MEFEPO
Making European Fisheries Ecosystem Plans Operational
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Assessing the impact of fishing on the Marine Strategy Framework Directive objectives for Good Environmental Status.

Developing and testing the process across selected RAC regions: The North Sea

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Executive Summary
European marine environmental management is currently undergoing a transition towards an ecosystem-based approach to management. As a contribution to integrated management the MEFEPO project is examining the requirements for implementing operational ecosystem-based fisheries management plans across Europe.

The Integrated Maritime Policy (IMP) is the over arching European policy framework that aims to integrate all aspects of maritime policy within the EU. The Marine Strategy Framework Directive (MSFD) was established as the environmental pillar of the IMP and is the thematic strategy for the protection and conservation of the marine environment with the goal of achieving good environmental status (GES) across all European waters by 2020. As such all other maritime polices, including the CFP, should be set up to provide the right instruments to support the ecosystem approach and attainment of GES by 2020.

As a step towards integrating the requirements for GES into European fisheries management this report develops, and trials, a process for operationally assessing the environmental impacts of fishing on GES as part of EU ecosystem based fisheries management.

Developing a set of operational environmental objectives for fisheries management is a three staged process:

i) Identify the minimum necessary set of environmental objectives that require explicit consideration by fisheries managers. These can be identified from the full list of environmental objectives that are applicable across all marine sectors.

ii) Develop 'operational' objectives in relation to specific and measurable aspects of the marine environment. Operational environmental objectives act as a bridge from general high level policy statements to sector-specific measures that are necessary to implement them.

iii) Select, or define, indicators and associated reference levels associated with each operational environmental objective.

The use of indicators should be consistent across the EU, but associated management reference levels may vary between assessment regions due to variation in the environmental setting. Therefore the selection of operational objectives and their associated region specific reference levels are conducted separately.

The initial set of eleven qualitative descriptors of GES listed in the MSFD was examined and reduced to a set of four descriptors that need explicit consideration by fisheries managers. These are GES descriptors 1, 3, 4 and 6 relating to biodiversity, commercial species, food webs and sea-floor processes respectively.

The 'conservation status of fish' indicator was selected to report on GES descriptor 1; biodiversity. The 'status of commercial stocks' indicator was selected to report on GES descriptor 3; commercial species. The 'large fish indicator' was selected to

report on GES descriptor 4; food webs. The ‘proportion of area not trawled’ was selected to report on GES descriptor 6; sea-floor habitats.

The selection of indicators was constrained by the requirement to establish a set of indicators that could be operationally implemented over a short timescale. This confined the set of indicators to those that have been developed, tested and are reasonably well understood, and to indicators that can be calculated with existing datasets. To allow fisheries managers to establish the impact of fishing on the attainment of GES the indicators need to be mainly responsive to the effects of fishing rather than other pressures.

Due to the above restrictions the set of indicators selected are primarily focussed on the fish community, or selected parts of the fish community. This limits the coverage of ecosystem components considered in indicator calculation. However as fisheries, other than invertebrate fisheries, specifically target the fish community it is considered that managing fisheries to enable GES for the fish community could go a long way to achieving GES for many ecosystem components, and thus provides a logical starting point for developing this framework.

Whilst it is considered that the indicators identified provide a rational starting point for the assessment of the impact of fishing on GES it was concluded that the indicators do not provide a complete and robust set of indicators to establish fishing impacts on GES. The indicators to assess GES in terms of biodiversity and sea-floor processes are identified as priority areas for development.

When considering the number and nature of indicators to include in this analysis it is necessary to have a clear understanding of exactly how the indicators are to be used in the management process; are the indicators used purely as an ‘indication’, or are they to be ‘hard wired’ as triggers in a management process? For example an indicator that provides a good measure of the state of an attribute but is sensitive to multiple pressures would be useful as an ‘indication’ of state, but inappropriate if it is used to ‘trigger’ specific management interventions.

The selected indicators were applied to the North Sea RAC region to i) trial combined simultaneous assessment of environmental status across a large multi-national region to examine the practicality of operationally implementing the approach; and to ii) attempt to assess the current status of the North Sea RAC region in relation to the impacts of fishing on GES.

The two survey based indicators, the conservation status and large fish indicators, could be applied across this region, and the status of commercial stocks indicator could be applied to the extent that stock assessments are available. Applying the indicator of the proportion of area not impacted by mobile bottom gears proved problematic as VMS data is required from individual nation states and national datasets were not made available to all partners.

The preliminary assessment concluded that GES is currently compromised within the North Sea RAC region by fishing activities. However a number of caveats are associated with this conclusion.

In summary this report describes the development and first implementation of a process to assess the impact of fishing on GES. Following the ethos of ‘not allowing the best to become the enemy of the better’ it is concluded that a preliminary process could be rapidly implemented. However there are a number of weaknesses and areas of concern with the tools as currently available. The limitations and directions for future development are discussed.

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Introduction

European marine environmental management is currently undergoing a transition towards an ecosystem based approach to management. As a contribution to fully integrated management, the MEFEPO project is examining the requirements for implementing operational ecosystem based fisheries management (EBFM) plans across Europe.

The phrase 'ecosystem based management' has become widely used and a variety of different definitions have been proposed. Despite this there are three aspects of ecosystem based management that are core to the concept, these are:

- Simultaneously accounting for the impacts of multiple pressures, both within and across sectors;
- Considering both the indirect, and direct, impacts of these pressures;
- Explicitly considering society's multiple objectives for the marine environment relating to environmental, social or economic aspects of the ecosystem.

This report is concerned with the last of these points; explicit consideration of multiple objectives for the marine environment. More specifically this report develops, and trials, a set of operational environmental objectives for ecosystem based fisheries management that could be implemented under the reformed Common Fisheries Policy (CFP).

Developing environmental objectives for operational implementation in European fisheries management is a three step process. The first step is to identify the complete set of environmental objectives for the marine environment on the basis of comprehensive high level policy commitments. Only a proportion of these will be affected by fisheries, or can be directly influenced by measures which target fisheries. These objectives are therefore screened to reduce the overall set to just those objectives relevant to EBFM.

The second step is to translate these high level policy objectives into specific and quantifiable attributes of the marine environment for which management action can be taken. The development of such 'operational' statements of objectives defines policy requirements in terms of measurable aspects of ecosystem components. This is the process of developing 'criteria' as defined in the MSFD.

The third step is to select, or define, an indicator or set of indicators to report on environmental status in relation to the objectives. As ecosystem status is to be reported in relation to these objectives it is necessary to define limit or target reference points for the indicator. The target or limit reference level may vary between assessment regions due to underlying variation in the climatic and ecological setting. Therefore the process of defining the operational objective and specifying the associated reference points are separated. The operational objectives and associated indicators are expected to be consistent across the EU, but the associated reference points can vary on a regional basis.

It should be noted that steps two and three may need to proceed as an iterative process as the choice of indicator will have implications for the specific wording of the operational objective. Operational objectives act as a bridge from policy aspirations to field measurements of the state of the environment; when building a bridge it is necessary to know both where it will start and where it should end.

This report is one of three related reports that trial the process across three RC regions, the North Sea, the North Western Waters and South Western Waters RAC regions. Section 1, developing the process, is common to all three reports. Section 2, trialling the process across a RAC region is unique to each report. This report considers the North Sea RAC region.

Section 1: Environmental objectives for ecosystem based management in the reformed CFP.

Section 1.1.1 The reformed CFP and environmental objectives in the Marine Strategy Framework Directive

The CFP is the primary legislation concerning marine fisheries in the EU. The current version of CFP was introduced in 2002[1], and is under review with a view to implementing a reformed version of the CFP in 2013. Whilst the current version of the CFP does explicitly state the need to consider environmentally status, this is essentially limited to the statement that:

> *The Common Fishery Policy shall ensure exploitation of living aquatic resources that provide sustainable economic, environmental and social conditions.*[1]

This statement provides no guidance on the relative prioritisation of economic, environmental and social objectives, nor does it specify or provide guidance on what is required of the marine environment for fishing to be considered environmentally sustainable. The CFP Green Paper recognises this weakness in the current iteration of the CFP and notes that 'imprecise policy objectives resulting in insufficient guidance for decisions and implementation' is one of the five structural failings of the policy.

