effects of fishing on the ecosystem (2010/93/EU). Currently, the most important data source for the LFI is fisheries groundfish surveys which are conducted as part of the ICES international bottom trawl survey programme in the North Sea, the Celtic Seas, Bay of Biscay and Iberia.

- Mean maximum length of demersal fish and elasmobranchs. The mean maximum length indicator (MML) is a size based indicator to measure the life history composition of the fish community. Size based indicators are considered suitable to measure the effects of fishing on the fishing community as they are responsive to fishing impacts. This indicator uses species' Lmax as a proxy for life-history characteristics and measures the potential size of species making up the community. The MML indicator is the average Linf (or Lmax) of fish making up the sampled community and provides a measure of the relative composition of species within the community. The MML does not reflect any change in size structure of individual populations. Data for this indicator comes from scientific fisheries surveys which sample the whole fish community and the methods require that surveys are conducted at regular intervals (annually) in the same area with a standard gear. Targets are set according to the principle that the fish community is moving towards recovery from fishing. The MML is part of the indicator suite that member states have to report on under the data collection framework directive to evaluate the effects of fishing on the ecosystem (2010/93/EU). Currently, the most important data source for the MML is fisheries groundfish surveys which are conducted as part of the ICES international bottom trawl survey programme in the North Sea, the Celtic Seas, Bay of Biscay and Iberia.

Benthic habitats

- Typical species composition. The indicator reflects the condition of benthic habitats by assessing either the integrity of the typical species composition within the associated community or the state of selected sensitive species. While the first describes the condition of the community more broadly or generic, the latter might be directly linked to a single pressure such as eutrophication. Typical species lists are commonly used in most national monitoring and assessment systems (e.g. according to the Habitats Directive Art. 17 reporting), but still have to be adapted and extended to the special requirements of the MSFD. The assessment is generally based on the simple presence of the species but potentially also on quantitative values like abundance, biomass or coverage which are usually generated in most monitoring programs. If simple species lists are used, the divergence from the full list may be interpreted as a degree of degradation leading to the target to maintain a substantial ratio of typical species of all regarded communities.
- Multi-metric indices. Diversity indices and species richness indices as well as sensitivity/tolerance species classification systems are since long used to assess the qualitative state of benthic communities. The development of multi-metric indices, combining these indices and classifications, was made mandatory by the EU Water Framework Directive (WFD). Here, the different indices used are presented and a new MMI is proposed. The latter has not yet been fully endorsed by the expert team, however, the proposal to BDC is the use of an MMI (this or similar concept) as such. The proposed MMI contains a diversity indicator (e.g. Shannon index or Simpson index), a species richness indicator (e.g. the number of species, Margalef d) and an indicator for the proportions of sensitive, tolerant and opportunistic species of the benthic community (e.g. AMBI or the Infaunal Trophic Index (ITI)). This metric is expected to give a useful integrated quality score of the condition and functionality of the infaunal benthic community. The proposed MMI responds well to the pressure of among others oxygen depletion by organic matter, sand extraction and hydrodynamic pressure, as demonstrated in transitional waters. Pressure-impact validation of the MMI setup with physical pressures (e.g. fisheries) is an important point of attention. The collection of quantitative pressure data and the construction of a suitable pressure index is a key step in the pressure-impact validation of this MMI. The current monitoring is mostly adequate for the use of this MMI, because it is estimated that most countries use box core sampling.
- Physical damage of predominant and special habitat. This indicator aims to address the most important pressures to sea floor habitats in the OSPAR area which are those causing physical damage. It is an area-related indicator closely linked to condition elements. It is being designed to assess predominant as well as special habitat types and regarded particularly useful to target larger sea areas with relatively low effort. It builds upon two types of information, i) the distribution and sensitivity of a particular habitat type and ii) the distribution and intensity of human activities potentially causing physical damage, such as mobile bottom contacting fisheries, sediment extraction or offshore constructions. Although the proposed approach is mainly focused on physical pressures, habitat damage caused by other pressures such as

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eutrophication, hazardous substances etc, could also be accommodated within this approach, as long as information on habitat sensitivities and pressures information are available. Data for this indicator could be mainly derived from activity data sources such as EIAs and VMS data, and potentially from the Data Collection Framework (DCF). It is envisaged that some data collection and analysis for the testing and validation of this indicator could be required, in particular to improve the confidence of the approach.

- Area of habitat loss. The proposed indicator assesses the proportion of the area of habitats that are permanently or for a long-lasting period lost due to anthropogenic pressures. In principle, any habitat type may be assessed on the basis of this indicator through the processing of spatial pressure data and the compilation of modelled, interpolated or directly measured habitat extent.
- Components of this indicator (some special habitats) are transferable from the assessment of habitat area according to the requirements of the Habitats Directive. For predominant habitats in the wider sea area the indicator addresses the highest impact on benthic habitats caused by human activities: total functional loss and physical loss of area by building upon two types of information, i) the distribution and sensitivity of a particular habitat type and ii) the distribution of human activities that might lead to a loss of area (e.g. harbour construction, coastal protection, offshore constructions, sediment extraction). Overall the indicator is partially developed. It originates from merged proposals from the OSPAR ICG-MSFD Workshop (Amsterdam, November 2011) and fulfils indicator 1.5.1 of the EU COM decision. A large part of this indicator is dependent on pressure data that is, in principle, already available, rather than on practical sampling and direct state assessments, the costs for monitoring low risk (predominant and certain special) habitats is therefore foreseen as relatively low. However, additional monitoring effort may be needed for some special habitat types.

3 REVIEW OF MANAGEMENT MEASURES

3.1 Approach

By fisheries management we mean: "The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives".

In literature several ways are mentioned to categorise management measures. For the evaluation of potential management measures we distinguish between the governance part involving the incentives to be applied and the physical impact part mitigating the actual impact of the fishing activities. In the BENTHIS project we will focus our evaluation on the performance of the measures to mitigate the latter (i.e. physical impact) part but will be considering how these can be best achieved in the current institutional context. This is addressed in two sections, the first describing the possible incentives and the second consisting of a few case studies showing how this performance is measured.

3.2 Governance perspective

In governance literature management measures are distinguished according to three different types of governance (van Vliet and Dubbink, 1999 ; Gray 2005):

1. The hierarchical governance model. Hierarchical governance is the 'state-centric' or 'directive' mode of fisheries governance, featuring a principal role for the state. The psychological underpinning of hierarchical governance is Hobbesian – that human nature is self-centred and egoistical, and that the only way to avoid "the tragedy of the commons" (Hardin 1968) is to institute strict measures of control, backed up by force. Typically, this requires input and output controls, such as area and time restrictions, minimum landing sizes, prohibition on certain gears, days-at-sea, regulation of fishing gear, mesh size and catch composition regulations, bag limits and TACs. Also decommissioning schemes, satellite surveillance, and inspectors on boats and in ports to check that catches and landings do not break the rules are examples of the hierarchical governance model. In other words, the stick rather than the carrot is necessary to discipline fishers' behaviour that puts fish stocks at risk.

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2. Market based governance model. This model follows the classical economic theory of Adam Smith, in that it assumes that the pursuit of individual economic self-interest within the legal framework of the protection of rights of life, liberty and property will lead to the optimal benefit for everyone. Applying this to fisheries, instead of trying to replace the free market forces of supply and demand (as the hierarchical CFP does by adjusting fish price levels; imposing the principle of relative stability; designating special boxes, such as the Ireland and Shetland boxes; and creating The Hague preferences), government should adjust market carrots and sticks to reward self-interest behaviour that protects public resources, and punish self –interest behaviour that damages them, and then leave the forces of supply and demand to get on with it. Although sometimes the market structure needs to be adjusted in such a way as to incentivise producers to take good care of the resources. An ITQ system fits well in the market based governance model as it has the assumption that people are much more likely to look after a resource that they themselves own. Also subsidies are a way to incentivise producers.
3. Participatory governance model. This model contains four distinct sub-types: industry self-regulation; co-management; community partnership (e.g. community quotas); and environmental stewardship (e.g. ecosystem based approach, as long as stakeholders have an influence on aims, RACs, and eco-labelling schemes). The essence of legitimacy in this mode lies in the involvement of stakeholders in decision-making.

Incentives can be influenced by (de Vos et al, 2013):

- Markets (e.g. through prices)
- Civil society (e.g. through labels and fish guides)
- Government (through management measures)

An incentive can be defined as 'any factor (financial or non-financial) that provides a motive for a particular course of action or counts as a reason for preferring one choice to the alternatives'. When influencing incentives through management one has to be constantly vigilant about what kind of perverse incentives are being created at the same time that one is trying to create positive incentives. We distinguish between three types of incentives:

- Financial incentives
- Coercive incentives
- Social/moral incentives

Financial incentives exist when an actor can expect some form of material reward — especially money — in exchange for acting in a particular way. They are applied because market prices usually do not integrate all costs and benefits. As a result, too much or too little is consumed or produced. In order to overcome this subsidies, charges and taxes are introduced to improve the functioning of markets. In fisheries policy financial incentives are a commonplace, although they have not always had the desired effect. For example decommissioning schemes stimulated the termination of the least efficient companies, and the result was that remaining fishermen were fishing more efficiently. Also tax reductions on fuel expenses led to dependence on fossil fuel (de Vos et al, 2013). Finally, higher prices or subsidies for eco-friendly fishery products led to an increase in demand, but at the same time also created an incentive to mislabel food (fraud) in order to earn more money.

Coercive incentives exist when a person can expect that the failure to act in a particular way will result in punishment (e.g. a fine, imprisonment, confiscating or destroying possessions) by others in the community (business dictionary). The idea behind these incentives is that because of the threat people will behave the way we would like them to behave. A downside is that it needs a high level of enforcement, especially when rules are not considered as legitimate.

Finally, social incentives involve the potential psychological costs (e.g. exclusion) to an individual of not behaving in line with a social norm. Social norms can provide an incentive for individuals to follow a certain course of action, which might be different from that based on financial incentives (Bruggen and Moers, 2007).
This last category of incentives is not often applied in fisheries management, but they can work well as people are social animals, which means their behaviour is largely influenced by the (perceptions on the) behaviour of other people (peer pressure, trust/distrust). When for example average numbers of discards are shown to

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fishermen, and they see what the social norm is, the ones that are above the norm will most likely adapt their behaviour, and start diminishing the amount of discards. (de Vos et al, 2014).

3.3 Case studies

This review is based on a number of case studies, some empirical, others based on computer simulations. These case studies are not intended to be comprehensive but provide the background to develop the framework for the evaluation of the BENTHIS management measures.

3.3.1 Plaice box

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’ (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. 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 and 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) and 1999 (ICES 1999). In 2004, an assessment of the ecological effects in the plaice box was performed (Grift 2004). And in 2010, IMARES has performed an evaluation of the effectiveness of the plaice box (Beare et al. 2013). 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 to reduce discarding and improve plaice yields and biomass. Literally “to establish seasonal limitations on certain fishing activities in the North Sea in order to limit fishing on juvenile plaice” (EU Council Resolution 4193/88).

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Table 7. Effect of the implementation of the plaice box arranged per D,P, S category and distinguishing between the ecological and the socio-economic realm.

		Seasonal closure (1989–1994)	Permanent closure (1995-present)
Driver	Capacity		
	Effort	Total fishing effort by Dutch beam trawlers inside the PB fell to 15% of the pre-box level. Spikes in fishing effort during quarters when the PB was temporarily opened. Effort by exemption fleet increased inside the PB	Total fishing effort by Dutch beam trawlers inside the PB fell to 3% of the pre-box level. Decrease of all metiers except shrimp trawlers. Many of the changes in the commercial fishery are unlikely to be driven only by the availability of the fish as the same temporal patterns are observed outside the PB
	Efficiency		
Pressure	Physical damage habitat		
	Input of organic matter		
	Fishing mortality/Selective extraction of species		The catch rate of demersal fish in the beam trawl survey in the PB showed an overall decline from over 300 kg·h−1 in the late 1980s to around 75 kg·h−1 in the 1990s and 2000s.
State	Fish	Diversity increased until 1995.	Diversity increased after a sharp drop in 1996 probably caused by the cold winter. Overall the time trends in biomass and diversity of demersal fish in the PB closely resembled those observed outside. Decrease in the growth rate of juveniles Offshore shift in distribution of juvenile plaice
	Habitat		Marked increase of the epibenthic predators Cancer pagurus and Asterias rubens
	Mammals		
	Seabirds		
	Environment	Temperatures have increased in both winter and summer, whereas the input of inorganic nutrients important in promoting primary production (e.g. phosphate) has fallen	
	Socio-economic		over 80% of the earnings by small (b=221 kW) shrimpers were made inside the PB. The small beamers targeting plaice and sole derive only 19% of their earnings from the area. The PB is also important to large static netters, mostly registered to Denmark, where they get 32% of their revenues.