Since the implementation of the 2002 CFP there has been increased acceptance that productive fisheries require a healthy and robust resource base, and that society has environmental objectives for the marine environmental in their own right aside from the desire for sustainable fisheries. The first point is born out by the CFP Green Paper which states that:

> *Economic and social sustainability require productive fish stocks and healthy marine ecosystems. The economic and social viability of fisheries can only result from restoring the productivity of fish stocks.*

The second point, that environmental objectives for the marine environment exist outside fisheries management, is manifest from a range of Directives including the Water Framework Directive, the Habitats and Birds Directives, and the introduction of the Marine Strategy Framework Directive[2] (MSFD). The MSFD forms the environmental pillar of the Integrated Maritime Policy[3] (IMP), and is the thematic strategy for the protection and conservation of the marine environment '*with the overall aim of promoting sustainable use of the seas and conserving marine ecosystems*'[2] with the goal of achieving or maintaining good environmental status (GES) across all European waters by 2020. The role of the MSFD in defining

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[1] Council Regulation (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy.
[2] Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing the framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive).
[3] An Integrated Maritime Policy for the European Union. COM(2007)575.

environmental objectives for fisheries policy is clearly stated in the MSFD. For example the MSFD states that it:

> *…should contribute to coherence between different policies and foster the integration of environmental concerns into other polices, such as the Common Fisheries Policy.*

Whilst in relation to the prioritisation of environmental objectives the MSFD states:

> *…while enabling a sustainable use of marine good and services, priority should be given to achieving or maintaining good environmental status in the Community's marine environment…*

This role for the MSFD in developing environmental objectives for all aspects of maritime management including fisheries is acknowledged in the Green Paper on the reform of the CFP which notes:

> *… the fisheries sector interacts closely with other maritime sectors. The Integrated Maritime Policy (IMP) addresses interactions between EU policies and maritime affairs.*

Furthermore the need for the reformed CFP to manage fisheries such that the objectives of the MSFD are not compromised is clearly stated in the CFP Green Paper which adds:

> *… an ecosystem approach to marine management, covering all sectors, is being implemented through the Marine Strategy Framework Directive, which is the environmental pillar of the IMP and sets the obligation for Member States to achieve Good Environmental Status in 2020. The future CFP must be set up to provide the right instruments to support this ecosystem approach.*

This illustrates the commitment for the reformed CFP to manage fisheries to operate within the constraint of achieving GES across European waters. To establish what this means for fisheries managers, and what the operational environmental objectives for fisheries management should actually be, requires closer examination of the MSFD definition of, and requirements for, GES.

1.1.2 Environmental Objectives for Fisheries Management in the MSFD

The MSFD is the European thematic strategy for the protection and conservation of the marine environment with the goal of achieving or maintaining GES across all European waters. Thus ecological objectives defined in the MSFD have been established with regard to the impact of all pressures on the system, not just fisheries.

Within the MSFD GES is broadly defined as:

> *… the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and*

the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations.

In addition to the general definition of GES, the MSFD lists eleven qualitative descriptors of good environmental status (hereinafter referred to as the 'GES descriptors') that provide more specific statements of desired environmental status (Table 1). These eleven more specific qualitative descriptors of GES provide an appropriately detailed starting point for the development of operational environmental objectives on the basis of policy aspirations.

Fisheries management is a complex process. Managers regulate pressures on a variable system that is driven by multiple extrinsic unpredictable drivers on the basis of imperfect data and have to simultaneously consider multiple -often conflicting-stakeholder demands. Therefore the general ethos behind developing environmental objectives for explicit inclusion in operational fisheries management was to keep the requirements as simple as possible given the relevant policy stipulations.

The first step in developing a set of operational environmental objectives for fisheries management on the basis of the eleven qualitative descriptors of GES is to identify which of the GES descriptors cover aspects of marine environmental status impacted by fishing. Thus only the descriptors notably affected by fishing are brought forward for explicit considerations by fisheries managers.

Table 1: The eleven qualitative descriptors of GES. Ticks indicate the descriptors of environmental status that were selected for explicit consideration by fishery managers, see text for discussion of selection.

Marine Strategy Framework Directive ANNEX I **Qualitative descriptors for determining good environmental status** (referred to in Articles 3(5), 9(1), 9(3) and 24)	
(1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	✓
(2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.	X
(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.	✓
(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.	✓
(5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.	X
(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.	✓
(7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	X
(8) Concentrations of contaminants are at levels not giving rise to pollution effects.	X
(9) Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.	X
(10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	X
(11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	X

The selection of GES descriptors that cover aspects of the marine environment impacted by fishing were made during two MEFEPO project workshops involving MEFEPO project partners and policy makers, NGO representatives and marine scientists external to the project. There was unanimous agreement amongst all participants over the selection of the four descriptors that were chosen for inclusion; namely descriptors 1, 3, 4 and 6 relating to biodiversity, commercial species, food webs and benthic processes respectively.

Descriptors 2, 9, 10 and 11, relating to invasive species, contaminants in seafood, litter and underwater noise, were highlighted during the workshops as possibly requiring inclusion. The reasons for not including these descriptors are briefly outlined below.

(2) *Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems*: The potential impact of non-indigenous species (NIS) on ecosystems and fisheries is of concern. For example introduction of the comb-jelly *Mnemiopsis leidyi* to the Black Sea is believed to have contributed to the poor recovery of Black Sea fish stocks following reduction in fish pressure (Shiganova & Bulgakova 2000). However fishing activities are not seen as the direct cause of species introductions; rather fishing may create conditions that facilitate establishment of introductions. Theory suggests that ecosystems that are species rich with many ecological links are more resilient to invasion (May & McLean, 2007). Therefore if fishing simplifies the system by, for example, selective removal of top predators or larger size classes there may be an increased likelihood that introduced species can become established. However as this effect is linked to fisheries impacts on biodiversity and food web structure it is considered that the effect of fisheries on system simplification will be addressed by GES descriptors 1 and 4 respectively.

(9) *Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards*: In relation to contaminants in seafood it was noted that whilst fisheries managers may have to respond to contamination in seafood, such as the monitoring and closure of shellfish areas, fisheries are not a significant cause of contamination. As fishery managers can not take measures to control the levels of contamination in the marine environment it was not considered appropriate for this descriptor to be included as an environmental objective for fisheries management.

(10) *Properties and quantities of marine litter do not cause harm to the coastal and marine environment*: Two separate aspects of fishing and litter were considered separately; these were ‘general’ litter from fishing vessels, and ‘ghost fishing’. Litter is widespread in the marine environment, and the incident of plastic litter is particularly prevalent due to its long lifetime in the marine environment. Monitoring of the incident of plastics in beachwashed dead fulmars (*Fulmarus glacialis*) in the Netherlands between 1999-2003 found that 98% of the birds examined contained plastics (Van Franeker et al. 2004), and it was assumed that many of the litter items observed were

discarded from ships (but not exclusively fishing vessels). However it was considered that general marine litter was under the remit of MARPOL and did not require specific consideration by fishery managers. Under MARPOL Annex V the North Sea is designated a special area and disposal of plastics at sea is entirely prohibited.

In relation to ghost fishing it is inherently difficult to quantify both the extent of gear loss and the effect of this gear loss on mortality rates. Despite the limited information available a review of ghost fishing in European waters concluded that ghost fishing accounted for less than 1% of fish mortality caused by fishing operations (not including discard mortality) (Brown & Macfadyen 2007). As ghost fishing is only responsible for a minor portion of the total mortality caused by fishing operations it was decided not to include impacts of ghost fishing as a specific separate objective for fisheries managers.

(11) *Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment*: During the expert workshops it was considered whether noise relating to fishing operations should be explicitly considered by fishery managers. It was concluded that whilst fishing operations did cause underwater noise, the levels were low compared to the noise produce by other parts of the shipping sector, other offshore developments (such as the renewable and hydrocarbon industries) and natural background levels, and that fishing operations were not a significant area of concern.

This process justifies the selection of four GES descriptors that need to be directly taken account of in European fisheries management. In the next section of this report the four selected GES descriptors are examined individually and operational objectives and associated indicators identified for each descriptor. So far within this report this has been referred to as the development of 'operational objectives'; within the context of the MSFD these operational objectives are termed 'criteria'. The MSFD states;

"criteria" means distinctive technical features that are closely linked to qualitative descriptors;

In other words the 'criteria' identify the ecosystem components, or aspects of ecosystem components, that can be monitored to assess the status of the environment with respect to the objective defined in a given descriptor. Separate region specific reference levels need to be associated with the criteria to allow status to be compared to the objective. The term 'criteria' will be used in this context to keep the terminology of this report aligned with the terminology used in the MSFD.