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The observed changes in the benthos and demersal fish of the southeastern North Sea are more likely related to changes in environmental conditions that are unrelated to the establishment of the PB. These environmental changes may have confounded the effect of the PB. Decrease in growth, although coinciding with a similar decrease in their main food (endobenthos), is probably more related to a decrease of benthic production precipitated by declining levels of nutrients like phosphate and nitrate. It should be stressed here that it is the general North Sea wide reduction in fishing mortality, due to the substantial decreases in the fishing effort and capacity, which have allowed the plaice stock to increase despite the continued high level of discarding (Aarts and Poos, 2009). The PB had a different effect on the various fisheries. The large flatfish beamers lost important fishing grounds inside the PB and were displaced to more distant fishing grounds. Although the exemption fleets (b=221 kW) are allowed to fish in the PB in the absence of competition from the larger vessels, their effort in, and landings from, the PB, relative to the rest of the North Sea have fallen. The real beneficiaries, therefore, have been the shrimpers showing a steady increase in effort, landings and earnings (Fig. 3). Table xx. Percentages of effort, catch and earnings inside the PB of total (in and outside the PB) effort, catch and earnings for small (b=221 kW) and large (>221 kW) vessels (mean of the years 2005 to 2008) for Denmark, Germany and the Netherlands combined, calculated using VMS data.

Table 8. Percentages of effort, catch and earnings inside the PB of total (in and outside the PB) effort, catch and earnings for small (b=221 kW) and large (>221 kW) vessels (mean of the years 2005 to 2008) for Denmark, Germany and the Netherlands combined, calculated using VMS data.

Métier	Effort	Catch	Earnings
Engine power < =221 kW			
Beam 16–31	79	82	82
Beam 90–99	23	22	19
Beam > 100	64	73	71
Gill–trammel	29	32	34
Other	13	14	14
Otter 80–99	3	4	4
Otter > 100	20	20	20
Engine power >221 kW			
Gill–trammel	31	25	32
Other	19	27	27

Conclusions

- It is necessary to set clear and inviolable objectives at the outset as well as designing a framework for evaluating its effectiveness. Initially the instigation of the PB was considered as a “Technical Fisheries Management” initiative to reduce discarding and improve plaice yields and biomass. Literally (EU Council Resolution 4193/88) “to establish seasonal limitations on certain fishing activities in the North Sea in order to limit fishing on juvenile plaice”. Later various stakeholders suggested new conservation objectives for the PB far exceeding its original remit.
- Fisheries scientists were naïve not to take the potential socio-economic, political, and governance dimensions into account.
- The fact that so much of the small plaice population lives outside the PB now renders any positive effects very small. Nevertheless the political decision to maintain the PB remains resulting in a loss of support among the fishing industry for MPAs, which will no doubt frustrate the eventual realization of a network of MPAs to achieve biodiversity and conservation obligations (Verweij and van Densen 2010).
- The story of the PB also highlights how poorly we still understand marine ecosystems, and the difficulties scientists have predicting how they will react to stimuli such as changing fishing effort.
- Assessment of the utility of the PB has been hampered because it was not set up so that it could be scientifically evaluated.

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Figure 1. Time-trends in endobenthos, epibenthos, fish, and environmental data 1970–2010 inside the Plaice Box but outside the 12 nm zone (full line: in–out), inside the Plaice Box but inside the 12 nm zone (dotted line: in–in), and completely outside the PB (dashed line: out–out). The horizontal bars indicate the periods of partial and complete closure.

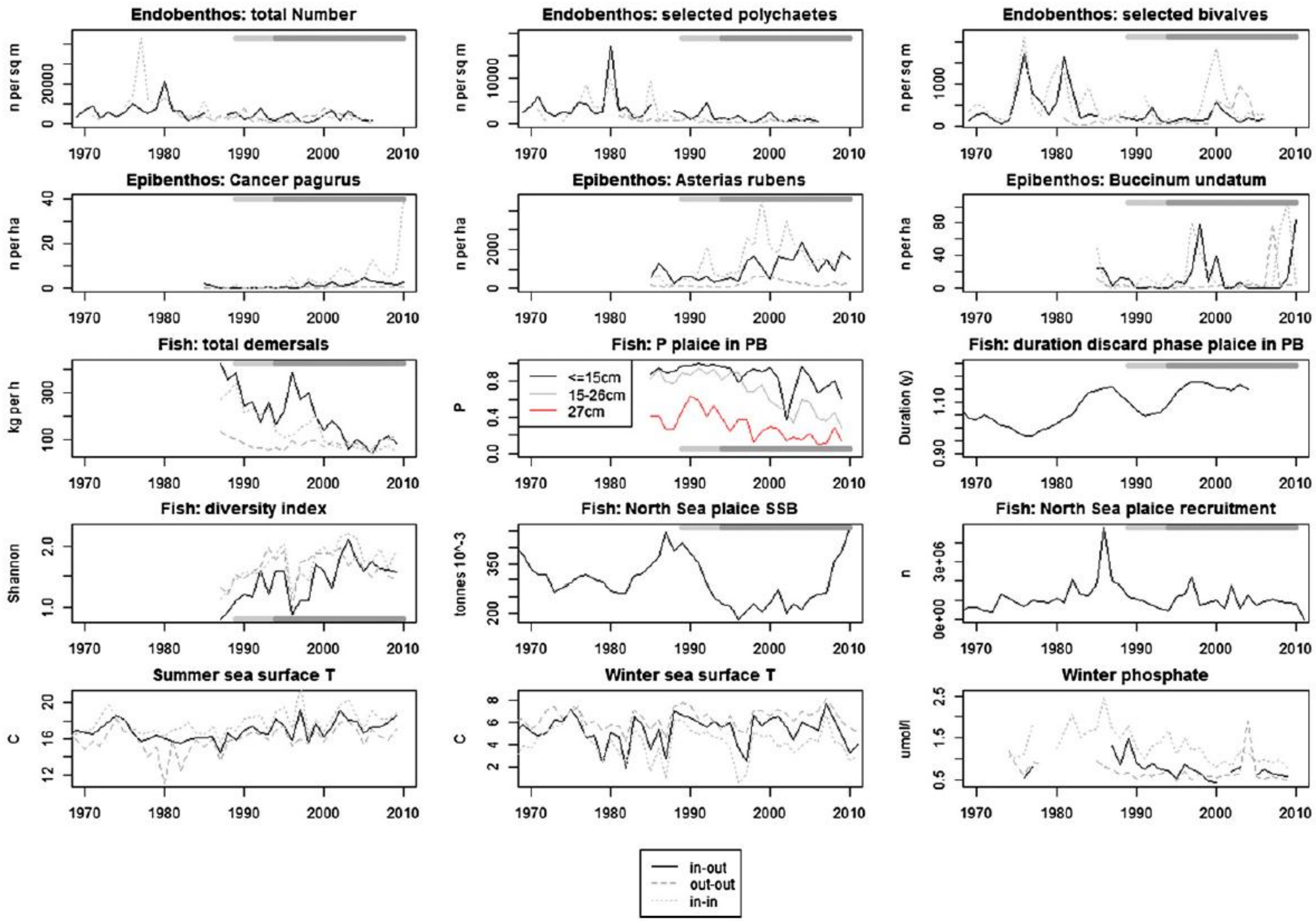

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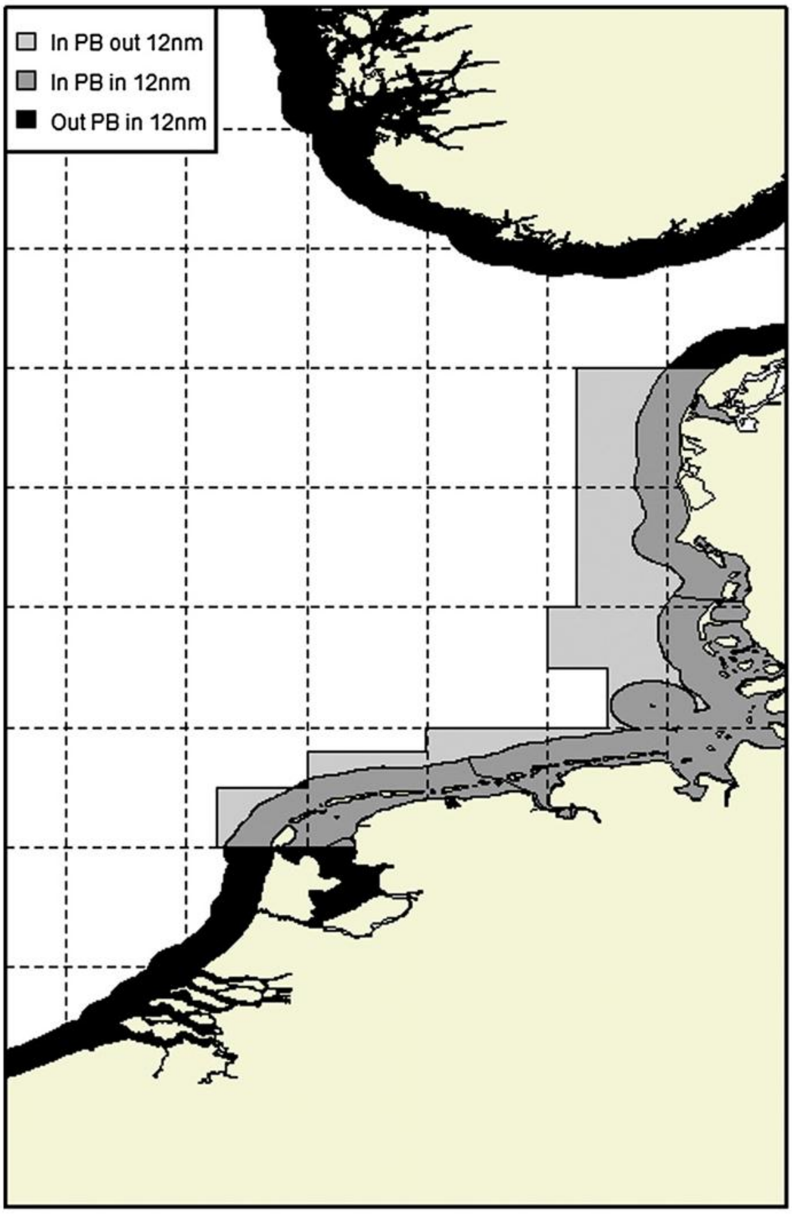
Figure 2. Map of the Plaice Box and the areas used to assess its effect: (i) inside the PB and the 12 nm zone (in–in); (ii) inside the PB but outside the 12 nm zone (in–out); and (iii) outside the PB and inside the 12 nm zone (out–in); and (iv) outside the PB and outside the 12 nm zone (out–out).



3.3.2 Closed areas for the protection of commercial fish stocks

Several closed areas (CAs) were implemented for the protection of commercial stocks. These CAs were evaluated by (STECF 2007) and the results are summarised below.

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Table 9. Summary of the evaluation of nine CAs for the protection of commercial fish stocks by (STECF 2007).

Closed Area (CA)	Goal	Indicators
North Sea sandeel closure	Avoid adverse changes in the north west North Sea food web; sandeel abundance remains high enough to provide food for a variety of predator species	Number of fledged chicks per kittiwake nest
	Avoid negative ecosystem effects of fisheries displacement; Minimise displacement of sandeel fishery to previously low and unfished areas	Monitoring fishery landings and effort inside and outside the CA
Norway pout box	To reduce the fishing mortality on juvenile gadoids such as, haddock, cod and whiting	Disaggregated catch rates from IBTS surveys of Norway pout and juveniles of cod, whiting and haddock inside and around the CA Catch rates of the same species from commercial fishery around the box based on further disaggregated catch data and from trial fishery with commercial vessels both inside and outside the CA
Area VIa cod closure	Protect spawning aggregations of cod	SSB and Fishing mortality Size structure (abundance by size class)
Area VIIf and g cod closure	Protect spawning aggregations of cod	Level of compliance F and SSB Catchability of cod by fleet metier. Timing and distribution of spawning aggregations relative to CA
Irish Sea cod closures	Protect spawning aggregations of cod	
Closures for hake stock	Improving the selection pattern and protecting juveniles	F at age or length
Herring spawning closures	Protection of herring stock through the prevention of fishing on herring spawning aggregations during specified period of time	F and SSB Timing and distribution of spawning aggregations relative to CA
Herring nursery closures	Protection of herring stock through the prevention of fishing on juveniles	Compliance Selectivity pattern Distribution of juveniles relative to CA

Objectives

For some of the older closures, these objectives were not stated in the regulation but could be assumed, whilst for others the objectives remained a mystery. For stocks the Closed Area (CA) is designed to benefit, ideally, the objectives will have been established as part of the design and regulation process. The objectives of CAs are generally focused on the following for specific areas at specific times of the year, if not all year:

- protect spawning stock/grounds
- protect juveniles/nursery grounds.