Two important points about this process need to be highlighted before considering the selection of operational objectives and associated indicators. Firstly this work is specifically trying to identify indicators that report on the status of the marine environment with respect to the impacts of fishing. The marine environment is subject to a number of anthropogenic pressures and no state indicator will respond only to fishing; however previous work on the application of indicators has to a certain extent identified which indicators are most responsive to fishing and which are sensitive to other pressures. This constrains the choice of indicators that can be used. This is to allow fisheries managers to identify the impact of fishing on GES; simply observing that GES is not being met without being able to identify the cause does not allow for targeted management interventions.

The second point to note is that this report attempts to develop a set of management objectives with linked indicators of status that can be operationally implemented within European fisheries management. To this end this report concentrates on selecting indicators that can be implemented immediately, or at least in the near future. This requires that the data necessary for the indicators are already collected on a regular basis, and that the indicator has been sufficiently developed and tested for its behaviour to be understood. From this it can be seen that the report is not attempting to produce a perfect set of operational objectives linked to indicators, rather the aim is to produce an operational set of objectives and indicators that can be implemented over the short term. This will undoubtedly leave room for development and improvement over forthcoming years, but given the rapid timescale required for the implementation of the MSFD it is necessary to make some pragmatic choices and to avoid letting the best become the enemy of the better.

1.2.1 GES Descriptor 1: Biological Diversity

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

The listing of biodiversity as the first GES descriptor in the MSFD reflects the importance that is attached to maintaining biodiversity as an attribute of good environmental status, and also reflects the growing public and political concern with the maintenance of biodiversity.

1.2.1.1 Developing a criteria statement with associated indicator.

In the context of the MEFEPO project the phrase 'biological diversity' was interpreted according to the definition in the Convention on Biological Diversity (CBD);

> *Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexities of which they are part: this includes diversity within species, between species and of ecosystems*

On the basis of the CBD definition of biodiversity, the first sentence of the qualitative descriptor is interpreted as meaning that to achieve GES the diversity of ecosystems, species and genetic diversity needs to be maintained. Whereas the second sentence regarding prevailing conditions acknowledges that the distribution of species is closely controlled by climate, and variation in climate should be taken into account when examining changes in biological diversity.

Therefore, ideally, assessment of biological diversity would be based on information on fish, invertebrates, mammals, reptiles, seabirds and habitats. The current sources of information provide very different levels of coverage for these different ecosystem components and there is wide variation in the frequency and spatial scale at which the different ecosystem components are monitored. Therefore on the basis of current data collection programs it will be difficult to robustly consider all relevant ecosystem components for the biodiversity descriptor.

In relation to selecting a metric of biodiversity to use as a basis for developing criteria to assess the biodiversity descriptor there are a number of well known diversity metrics, such as species richness, species evenness and species dominance. However the link between these metrics and fishing pressure is neither straightforward nor well understood (Bianchi et al. 2000; Piet & Jennings 2005; Trenkel & Rochet 2003). Therefore the standard diversity metrics are not well suited to assessing the impact of fishing on marine biological diversity.

The possible indicators to report on the status of biological diversity identified by the COM(2008) 187 and Indiseas project are listed in tables 1.2.1.1 and 1.2.1.2 respectively.

Table 1.2.1.1 List of indicators related to biodiversity from COM(2008) 187.

Indicator	**SGRN (2006) recommendation**	**Proposed indicators or research projects**	**Purpose**
Conservation status of vulnerable fishes according to IUCN decline criterion	Operational immediately	Conservation status of fish species	State
Abundance of vulnerable marine mammals, reptiles or seabirds	Additional data sources required, research priority	Research project	-

Table 1.2.1.2 List of indicators related to biodiversity from the INDISEAS Project:

Indicators	Headline Label	Calculation	Management direction	Purpose
Proportion of under and moderately exploited stocks	% sustainable stocks	number (under + moderately exploited species)/total no. of stocks considered	Decrease fishing effort on overexploited fish species. Diversify resource composition	State
Proportion of predatory fish	% predators	prop predatory fish= B predatory fish/B surveyed	Decrease fishing effort on predator fish species	State Trend
Trophic level of landings	Trophic level	Biomass weighted average trophic level of landings	Decrease fishing effort on predator fish species	State Trend

From this list of possible indicators the conservation status of vulnerable fishes is an indicator that directly reports on the condition of vulnerable fishes and is immediately operational on the basis of current data collection. Furthermore by focusing on the large fish in the community it focuses on the portion of the fish community most impacted by fishing. The conservation status of fishes is obviously limited to the fish community and gives no information on the impact of fishing on other ecosystem components, however as noted by the COM(2008) 187 there is currently insufficient data collection to allow similar indicators to be implemented for mammals, reptiles or seabirds.

The Indiseas project has incorporated three structural indicators of ecosystem status that are related to biodiversity. The % of sustainably exploited stocks provides a measure of the condition of commercially exploited populations, and hence gives an indication of the 'diversity' of these populations. However it was considered that an indicator of this nature would be employed to report against GES descriptor 3, and that by focusing on commercial species the indicator does not provide any coverage of no (or low) value species that are not considered by production-related fishery concerns.

The proportion of predatory fish, and trophic level of landings (aka Marine Trophic Index) do both provide an indication of the structure of the community, and any changes in community structure are likely to be associated with a change in aspects of biological diversity. However both these indicators may be considered under the food webs descriptor, and critically both are biomass weighted indices. There are two main aspects to maintaining biodiversity, firstly to stop species becoming (regionally) extinct, and secondly to maintain the general structure of the community. Biomass weighted indices can provide a good indication of the overall structure of a community, but they are limited in their ability to pick up species losses as species that are being lost from a system tend to make up only a very small proportion of the biomass of the system. As the GES descriptor associated with food webs will focus on system structure it was decided that the biodiversity descriptor should focus on the rare and more vulnerable species within the community. The proportion of predatory fish and trophic level of landings were therefore considered inappropriate to report on the biodiversity descriptor.

From the available indicators, conservation status of vulnerable fishes was selected as the appropriate metric to report on biodiversity of the marine environment with respect to the impact of fishing. Whilst this provides a metric for the impact of fishing on the most vulnerable portion of the fish community, it provides no information on the impact of fishing on mammals, seabirds, reptiles or habitats. Whilst this leaves large gaps in the coverage of biological diversity it should be noted that the management actions required to maintain biological diversity of the most sensitive part of the fish community may also fulfil the requirements for maintaining biological diversity of many other vulnerable ecosystem components.

Although the indicator is considered 'operational' according to COM(2008) 187 it has not be widely applied across European waters and there may be problems associated with applying this indicator across large areas. For example this indicator is very sensitive to the gear used in the surveys. Within the North Sea (NS) and North West Waters (NWW) RAC areas the IBTS surveys are carried out using GOV trawls, whereas across the SWW a range of gears are used for surveys. Most notably the demersal assessments in Azorean waters are based on a long line survey. The variation in gears makes it difficult to directly compare the indicator between areas, but the indicator can be used to follow trends in the surveys over time.

Now that the metric for monitoring biodiversity has been selected a criteria statement can be proposed to link from the GES descriptor to the specific aspects of the marine environment that will be objectively monitored by the selected indicator. A criteria statement of this nature could specify the target reference level in the objective statement, or the target level can be left obscure in the objective statement. Within the MSFD the development of criteria (that should be applicable across all EU waters) and the selection of reference levels (which may vary between regions) are considered separately. Following this approach the criteria statement deliberately does not specify a target level, and identification of target levels is considered separately.

The criteria statement for GES descriptor 1 is:

The conservation status of fish is maintained.

Where the conservation status of fish is monitored according to the "Conservation status of fish species" indicator as defined in COM(2008) 187.

1.2.1.2 Method for calculating the "Conservation Status of Fish Species" indicator and associated reference levels.

The 'conservation status of fish species' (CSF) indicator was calculated as specified in COM(2008) 187 apart from the alterations and additions to the method outlined below.

The CSF indicator specified in COM(2008) 187 is based on analysing the survey abundance of large vulnerable fish. COM(2008) 187 specifies two separate indicators that can be calculated from the survey abundance data:

CSFa: the average IUCN threat rating of species in the large fish community

Where the proposed limit reference level (i.e. the level which should be avoided) for CSFa is 1 (COM(2008) 187). The proposed limit reference value of 1 was first proposed by Dulvy et al (2006) implies that on average all species in the large fish community are considered 'vulnerable' according to IUCN threat criteria.

and

CSFb: the average relative abundance of the large fish community compared to a reference period.