There is potential for coincidental habitat and species conservation benefits through such CAs, i.e. nature or biodiversity conservation objectives. Such benefits are unlikely for temporary CAs but are very likely for permanent restrictions for habitats and species that occupy the same compartment of the CA, particularly

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habitats and species that are impacted by the gears that are banned in the CA, e.g. benthic habitats, and species will benefit where demersal gears that impact them are banned.

Having clear objectives is a key prerequisite for evaluation.

Indicators

Ideally, for any given CA the following parameters should be monitored both pre and post-closure (time series data), and both inside and outside the CA (spatial data), i.e. Before- After-Control-Impact experimental design (BACI).

- Fishing effort and mortality (retained and discarded) for the total area of the stock in question;
- CPUE: for surrounding open area where stock is exploited and/or in the CA during the open season. This will provide for extrapolations to assess density gradients of the stock(s) in question across the CA boundaries, i.e. the effectiveness of the CA in reducing fishing mortality and increasing stock densities. These should be derived from a combination of experimental trawls and data derived from log books, rather than a reliance on the latter.
- Population structure inside and outside the CA: gradients. This will provide for assessments of the effectiveness of the CA in increasing the stock reproductive potential. These should similarly be derived from a combination of analyses of experimental and commercial trawls.
- Actual assessments of fish movements for the stocks in question would be undertaken through the tagging of fish and studies on propagule/larvae movements (otolith micro-chemistry, particle tracking, population genetics)
- If the CA is designed to reduce the bycatch of sympatric stocks, eg Norway Pout CA to protect other roundfish, the total bycatch in the fisheries surrounding the CA should be monitored as it is important to determine the bycatch through displaced effort around the CA. If the effort required to take the TAC has increased due to the CA preventing exploitation of the denser target populations, it is possible that the total bycatch may actually have increased if the distribution of the sympatric stocks is not the same as the target stocks.

Evaluation

The problem with every CA management measure was that a proper evaluation was not possible because the design of the CA did not allow this. The recommendation to (partly) resolve this is that CAs should be designed so that they can be evaluated using existing data. In other words, since most stock evaluation data is collected on the basis of specific spatial units (e.g. ICES rectangles), the boundaries of CAs should also be designed on the basis of these units where possible. Where not possible, systems for recording fishing activities and catches should be designed to provide data separately for the closed and non-closed areas at the appropriate spatial resolution.

The following confounding factors may hamper the evaluation of the CA:

- Trends in fleet structure through, for example, vessels switching from gears restricted or banned in the CA to gears that target other stocks but can still directly/indirectly affect the stocks on which the CA is focused: creeping technical/effort shifts, particularly those related to the impacts of derogations in the CA, e.g. smaller, less powerful vessels allowed to fish, vessels from certain member states allowed to fish or gain earlier access;
- Trends in the behaviour of the fleets related to the CA, e.g. the impacts of ‘fishing the edge’; the impacts of displaced effort on the target stocks of the CA and for other target stocks, recognising that effort displacement arguably applies to any restrictions on fishing;
- Trends in fleet structure and behaviour related to changes in market conditions, technological developments, etc.
- Impacts of illegal fishing in the CA;
- Impacts of wider scale technical regulations, effort reductions, etc;
- Environmental changes due to natural and other anthropogenic factors that affect the status and distribution of stocks. Some of these factors are under the control of the CFP and could be minimised in order to support CA evaluations. This may, however, be counterproductive as wider scale measures often complement site specific measures such as CAs in improving fish stocks, so a trade-off must be made between designing a rigorous evaluation programme and recognising the necessity for concurrent wider

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scale regulatory changes, all be they changes that represent confounding factors in CA evaluation. Confounding factors that are not under the control of the CFP such as natural environmental changes and those related to other regulatory frameworks must, as far as is practicably possible, be taken into account in CA evaluations.

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4 PROPOSED SUITE OF BENTHIS INDICATORS

In this chapter we present the comprehensive suite of BENTHIS indicators including ecological, economic and social indicators. While the economic and social indicators are adopted from existing frameworks, new ecological indicators needed to be developed in order to cover the provision of ecosystem services that need to be considered when developing EBM.

4.1 Approach for additional ecological indicators

In order to assess the state of the seafloor, the pressure of the fishery and its impact on the integrity of the seafloor and evaluate the performance of management measures to reduce this impact we developed an approach that allows the selection of a comprehensive suite of operational indicators. Ultimately the selection of which of these indicators can be made operational in a particular (sub)region depends on the availability of data.

The DPSIR framework is often applied to understand the causal relationships that determine the effects of human activities on the environment and how this can be mitigated through management. The selection of indicators to assess the impact of fishing on the seafloor is therefore based on this framework and the different pathways through which fishing may impact the seafloor are given in table 10. The three pressure categories distinguished in table xx1 with its proposed indicators are given in table 11.

Table 10. The different mechanisms through which fishing may impact the seafloor. The pressures and state components are according to the MSFD Annex III. For the seafloor we distinguished between two types of predominant habitats and their associated benthic community because the mechanisms of impact differ.