No limit reference level has been proposed for CSFb, the reference direction is an increase in the indicator value which indicates an average increase in the abundance of large vulnerable fish. CSFb compares the current abundance of the large fish community to a reference period (normally the start of the survey time series), determining a target or limit reference point may vary depending upon the condition of the community during the reference period.

Within this project both indicators CSFa and CSFb were calculated.

The following modifications were made to the method described in COM(2008) 187:

- For each species and each survey time series L_{max} observed in the survey time series was used instead of L_{inf}. This allows the indicator to be applied over a wide range of areas, as the L_{inf} for a species reported in wider literature may be from a different area or region and inappropriate for the location where a specific survey is conducted.

- Both CSFa and CSFb were calculated compared to a reference period. According to the procedure in COM(2008) 187 the reference period for CSFa is the first year of the time series, whereas for CSFb the reference period is the average of the first three years of the time series. Within this assessment CSFa was also calculated using the first three years of the time series as the reference period to examine the influence this had on indicator behaviour. This avoided CSFa being skewed by a single years' data, and also reduced the incidence of zero abundance for a given species in the reference period that hinders calculation of relative abundance.

- The first step in calculating both CSFa and CSFb is to develop a list of species to include in indicator calculations. One of the criteria for inclusion in the list is a minimum abundance threshold. Species that are declining, or disappear, over the time series may fail to reach the minimum abundance threshold when considered over the whole time series. As these are the very species that are most in need of consideration from a biological diversity point of view it seems undesirable that they are excluded from indicator calculations. The method specified in COM(2008) 187 is for the average abundance over the whole time series to be considered when compiling the species list. In this study an alternative criterion was developed to construct the species list by just considering the average abundance over the first three years of the time series.

- When considering the annual abundance of a species, only individuals larger than $L_{max}/2$ are included in the calculations to reduce the noise from young age groups with variable abundance. In surveys where the observed L_{max} is particularly large compared to the length distribution of species observed in the time series this will lead to an abundance of 0 being reported for many years. In specific cases where this occurred the minimum length for consideration was reduced to half of the quartile $0.75L_{max}$ rather than half of L_{max}.

  This procedure was applied as standard for the Azores demersal long line (DLL) survey, and also when selecting the species list when only the first three years of data were used to select the species list (see point above).

- The threshold for minimum average abundance per year specified by COM(2008) 187 is 20 per year on the basis of previous work using demersal trawl surveys. The Azorean DLL survey abundance is reported as CPUE per hook, so in this case the minimum abundance threshold was set to 0.1 as the threshold set for demersal trawl surveys are not appropriate for direct transfer to a long line survey.

1.2.2 GES Descriptor 3: Commercial Species

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

1.2.2.1 Developing a criteria statement with associated indicator

The phrase "Safe Biological Limits" (SBL) was first coined by ICES where stocks are characterised as being within SBL when they have full reproductive capacity. This means that spawning stock biomass (SSB) (the mature part of a stock) is above the value corresponding to a precautionary biomass reference value (B_{pa}) identified by ICES. Another criterion for SBL is that the stock is harvested sustainably which requires that fishing mortality (F) (an expression of the proportion of a stock that is removed by fishing activities in a year) does not exceed a precautionary fishing mortality reference value (F_{pa}). The most precautionary criterion is where both criteria apply, i.e. $SSB \geq SSB_{pa}$ and $F \leq F_{pa}$. This implies that only stocks for which SSB and F, as well as both reference values, are known can be included in indicator calculations. As this framework is well developed, and already provides an assessment of SBL for many of the EU waters we decided to adopt it for determining GES for the commercial stocks.

The choice of only using assessed stocks may compromise representativity as there are many stocks that are commercially exploited but for which no formal stock-assessment is conducted. This occurs with commercially exploited fin-fish but is a more widespread problem for shellfish stocks. In order to identify the representativity of the indicator for each area the proportion of the landed value and/or catches represented by the assessed species should be determined.

The advantage of this approach is that at least for those EU regions that fall within the ICES area (i.e. North Sea, Baltic Sea, North Western Waters and South Western Waters) the descriptor can draw from an existing rigorous scientific framework and knowledge base and benefit from the high level of quality control that is applied.

The disadvantage is that this same framework is not applied to the same extent in all EU regions. Both in the Mediterranean and the Black Sea some ICES-style assessments are conducted but these cover only a relatively small proportion of the stocks. For the Mediterranean there are other existing assessment frameworks such as one based on the uni-dimensional FAO (2005) criteria (exploitation) or another based on the bi-dimensional criteria (exploitation and abundance) usually applied in Regional Fishery Bodies other than the General Fisheries Commission for the Mediterranean (GFCM). However, since these other regions fall outside the remit of MEFEPO this issue will not be considered further at this stage.

For this study it was decided not to go beyond the ICES definition of "within SBL" and incorporate any other reference values. Though it should be noted there is potential to develop a framework based on maximum sustainable yield (MSY), a concept which has a long history in fisheries management. It was enshrined in national and international legislation throughout the 1970's and 1980's although by the end of the 1970's the shortcomings of using MSY to set catch levels were already apparent (Beddington & May, 1977; Larkin, 1977; Sissenwine, 1978). Subsequently emphasis shifted to MSY-based reference points such as F_{msy}, B_{msy} and more conservative proxies for F_{msy} such as $F_{0.1}$. Several recent studies have expressed caution regarding the wide-scale adoption of MSY based targets (F_{msy}, B_{msy}) as a management tool. Pilling et al. (2008) suggest that MSY based targets may not provide robust objectives in the face of uncertainty and variability in the biological processes on which they depend. Kell & Fromentin (2007) also note the difficulties associated with making the MSY concept operational in dynamic and changing fisheries where there may be trends in yield or shifts in selection patterns. Furthermore Walters et al. (2005) identify problems of applying the single species MSY approach in an ecosystem context.

Nevertheless MSY has been identified as a management goal in numerous management systems including the US Magnuson-Stevens Fishery Conservation and Management Act, the International Commission for the Conservation of Atlantic Tunas and in the commitments of the World Summit on Sustainable Development. The use of F_{msy} as a target or as a limit reference point is also debated. Mace (2001) considered that treating F_{msy} as a limit reference point was a necessary first step towards EAF because it would result in an overall reduction in fishing mortality rates, although Jennings (2005) notes that EAF is expected to provide greater long-term benefits to society if managers can meet targets rather than avoid limits. Notwithstanding the above arguments on whether or not MSY should be used as another reference point it was decided not to since there are only few, if any, stocks for which an MSY value is known. Hence, using MSY would have further compromised the representativity of this exercise.

Other potential reference values that are provided by ICES for few stocks are F_{max} which is close to F_{MSY} but with the assumption of average recruitment, F_{mngt} (F according to management plan) or $F_{0.1}$ where slope of the yield curve is 0.1 that at the origin.. However, for the same reasons as MSY these reference points were not considered in this analysis.

The second part of this GES descriptor, i.e. “exhibiting a population age and size distribution that is indicative of a healthy stock”, is less straightforward. Even though several indicators exist that characterise the age- and/or size-distribution of a fish stock (Shin et al. 2005) it is unclear what the age- and/or size-distribution of a “healthy” fish stock should look like. The main characteristic of a healthy fish stock is considered to be a full reproductive potential which is often assumed to equate to SSB. This is challenged by many studies, as reviewed by Green & David (2008), who identified maternal factors (Marshall et al. 1998) such as age, size or condition as often at least equally important sources of variation in recruitment (Nikolskii 1962) or offspring quality (Gall 1974) within fish stocks. Specifically, recruitment variation has been shown to increase with decreased female longevity (Longhurst 2002), or age variation as represented by a Shannon index (Marteinsdottir & Thorarinsson 1998). In broad-scale analyses, reproductive effort has been demonstrated to increase with age (Charlesworth & Leon 1976, Roff 1991), probably because many physiological, morphological and behavioural traits in fishes change with the progression time, and therefore, the fish’s age (Green & David 2008). Size and condition are typically related, though not equally predictive of fecundity or other measures of reproductive quality (Koops et al. 2004). Even though many indices related to size and/or condition exist and have been proven to, or can be expected to, influence the quality or quantity of progeny (Green & David 2008) as yet there appears to be no one indicator that overall performs best in describing the reproductive potential and thus the "health" of the fish stock.

The two indicators that are currently in use to define SBL, i.e. SSB and F are both linked to the size- and age-distribution (Ostrovsky 2005, Shin & Cury 2004) and as there are no other indicators known to perform better on this criterion we consider the "age- and size distribution" criterion redundant.

Additional work that is required to improve this descriptor consists of:

- Formal stock assessments for more stocks, this applies notably for shellfish
- Identification of other reference points (i.e. MSY)
- Identification of additional indicators and reference levels that cover the "age- and size distribution of a healthy stock" criterion.

This approach and interpretation of the descriptor were discussed and validated during an expert workshop with external stakeholders as well as the first workshop hosted by ICES/JRC to develop this descriptor and attended by 12 international experts.

The choice of using assessed stocks only also compromises representativity as there are many stocks that are commercially exploited but for which no formal stock-assessment is conducted. This is relevant for finfish stocks but applies more widely for shellfish stocks. The desired level of representativity of assessed commercial stocks as a proportion of total landings was considered during a MEFEPO expert workshop with outside stakeholders. It was acknowledged that to operationally implant the commercial species assessment it was necessary to work with the currently available data. However it was considered desirable for the indicator to incorporate species accounting for 75% of the total value of landings to provide a robust indication of the state of stocks.

The criteria statement for GES descriptor 3 is:

Populations of all assessed commercially exploited fish and shellfish are within safe biological limits.

Where the indicator used to assess status against this objective is the proportion of commercially exploited stocks within safe biological limits, calculated as defined below.

1.2.2.2 Method for calculating the "Proportion of commercial stocks within Safe Biological Limits" indicator and associated reference levels.

This indicator was calculated according to the method developed by Piet & Rice (2004) apart from modifications specified below. The initial reference point for this indicator is that 100% of assessed stocks should be within safe biological limits as this reference level is inherent in the wording of GES descriptor 3 where it says "populations of *all* commercially exploited…". This interpretation was validated during the MEFEPO expert workshop.

The only differences between the method used in this study and the method of Piet & Rice (2004) are modifications to the species selection criteria. These are:

- The stock should be assessed so that yearly values for the indicators SSB and F are available for the assessment
- The chosen reference values should be known (here only SSBpa and Fpa)
- The stock area needs to overlap sufficiently with the MSFD region for which the assessment is done. The criteria that determine which stocks are appropriate for the region and why others are excluded need to be explicitly stated.
- Only stocks for which SSB ≥ SSBpa and F ≤ Fpa are considered to be "within SBL" and hence with GES. Though it is noted in limited cases where SSB is greater than SSBpa it may be possible to fish above Fpa for a limited time whilst maintaining SSB ≥ SSBpa.

1.2.3 GES Descriptor 4: Food Web Structure

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

All animals need energy to live; they derive this energy by feeding on other components of the ecosystem. Growth rate and reproductive success can be controlled by the amount and location of suitable prey, which can affect the productivity and distribution of populations and species. If species are notably food limited this could compromise objectives for biodiversity and status of commercial stocks. Maintaining the structure and status of food webs has therefore been identified as being important to maintaining environmental status.

1.2.3.1 Developing a criteria statement with associated indicator.

A food web is made up of a number of individual predator-prey linkages. Food webs can therefore be assessed by examining individual predator-prey linkages, or by assessing aspects of the structure of the food web as a whole. During the MEFEPO expert workshop the merits of assessing structural aspects of food web structure or assessing individual predator-prey linkages were considered. It was concluded that it would not be possible to assess every predator-prey linkage individually; therefore structural measures of food web status should be considered as they provide information on the status of the system as a whole. However it was noted that structural measures may not be sensitive to individual predator-prey links, and where specific predator-prey links are known to be important to an ecosystem feature of interest then these links could be assessed individually. Despite the potential need to assess individual predator-prey links it was decided that the work in this section of the MEFEPO project would concentrate on assessing the structural status of food webs.

Marine food webs can be very variable in time and space. A species that mainly eats one prey type at one specific time and place may rely on alternative prey at a later time or in a different location. Therefore whilst it is clear that maintaining food web condition is important to achieving other objectives for environmental status it is less clear what food webs should look like, which aspects of their structure are important to their functioning and how much they can be altered before they are no longer considered to be in 'good' condition.

Structural measures of food web status have been developed and presented in a number of preceding projects and reports. The choice structural food web indicators for consideration in the MEFEPO project was limited to indicators previously considered in the Indeco (EU FP6 project # 513754) or Indiseas (www.indiseas.org) projects, or considered in COM(2008) 187 (Table 1.2.3.1). It is acknowledged that a number of other trophic indicators have been proposed; however one of the main challenges is to consistently apply well understood and well worked indicators, rather than to continually propose and develop new indicators (Cury at al 2005).

Table 1.2.3.1 List of indicators relating to food web structure from specified project considered in this work.

Indicator	**Project or report where considered**
Trophic level of landings	Indeco, Indiseas
Proportion of predatory fish	Indiseas
Mean length of fish	Indeco, Indiseas
Mean maximum length of fish	COM 187, Indeco
Proportion of large fish	COM 187, Indeco
Mean age of fish/ average lifespan	Indeco, Indiseas
Mean weight of fish	Indeco
Total biomass of surveyed species	Indiseas
Coefficient in variation of total biomass	Indiseas
Fishing in balance index	Indeco

ICES (2005) lists eight criteria for assessing the utility of indicators for use within management structures. When selecting an indicator for operational use, key criteria are the availability of necessary data, the responses of the indicator are understood and interpretable, the indicator can be clearly explained to a wide range of stakeholders, and the indicator is sensitive to the pressure which it is designed to monitor.

A majority of the indicators listed in table 1.2.3.1 are based on measures of trophic level or size. Measures of the average trophic level of landings, or the system, have received much interest since the work of Pauly et al (1998) on fishing down food webs; the theory that fishing leads to a reduction in trophic level. Trophic level based indicators are appealing in this context as they directly report a measure of the trophic status of a food web and have been show to respond to fishing (Pauly et al. 1998). However more recent studies have found that trophic level does not always track fishing pressure (Piet & Jennings 2005), and the average trophic level of landings is responsive to fishers' behaviour as well as system status (Essington et al. 2006). Both of these factors can confound interpretation of trophic level based indicators of food web status. As landings and catch based trophic indices are sensitive to fishers' behaviour as well as changes in environmental status interpretation the effect of management intervention on environmental status is confounded. Any meaningful management intervention will simultaneously affect fishers' behaviour as well as the impact of fishing on environmental status, thus undermining interpretation of changes in state of the environment on the basis of changes in the indicator value. This criticism holds for most fishery dependant metrics and strengthens the appeal of fishery independent assessment. Although if applied at a broad spatial scale it is possible the effect on fishers' behaviour may be masked as the indicator integrates across a range of fleets and fisheries thus ameliorating the impact of variation in fisher's behaviour on the indicator value.

Indicators based on trophic level tend to assign a single consistent trophic level value to a given species, this can be based on gut content or isotopic analyses, or derived from models. Treating a species as consistently operating at a single specific trophic level does not allow for the fact that an organism can move through a range of trophic levels during development, thus as the size structure of population varies over time (e.g. due to fishing) the average population trophic level will vary over time (Jennings et al. 2002). Similarly the trophic level of a species can vary spatially due to spatial variation in diet. Size based variation in diet can be allowed for by applying a trophic level at size for each species, although this has rarely been applied. Regular collection of information on the trophic level of fish is not currently undertaken under formalised sampling programs.

Measures of community size structure have been proposed as an alternative framework to provide robust indicators of the effects of fishing on the fundamental trophic structure of marine ecosystems. This is due to the fact that predator prey relationships in aquatic environments are strongly size dependant (Jennings et al. 2001; Kerr & Dickie 2001), and that fishing is size selective and leads to a reduction in the average size of the fish community (Bianchi et al. 2000). This is well supported by macroecological theory, and comparative studies of the ability of different indicators to show fishing signals have demonstrated that size based indicators are responsive to the effects of fishing (Bianchi et al. 2000; Greenstreet & Rogers 2006; Jennings et al. 2002), even in the presence of confounding drivers (Blanchard et al. 2005).