Mechanism	MSFD Pressure	State: Ecosystem component		State aspects impacted
Direct effects through extraction of shellfish Indirect effects of removal of fish through predator-prey relationships	Biological extraction	Benthos		Abundance/Biomass Productivity Structure: • Size • Taxa • Functional groups
Destruction of structural elements	Abrasion Habitat loss	Habitat	Rock and biogenic reef	Various habitat functions
Disturbance of sediment (e.g. Homogenisation, Compression, Resuspension)	Habitat loss Smothering Siltation Nitrogen & Phosphorus enrichment	Habitat	Sediment	Various habitat functions
Trawl-path mortality	Abrasion Smothering	Benthos		Abundance/Biomass Productivity Structure: • Size • Taxa • Functional groups
Food subsidies through discarding	Input of organic matter	Benthos		

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Table 11. Proposed operational indicators for three types of fishing impacts (CFP) or pressures (MSFD). These indicators should be reported per metier and aggregated per (sub-)region across metiers (i.e. total).

MSFD Pressure category	CFP Fishing impacts	Proposed indicator
Biological extraction	Catch	Catch per species, per year Landings per species, per year
Abrasion/smothering/habitat loss	Habitat damage	Frequency of disturbance per habitat per unit area Frequency of disturbance per unit area
Input of organic matter	Discarding	Amount of discards per species, per year returned to the sea

Table 12. Proposed operational indicators for the relevant aspects of state of the seafloor. This is based on the criteria for the MSFD seafloor integrity descriptor. Where possible these indicators should be reported per predominant habitat (see table xx4) and aggregated across the total MSFD (sub)region.

State category	MSFD criteria	MSFD indicators	Proposed operational indicator
Physical habitat	6.1 Physical damage, having regard to substrate characteristics	Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)	Areal extent of biogenic reefs as described under the Habitats Directive (1170) Reefs
		Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)	DCF indicator: Areas not impacted by mobile bottom gears
Associated benthic community	6.2 Condition of benthic community	Presence of particularly sensitive and/or tolerant species (6.2.1)	Identification of sensitive/tolerant species in relation to two aspects of vulnerability based on traits (single or combination): Direct mortality and Recovery potential
		Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)	Taxonomic (genus level) and functional (traits) diversity and richness
		Proportion of biomass or number of individuals above some specified length/size (6.2.3)	Mean size, based on biomass per Maximum bodysize trait category
		Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)	Biomass per specific Maximum bodysize trait category or group of categories (e.g. largest category)

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Table 13. Predominant seabed habitat types, including their biological communities (angiosperms, macroalgae, bottom fauna) according to the MSFD (EC 2008b).

PREDOMINANT HABITATS
Littoral rock and biogenic reef
Littoral sediment
Shallow sublittoral rock and biogenic reef
Shallow sublittoral coarse sediment
Shallow sublittoral sand
Shallow sublittoral mud
Shallow sublittoral mixed sediment
Shelf sublittoral rock and biogenic reef
Shelf sublittoral coarse sediment
Shelf sublittoral sand
Shelf sublittoral mud
Shelf sublittoral mixed sediment
Upper bathyal rock and biogenic reef
Upper bathyal sediment
Lower bathyal rock and biogenic reef
Lower bathyal sediment
Abyssal rock and biogenic reef
Abyssal sediment

In order to guide the selection of operational indicators covering the most relevant aspects of state that are impacted we considered the ecosystem services the benthic habitat and its associated communities is expected to provide. For this we used what is considered the most authorative source for the classification of ecosystem services, the Common International Classification of Ecosystem Services (CICES) and its most recent version, i.e. CICES 4.3. For each potential ecosystem service that may be affected by the fishing impact on the seafloor we propose one or more of what can be considered the most appropriate indicators (Table 14).

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Table 14. Selection of ecosystem services based on CICES 4.3 that can be provided by the seafloor and their preferred indicators.

Section	Division	Group	Class	Class type	Indicator	Examples
This column lists the three main categories of ecosystem services	This column divides section categories into main types of output or process.	The group level splits division categories by biological, physical or cultural type or process.	The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.	Class types break the class categories into further individual entities and suggest ways of measuring the associated ecosystem service output.	Possible indicators based on information potentially available within the BENTHIS project	
Provisioning	Nutrition	Biomass	Wild plants, algae and their outputs	*Plants, algae by amount, type*	Extent of specific habitat (e.g. seagrass), Biomass total or per specific taxa	Seaweed (e.g. Palmaria palmata = dulse, dillisk) for food
			Wild animals and their outputs	*Animals by amount, type*	Biomass total or per specific taxa	Marine fish (plaice, sea bass etc.) and shellfish (i.e. crustaceans, molluscs), Includes commercial and subsistence fishing for food
	Materials		Fibres and other materials from plants, algae and animals for direct use or processing	*Material by amount, type, use, media (land, soil, freshwater, marine)*	Biomass total or per specific taxa	Sponges and other products, which are not further processed; material for production e.g. chemicals extracted or synthesised from algae, plants and animals such as turpentine, rubber, flax, oil, wax, resin, soap (from bones), natural remedies and medicines (e.g. chondritin from sharks), dyes and colours, ambergris (from sperm whales used in perfumes); Includes consumptive ornamental uses.

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			Materials from plants, algae and animals for agricultural use		Biomass total or per specific taxa	Plant, algae and animal material (e.g. grass) for fodder and fertilizer in agriculture and aquaculture;
		Biomass	Genetic materials from all biota		Taxonomic diversity	Genetic material (DNA) from wild plants, algae and animals for biochemical industrial and pharmaceutical processes e.g. medicines, fermentation, detoxification; bio-prospecting activities e.g. wild species used in breeding programmes etc.
	Energy	Biomass-based energy sources	Plant-based resources	*By amount, type, source*	Biomass total	Wood fuel, straw, energy plants, crops and algae for burning and energy production
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*	Biomass per Bioturbation mode trait	Bio-chemical detoxification/decomposition/mineralisation in land/soil, freshwater and marine systems including sediments; decomposition/detoxification of waste and toxic materials e.g. waste water cleaning, degrading oil spills by marine bacteria, (phyto)degradation, (rhizo)degradation etc.
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*	Biomass per appropriate Feeding mode trait (e.g. Suspension & Filter feeders)	Biological filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine biota, adsorption and binding of heavy metals and organic compounds in biota
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*By amount, type, use, media (land, soil, freshwater, marine)*	Proportion of specific habitat (ie. Soft sediment) disturbed, Amount of sediment suspended	Bio-physicochemical filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine ecosystems, including sediments; adsorption and binding of heavy metals and organic compounds in ecosystems (combination of biotic and abiotic factors)
			Dilution by atmosphere, freshwater and marine ecosystems		Proportion of specific habitat (ie. Soft sediment) not disturbed, Amount of sediment suspended	Bio-physico-chemical dilution of gases, fluids and solid waste, wastewater in atmosphere, lakes, rivers, sea and sediments