In other words the size structure of a community reflects the trophic structure of the community, and the relationship between fishing pressure and size structure of fish communities is well known; therefore size based indicators can provide a well understood measure of the impact of fishing on food web status. Given the proven ability of size based indicators to respond to fishing, and the importance of size in defining predator-prey links, a size based indicator was selected for the use as the indicator of food web structure in the MEFEPO project. The data requirement for calculating most size based indicators is fishery independent survey data of abundance by length of all fish species collected in a survey. This data is widely collected in formal surveys across the EU, and in many cases past time series data are available. This allows the operational implementation of size based indicators on the basis of current data collection and supports the choice of a size based indicator of food web structure.

COM(2008) 187 lists two size based indicators as being immediately operational, the proportion of large fish indicator (LFI) and the mean maximum weight of fish indicator. Of these two the LFI was selected as the indicator of trophic structure to report against GES qualitative descriptor 4 as it has been developed as an EcoQO as part of the OSPAR North Sea pilot project and is supported by the OSPAR EcoQO process. The LFI is defined as the proportion of fish larger than 40cm in the community by weight. The proportion of 'large fish' is calculated as:

$$P_{>40cm} = \frac{W_{>40cm}}{W_{Total}}$$

where $W_{>40cm}$ is the weight of fish greater than 40 cm in length and *WTotal* is the total weight of all fish in the sample.

The criteria statement for GES descriptor 4 is:

The proportion of large fish is maintained

Where the proportion of large fish is calculated using the large fish indicator as defined in COM(2008) 187 and modified according to procedures outlined in 1.2.3.2.

As with all trophic indicators the LFI does not perfectly fulfil the requirements of an indicator to address GES qualitative descriptor 4. Inevitably in reducing information down to a single indicator value information is lost, and no indicator will be sensitive to all changes in state. There are three main critiques to applying the LFI. Firstly it has been developed for, and mainly applied to, the North Sea. When it is applied across wider areas it may not provide as sensitive an indicator to fishing as in the North Sea. In developing the indicator for the North Sea procedures have been developed (mainly not including climatically sensitive small pelagic fish) to reduce the effect of climatic signals on indicator behaviour. These procedures may not be appropriate when the indicator is applied to regions outside the area for which the indicator was developed, in particular the size at which fish are considered ‘large’ and the limit level of proportion of ‘large’ fish may need to be redefined for new areas. Secondly the indicator only considers the fish community and takes no account impacts on the benthic invertebrates, seabirds, reptiles or marine mammals. Thirdly, the LFI can be affected by variation in both the numerator and the denominator. In other words it is sensitive to both the numbers of small fish and the numbers of large fish. A change in indicator value could be caused by fishing pressure on large fish, but the indicator can also be driven by changes in the abundance of small fish.

The LFI is calculated with data on a subset of fish species; species with variable catchability are excluded from the calculations as they can introduce noise into the indicator signal. The text of GES qualitative descriptor 4 refers to ‘*all elements of marine food webs*’. Is an indicator based on a selected part of the fish community sufficient to report on the effects of fishing on all elements of marine food webs? Other than invertebrate fisheries, fisheries target fish and thus fish community is the ecosystem component expected to be most directly impacted by fishing. Key functional groups within a system can provide a good characterisation of the whole system status with respect to a given driver (Fulton et al. 2005). Therefore although the LFI does not consider all elements of marine food webs it may provide a sensitive indicator of the main impacts of fishing on food web structure. Further research is required to establish to what extent this is the case.

1.2.3.2 Method for calculating the large fish indicator and associated reference levels.

The proportion of large fish indicator was calculated according to the procedure outlined in COM(2008) 187 unless otherwise specified.

The limit reference level for the LFI, as implement by OSPAR, is for the LFI to be 0.3 or greater. This reference level was defined for the North Sea on the basis on assessment of past behaviour of the LFI. It was considered that the early 1980's was the last period when North Sea stocks were not suffering from widespread overfishing (Figure 1.2.3.1), and that this provided reasonable reference period. The LFI in the early 1980's was approximately 0.3. This also roughly corresponds with the average LFI (0.29) of the Scottish August Groundfish Survey from the 1920's through to the early 1980's, which provides support to setting the reference level to 0.3. However it is interesting to note that for five of the eight records between the 1920's and early 1980's the value of the LFI was below 0.3. Furthermore it should be noted that these values were determined purely on the basis of survey information from the North Sea, and thus this reference level will not be applicable to areas outside the North Sea.

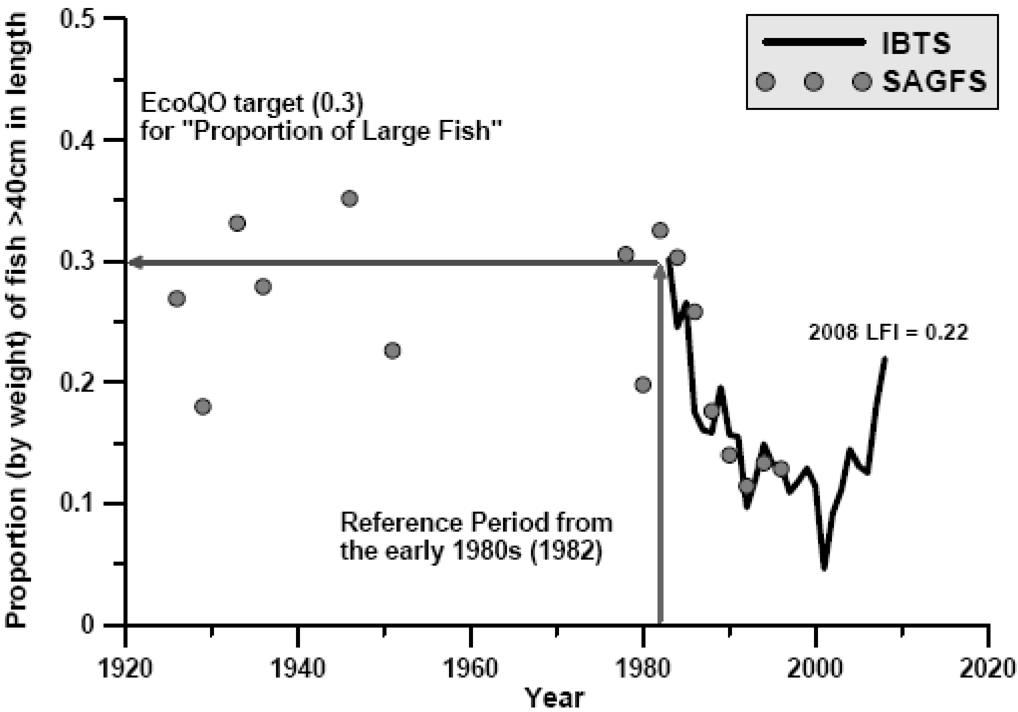

Figure 1.2.3.1: Time series of the LFI for the North Sea based on the Q1 North Sea IBTS and the Scottish August Groundfish Survey (SAGFS). Source: ICES 2009.

1.2.4 GES Descriptor 6: Benthic Habitats

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

The seafloor and associated benthic communities play a key role in a number of ecosystem processes, this includes carbon and nutrient recycling, habitat provision and secondary production. There is a general trend for legislation referring to benthic habitats to concentrate on rare and vulnerable habitats, and to provide little coverage for the widespread abundant benthic habitats and communities. However, simply due to the fact that they cover a large proportion of the sea floor it is the widespread habitats that make the largest contribution to see floor functions. Maintaining these processes is therefore important to supporting wider marine ecosystem functioning and it is considered that GES descriptor 6 refers to structure and function of key benthic processes, and that protecting rare and threatened habitats comes under the remit of GES descriptor 1.

1.2.4.1 Developing a criteria statement with associated indicator.

The ICES-JRC group has interpreted GES descriptor 6, to include both the physical and biotic components of the seafloor, and considers that its integrity includes a measure of spatial connectedness (in terms of its habitat function) and natural ecosystem processes ('functioning in characteristic ways'). This indicates a desire to manage processes rather than places.

Experimental attempts to use functional approaches to delineate Special Areas of Conservation (SACs) have been undertaken (Bremner et al., 2006; Frid et al., 2008). Frid et al. (2008) defined functioning, following Naeem et al. (2004) as '…the activities, processes or properties of ecosystems that are influenced by their biota', and used Biological Traits Analysis (BTA) to provide a measure of the functions delivered by benthic systems (Table 1.2.4.1).

Table 1.2.4.1. A list of ecosystem functions delivered by benthic systems (Frid et al., 2008).

• Energy and nutrient cycling	• Habitat/refugia provision
• Silicon cycling	• Temporal pattern (population variability, community resistance and resilience)
• Calcium carbonate cycling	• Propagule supply/export
• Food supply/export	• Adult immigration/emigration
• Productivity	• Modification of physical processes

This study showed that whilst it is possible to link the physiological and behavioural traits of biological organisms to the delivery of the ecosystem functions, and consequently provide some measure of the functions delivered by an area, functional techniques need significant further development before they can be used for management purposes. Techniques to measure ecological functions are still subject to high levels of scientific debate due to our limited understanding of how ecosystems function and a lack of very basic information on the majority of taxa. This means that it is often difficult to identify how, and which, organisms deliver the functions. There is also a significant scientific debate over what would constitute 'good' functional status.

As the science underpinning our understanding of how ecosystems (and sea floor) function is still being developed and significant advances in the science are required before functioning can be used in a management context, a more pragmatic approach based on existing information is required to develop this sea floor GES descriptor. Thus the desire to manage processes rather than places is not yet achievable, and the current assessment of seafloor functioning will have to revolve around managing places.

Following a MEFEPO workshop where policy makers were asked how to interpret the GES descriptor for management, the delegates thought it was best to focus on protecting those areas of the sea floor which were least impacted by human activities. The workshop delegates thought that whilst it was relatively straightforward to argue for the protection of areas of high natural biological diversity, it was more difficult to argue convincingly that areas should be protected for wider functional purposes, so protecting the least impacted areas was an acceptable compromise.

Identifying areas which are least impacted by human activities does not necessarily equate to identifying the areas of least human activity. The level of impact 'per unit of disturbance' depends upon the level of natural disturbance in the area, as some types of sea floor are subject to high levels of natural disturbance and highly resilient to further disturbance. Again, the science underpinning our understanding of the sensitivity of marine habitats to human disturbance is still underdeveloped although there are studies which are addressing this issue.

As there is limited information in the state of benthic habitats, the alternative approach of assessing pressure indicators for benthic habitats has been developed. Indicators based on mapping the distribution of fishing activities have been developed (ICES, 2009, Lee et al., submitted) using VMS data which is available through the EU data collection regulations (Council Regulation (EC) 199/2008). These are:

Indicator 1: Distribution of fishing activities
Indicator of the spatial extent of fishing activity. It would be reported in conjunction with indicator 2. It would be based on the total area of grids (3km x 3 km) within which VMS records were obtained, each month.

Indicator 2: Aggregation of fishing activities
Indicator of the extent to which fishing activity is aggregated. It would be reported in conjunction with the indicator for 'Distribution of fishing activities'. It would be based on the total area of grids (3 km x 3 km) within which 90% of VMS records were obtained, each month.

Indicator 3: Areas not impacted by mobile bottom gears
Indicator of the area of seabed that has not been impacted by mobile bottom fishing gears in the last year. It responds to changes in the distribution of bottom fishing activity resulting from catch controls, effort controls or technical measures (including MPA established in support of conservation legislation) and to the development of any other human activities that displace fishing activity (e.g., wind farms). This indicator could be reported annually and would state the total proportion of the area by depth strata (0–20 m, 20–50 m, 50–80 m, 80–130 m, 130–200 m, >200 m) in each marine region that has not been fished with bottom gear in the preceding one year period.

These indicators are not without criticism however. Whilst there is an extensive literature on the impact of single fishing impacts on benthic systems, there are few data on the cumulative impacts of fishing activities or on the synergistic effects of fishing with other human activities (van Hal & Piet, 2009). This makes it difficult to consider the status of the sea floor beyond the fact that it is not fished. It also makes it difficult to incorporate information on functioning unless biological data is also collected.

Indicator 3, the proportion of area not impacted by mobile bottom gears provides a direct measure of the main pressure on benthic systems. Where information is limited a standard management approach is to protect representative areas of different habitats. The ‘proportion of area not trawled’ indicator is currently worded such that it is reported by depth strata. This only provides limited resolution of the indicator as numerous distinct benthic habitats can occur within a single depth band. To improve the resolution of the indicator the depth strata were combined with information on sediment type to divide the assessed area into ‘habitats’ defined by depth and sediment type. Improved mapping of sea-floor habitats would improve the resolution of the indicator.

The criteria statement for GES descriptor 6 is:

Representative areas of each habitat are not impacted by mobile bottom gears

Where the proportion of area for each habitat type not impacted by mobile bottom gears is calculated on the basis of VMS records.

Basing this indicator solely on VMS data means that only the larger vessels in the system are included in the measure of proportion of area not trawled. Currently only vessels over 15m are required to carry VMS, the smaller section of the fleet is thus ignored. This could cause significant bias in the indicator, especially in inshore areas. This could be remedied by requiring more of the fleet to carry VMS. Furthermore, currently in European waters vessels are only required to send a VMS location on a 2 hourly basis thus only providing a limited picture of the location of fishing effort. Thus the raw VMS data requires processing to fill in the gaps between the position records, a number of processing methods have been applied and are under development, however none of the processing methods can recreate a completely accurate picture of fishing locations.

The VMS data enables a map of fishing effort by mobile bottom gears to be created. This map needs to be coupled with a habitat map to enable the indicator to be calculated for each habitat. Due to the lack of high quality habitat maps covering wide areas of the European shelf the DCR specifications for the indicator are that it should be reported by depth bands. To try and improve the habitat resolution beyond simple bathymetric discrimination seafloor habitat maps were overlaid over the bathymetry when available.

A further comment needs to be made about the proportion of area not impacted by mobile bottom gears as specified in COM(2008) 187; the current definition of this indicator is that it should be reported as the area not impacted by mobile bottom gears on an annual basis. Recovery time of benthic habitats to impacts of mobile bottom gears varies depending on the type of habitat and gear used, and can vary from hours and days to years and decades (Jennings & Kaiser, 1998). Reporting the indicator on an annual basis is sufficient to understand the impacts of fishing on sea-floor habitats where the recovery time from the disturbance is less than one year. However for habitat-gear combinations where the recovery time is greater than a year, reporting the indicator on an annual basis and only considering the previous years fishing will underestimate the extent of impact. The time period over which VMS records incorporated for calculating this indicator should be reassessed to ensure it is sufficient to allow for the prevalent recovery time with regard to the sea-floor functions of concern.

1.2.4.2 Method for calculating the proportion of area not impacted by mobile bottom gears and associated reference level.

The proportion of area not impacted by mobile bottom indicators was calculated on the basis of VMS records. The first step is to process the VMS data to create a map of fishing effort by mobile bottom gears. This is then overlaid over a bathymetry chart, and if available a habitat map, and the final indicator of the proportion of area not trawled by depth band and habitat type calculated. The VMS processing method used is the 'point summation method' as developed by Lee et al (submitted), the exact instructions circulated amongst project partners listing the steps used to calculate the map of fishing effort from VMS data in the MEFEPO project are included in Appendix 1. Additional modifications to the method had to be introduced when working up the VMS data for certain countries as the available data were not identical in their coverage and format, these modifications to the method are presented in section 2.

Currently there are no robustly justified reference levels as target or limit values for this indicator. The acceptable level of mobile bottom gear impact will depend on the resilience and susceptibility of the habitat (and its key functions) to damage, thus a single unified reference level to be applied across all habitat types may not be possible. Until justified reference levels are developed the target reference direction for the indicator is for the proportion of area not impacted by mobile bottom gears to remain constant or increase.

Section 2: Current status of the North Sea RAC region in relation to ecological objectives for good environmental status in European waters.

This section of the report presents the results of the assessment of the current environmental status of the North Sea RAC region with respect to the ecological objectives developed in Section 1. To this extent section 2 of the report is a technical exercise listing the data requirements, and availability, for each of the indicators. The indicator values are reported based on the data that was available during the development of this report. Brief interpretations of the results are presented, however this report was not intended to provide a detailed analysis of the underlying factors explaining indicator performance.

2.1 GES Descriptor 1: Biological Diversity

2.1.1 Data requirements and availability

Calculation of the "Conservation Status of Fish" (CSF) indicators is based upon fishery independent trawl survey data that reports CPUE of species by length. This data is available from surveys conducted under the DCR. The North Sea IBTS survey provides coverage of the whole North Sea area as a single co-ordinated survey and can provide the information required to calculate the CSF indicators. The North Sea IBTS survey data were available from DATRAS to calculate the indicator in this report. The time period used was all data from 1983 until 2007. 1983 was chosen as the first year in the time series to use as this was the first year in which all component parts of the IBTS survey were conducted with a GOV trawl; 2007 was the latest available data at the time of this work.