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	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*By reduction in risk, area protected*	Extent of specific habitat (e.g. seagrass)	Erosion / landslide / gravity flow protection; vegetation cover protecting/stabilising terrestrial, coastal and marine ecosystems, coastal wetlands, dunes; vegetation on slopes also preventing avalanches (snow, rock), erosion protection of coasts and sediments by mangroves, sea grass, macroalgae, etc.
		Liquid flows	Flood protection	*By reduction in risk, area protected*	Extent of specific habitat (e.g. seagrass)	Flood protection by appropriate land coverage; coastal flood prevention by mangroves, sea grass, macroalgae, etc. (supplementary to coastal protection by wetlands, dunes)
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats	*By amount and source*	Extent of specific habitat (e.g. seagrass, gravel)	Habitats for plant and animal nursery and reproduction e.g. seagrasses, microstructures of rivers etc.
		Pest and disease control	Pest control	*By reduction in incidence, risk, area protected*	Taxonomic diversity	Pest and disease control including invasive alien species
		Soil formation and composition	Weathering processes	*By amount/concentration and source*	Biomass per appropriate Bioturbation mode trait	Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure; includes biological, chemical, physical weathering and pedogenesis
			Decomposition and fixing processes		Biomass per appropriate Bioturbation mode trait	Maintenance of bio-geochemical conditions of soils by decomposition/mineralisation of dead organic material, nitrification, denitrification etc.), N-fixing and other bio-geochemical processes;
		Water conditions	Chemical condition of salt waters		Biomass per appropriate Bioturbation mode trait	Maintenance / buffering of chemical composition of seawater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*By amount, concentration or climatic parameter*		Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota; transport of carbon into oceans (DOCs) etc.

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Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*By visits/use data, plants, animals, ecosystem type*	Extent of specific habitats, Taxonomic diversity	In-situ whale and bird watching, snorkelling, diving etc.
			Physical use of land-/seascapes in different environmental settings		Extent of specific habitats, Taxonomic diversity	Walking, hiking, climbing, boating, leisure fishing (angling) and leisure hunting
		Intellectual and representative interactions	Scientific	*By use/citation, plants, animals, ecosystem type*	Extent of specific habitats, Taxonomic diversity	Subject matter for research both on location and via other media
			Educational		Extent of specific habitats, Taxonomic diversity	Subject matter of education both on location and via other media
			Heritage, cultural		Extent of specific habitats, Taxonomic diversity	Historic records, cultural heritage e.g. preserved in water bodies and soils
			Entertainment		Extent of specific habitats, Taxonomic diversity	Ex-situ viewing/experience of natural world through different media
			Aesthetic		Extent of specific habitats, Taxonomic diversity	Sense of place, artistic representations of nature
	Spiritual, symbolic and other interactions with biota, ecosystems,	Spiritual and/or emblematic	Symbolic	*By use, plants, animals, ecosystem type*	Extent of specific habitats, Taxonomic diversity	Emblematic plants and animals e.g. national symbols such as American eagle, British rose, Welsh daffodil
			Sacred and/or religious		Extent of specific habitats, Taxonomic diversity	Spiritual, ritual identity e.g. 'dream paths' of native Australians, holy places; sacred plants and animals and their parts

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	and land-/seascapes [environmental settings]	Other cultural outputs	Existence	*By plants, animals, feature/ecosystem type or component*	Extent of specific habitats, Taxonomic diversity	Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes
			Bequest		Extent of specific habitats, Taxonomic diversity	Willingness to preserve plants, animals, ecoystems, land-/seascapes for the experience and use of future generations; moral/ethical perspective or belief

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4.2 Selected suite of BENTHIS indicators

The indicators covering all the relevant ecological aspects in terms of fishing pressure and ecosystem state/impact was summarised in table 15.

Table 15. Selected BENTHIS ecological indicators

Pressure State Impact	Indicator
Fishing pressure	• Catch per species, per year • Landings per species, per year • Proportion of specific habitat disturbed • Frequency of disturbance per habitat per unit area • Frequency of disturbance per unit area • Amount of discards per species, per year returned to the sea
Species state or impact	• Biomass relevant for nutrition or materials : – per specific taxa (fish and benthos) – total • Diversity: – Taxonomic (fish: species level, benthos: genus level) – Functional (traits) • Biomass per trait (benthos only) – Bioturbation mode – Feeding mode – Direct mortality – Recovery potential – Maximum bodysize
Habitat state or impact	• Extent of specific predominant habitat relevant for – Nutrition or materials, – Mediation of flows – Nursery areas • Extent of biogenic reefs • Proportion of specific habitat not impacted by mobile bottom gears

In order to evaluate the performance of (possible) management measures we need, apart from these ecological indicators, social and economic indicators. EU fisheries management relies on data collected, managed and supplied by EU countries under the Data Collection Framework (DCF) (see table 16) Commission, 2008). These indicators can be calculated per fleet segment or metier. However, the DCF does not include social indicators. A number of other initiatives, such as the Aquaculture Stewardship Council (ASC), and The Sustainability Consortium (TSC, Benoit et al 2013) have developed social indicators, which are useful for the Benthis project (see table 17).

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Table 16. Selected BENTHIS economic indicators

Group	Variables
Income	Gross value of landings
	Income from leasing out quota or other fishing rights
	Direct subsidies
	Other income
Personnel costs	Wages and salaries of crew
	Imputed value of unpaid labour
Energy costs	Energy costs and efficiency
Repair and maintenance costs	Repair and maintenance costs
Other operational costs	Variable costs
	Non-variable costs
	Lease/rental payments for quota or other fishing rights
Capital costs	Annual depreciation
Capital value	Value of physical capital: depreciated replacement value
	Value of physical capital: depreciated historical value
	Value of quota and other fishing rights
Investments	Investments in physical capital
Financial position	Debt/asset ratio
Employment	Engaged crew
	FTE National
	FTE harmonised
Fleet	Number
	Mean LOA
	Mean vessel's tonnage
	Mean vessel's power
	Mean age
Effort	Days at sea
	Energy consumption
Number of fishing enterprises/units	Number of fishing enterprises/units
Production value per species	Value of landings per species
	Average price per species

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Table 17. Selected BENTHIS Social indicators (based on ASC, Benoit et al 2013, and Kruse 2012)

Education	Educational level of boat owners
	Educational level of fishing crew
	Availability of vocational training for fishers
Health and safety on board	Number of reported injuries/accidents on board
	Safety and health measures taken on board
	Percentage of workers trained in health and safety practices
Labour rights	Working hours per day/week
	Violations or abuse of working hours and overtime laws and agreements
	The percentage of fishers who are paid a basic needs wage
Child Labour	Minimum working age
Women's rights	Number of women working as fishers
	Level of income compared to men
Freedom of association	Right of fishermen and women to organise themselves
	Level of organisation of men and women
Legitimacy of rules	Compliance rates

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5 BENTHIS MANAGEMENT MEASURES

The combination of an existing typology of management measures based on van Vliet and Dubbink (1999) and Gray (2005) and the incentives that drive the measures Vos et al. (2013) with a hierarchical characterisation of the different types of measures resulted in table xx. In the BENTHIS project the case studies will consider which of the types of measures will be considered in the workpackage on management we will also discuss how these types of measures can best be implemented in terms of the possible incentives.

Table 18. Typology of management measures, based on van Vliet and Dubbink (1999), Gray (2005) and de Vos et al. (2013), and a hierarchy of specific types of measures.

<table>
<tr><th>Category</th><th>Incentives</th><th>Type</th></tr>
<tr><td>Regulatory (Hierarchical)</td><td>Coercive</td><td rowspan="3">

Area and/or time restrictions,
Marine Protected Areas/Closed areas
Zoning
Real-time closures
Technical measures:
modification of gear
gear substitution
Catch/landing restrictions
TAC/Quota/ITQs
Minimum landing size
Discard ban
Effort management
Days-at-sea
Footprint on the seafloor
Public awareness
Labelling schemes
Environmental stewardship (MSC)

</td></tr>
<tr><td>Economic (Market based)</td><td>Financial</td></tr>
<tr><td>Social (Participatory)</td><td>Social/moral</td></tr>
</table>

5.1 Baltic sea Case Study

In the Baltic sea Case Study the following Management Measures will be considered:

Area restrictions:
Closed areas and zoning will be explored including effort re-allocation for several fisheries in different areas including Nephrops trawling in Kattegat, Cod trawling in the Western Baltic Sea, Mussel dredging in the Belt Sea, and Nephrops Creel fishery in Kattegat

Technical measures, modification of gear:
- Nephrops trawling in Kattegat with respect to long (standard) and short sweep lengths
- Cod trawling in the Western Baltic Sea with respect to standard demersal trawl doors and pelagic trawl doors as well as effort re-allocation according to sensitive habitats
- Mussel dredging in the Belt Sea with standard heavy and new light weight dredging gear as well as with respect to smart fishing applying real time video monitoring in order to increase fishing efficiency

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- Nephrops Creel fishery in Kattegat with respect to mounting of the creels (top or center point), making shelters in the creels, etc. as well as to compare catch rates between creels and trawling in overlapping fishery, and finally to measure catch rates of creels according to sediment softness in Kattegat.

5.2 Mediterranean Case Study

In the Mediterranean Case Study the following Management Measures will be considered:

Area restrictions:
Dynamic spatio-temporal restrictions will be assessed based on an initial assessment of the current footprint of the demersal otter trawl fisheries in Italy and Greece in terms of its spatial and temporal extent including the overlap with depth zones and certain predominant or sensitive habitat types, the effect of closed areas and zoning will be explored taking effort re-allocation into account.

Technical measures, modification of gear:
Modifications of gear parts for the demersal otter trawl fishery in Italy with the aim to reduce unwanted catches in trawl fisheries and the physical impacts on the seabed:
- testing different and new otter trawl door designs including semi-pelagic otterboards
- testing selection grids and novel trawl designs

Technical measures, gear substitution:
- exploring the use of fish pots focusing on the Norwegian floating pot in otter trawl grounds in Greece and Italy
- exploring the use of Nephrops creels in otter trawl grounds in Greece (Aegean Sea: mixed shrimp/fish fishery) and Italy (Adriatic Sea: Nephrops fishery), Sicilian/Calabrian Sea: mixed shrimp/fish fishery) as alternative targeted crustacean fisheries for Nephrops or shrimps.

For both pots and traps, tests will include comparisons of selectivity, CPUE, catch, bycatch, discards, behaviour of the traps (recorded underwater video observations), gear investment and ease of use.

5.3 North sea case study

In the North Sea Case Study the following Management Measures will be considered:

Area restrictions:
- Marine Protected Areas/Closed areas: this topic is mainly related to the Natura 2000 areas in the North Sea. Conservation measures, in terms of which gear to be allowed when, have been or are being installed. These measures will be evaluated and may lead to alternative options in a next phase. An evaluation of the different options is valuable to support management.
- Zoning: Zoning can be a good tool in protecting certain habitats against fisheries impact but will lead to a redistribution of fishing effort which will in its turn affect fisheries impact in other areas. An estimation of the effects of such management measures is necessary to understand the implications.

Technical measures, modification of gear:
- Gear substitution: in the North Sea an obvious gear substitution that is already taking place is the replacement of the beam trawl by the pulse trawl with sole as a target species. A less obvious gear substitution is the beam trawl targeting sole being replaced by static gear such as trammel and gill nets. The evaluation of this latter measure may suffer from problems in the parameterisation of the models and feasibility of such measures versus their relevance will therefore first be discussed among the case study participants.

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Catch/landing restrictions

- ITQs and discards ban: in the light of the new CFP these two options are an obvious choice, especially because they have a direct relevance for the industry.

Effort management

- Footprint on the seafloor

Public awareness

- Labelling schemes

5.4 Black sea case study

In the Black sea Case Study the following Management Measures will be considered:

Technical measures, modification of gear:
Several modifications to the beam trawl (algarna) which is used for rapa fishery, will be explored:

- Use of ‘sledges’ made of steel instead of the traditional shoes.
- Use the ‘flying doors’ in water column instead of dragging doors on substratum.
- Change the type of mesh size in the trawl codend using 40 mm square mesh and T90 (the attachment of diamond mesh to the bag by a 90 degree torsion) as gear material.'

Technical measures, gear substitution:
The use of pots as an alternative to beam trawl will be explored.

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