The method used to calculate the indicators is the method defined in COM(2008) 187 apart from the modifications listed in section 1. The only further modification on this method was that the alternative species list used to calculate the indicators was based on the average abundance of species during the first five years of the time series. This is compared to using the average abundance over all years of the time series as indicated in COM(2008) 187.

2.1.2 Modifications to indicator calculation method

The first stage of the indicator calculation is to develop a species list of the large vulnerable species. This was calculated using the full time series, as specified in COM(2008) 287, and a comparative list based was compiled just using the first 5 years of the time series. The second method for calculating the species list was applied to avoid a 'shifting baseline' as it was noted that species that were declining over time could be excluded from the list due to failing to meet the minimum average annual abundance requirement of 20 individuals being present each year even if they achieved the abundance requirement over the early period of the time series. The two comparative species lists are listed in table 2.1.1, the indicators were calculated using both species lists, the 'full list' and the '5 year list'.

Table 2.1.1 Species included in the original species list and species included in the list based on the first 5 years of records. A '1' indicates that the species was included in the list.

Species	Common names	Full list	5 year list
Anarhichas lupus	Wolf fish		1
Gadus morhua	Cod	1	1
Leucoraja naevus	Cuckoo ray	1	1

Lophius piscatorius	Angler fish	1	
Pollachius virens	Saithe	1	1
Squalus acanthias	Spurdog		1
Amblyraja radiata	Starry ray	1	1
Merluccius merluccius	Hake	1	
Melanogrammus aeglefinus	Haddock	1	1
Merlangius merlangus	Whiting	1	1
Pleuronectes platessa	Plaice	1	1
Lepidorhombus whiffiagonis	Megrim	1	
Cyclopterus lumpus	Lumpsucker	1	1
Glyptocephalus cynoglossus	Witch	1	1
Microstomus kitt	Lemon sole	1	1
Entelurus aequerius	Snake pipefish	1	
Enchelyopus cimbrius	Fourbeard rockling	1	1
Eutrigla gurnardus	Grey gurnard	1	1
Solea vulgaris	Common sole	1	1
Trachurus trachurus	Horse mackerel	1	
Hippoglossoides platessoides	Long rough dab	1	1

The criteria for including species in the species list required that the maximum length was over 40cm, and species could be further excluded if "*they have morphology, behaviour or habitat preferences that are expected to lead to low and variable catchability in the survey gear.*" The species that were excluded due to limited or variable sampling are listed in table 2.1.2 along with the reason for exclusion.

Table 2.1.2: Species meeting length and abundance criteria excluded from final species list due to variable sampling or other reasons.

Species name	Common name	Reason for exclusion
Platichthys flesus	Flounder	Strong estuarine affinity, limited sampling
Alosa fallax	Twaite shad	Anadromous, limited sampling in survey
Scomber scombrus	Mackerel	Shoaling, variable catchability
Spinachia spinachia	Fifteen-spined stickleback	Presumed mis-identification or mis-recorded in records, unlikely to reach 40cm

According to COM(2008) 187, CSFa (based on IUCN criteria) compare the annual abundance with the first year in the time series, CSFb (comparing annual abundance with the initial reference period) uses the average abundance over the first three years as the reference period. CSFa is therefore highly sensitive to abundance in the first year of the survey time series; to reduce this sensitivity the indicator was calculated according to COM(2008) 187, and also using the average abundance over the first three years as the reference level.

2.1.3 Indicator assessment

2.1.3.1 CSFa, IUCN criteria

CSFa is the conservation status indicator calculated with reference to the IUCN threat criteria. Four versions of the indicator were calculated (Figure 2.1.1), using the full or 5 year species lists, and using just the first year as the reference abundance, or the first three years as the reference abundance. COM(2008) 187 suggested a value of 1 as a limit reference point, this equates to all the species in the list being considered 'vulnerable' or more threatened. It should be noted that as this is the average IUCN threat status of species in the list, a single species could become 'critically endangered' or even lost from the system without the indicator value reaching the limit threshold.

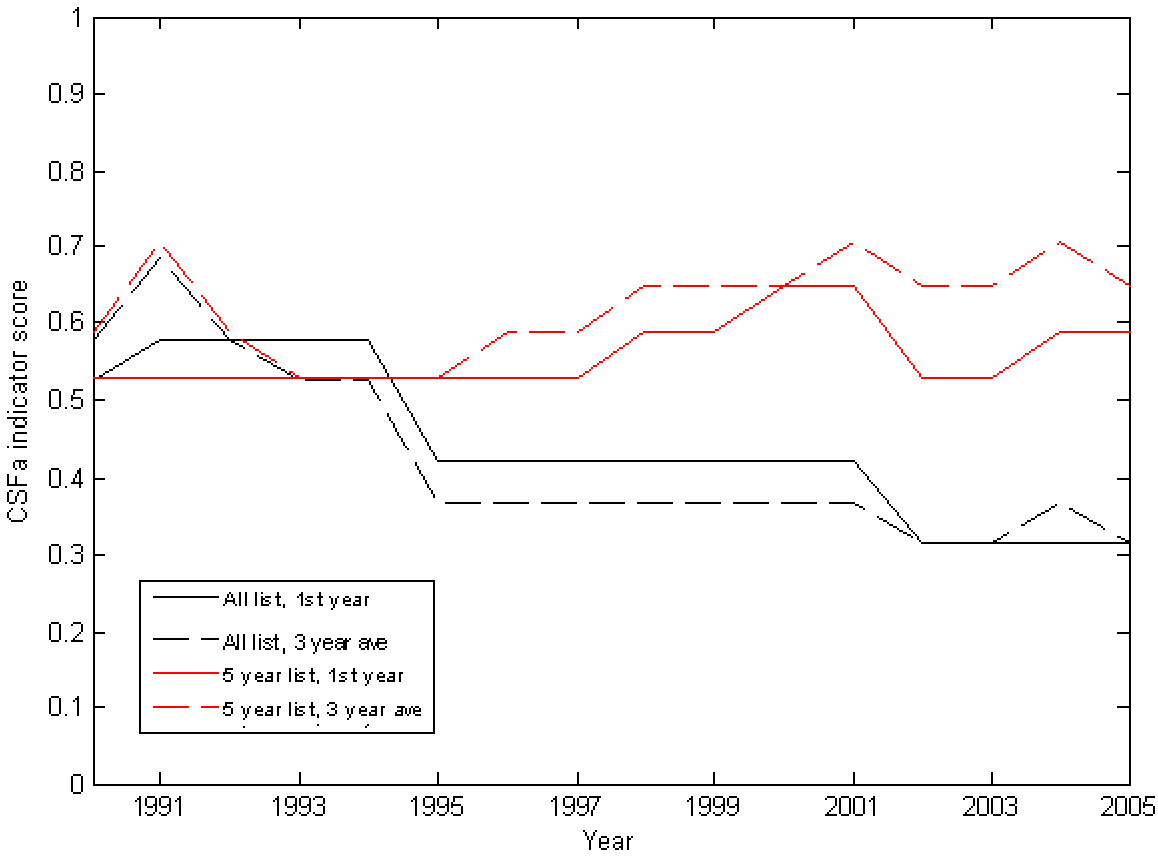

Figure 2.1.1: CSFa indicator values calculated with the full and 5 year species lists, and using either the first year or average of the first three years as the reference period.

The indicator value for the CSFa, calculated with either the full or 5 year species list, and with either just the first year, or the average of the first 3 years as the reference period is shown in figure 2.1.1.

There is variation in the quantitative and qualitative performance of the indicator depending on the species list chosen and the reference period used. When the full species list is used there is a decline in the indicator value (improvement in conservation status) over the full survey period, irrespective of the reference period chosen. Conversely when the 5 year species list was used the indicator value increased (decline in conservation status) over the full survey period, irrespective of the reference period used. However in all cases the indicator values remain below the suggested threshold of 1.

2.1.3.2 CSFb, relative abundance

CSFb is a conservation status indicator that reports the average abundance of the large fish community on an annual basis in relation to reference period. The reference period is the average abundance over the first three years of the time series. The CSFb indicator was calculated using both the full species list and the 5 year species list (Figure 2.1.2). No reference limits have been suggested, a reference direction of an increase in the indicator value was suggested by COM(2008) 187.

As with CSFa, there is variation in quantitative and qualitative behaviour of the indicator depending on the species list used to calculate the indicator. When the full species list is used the indicator reports a greater than 80% increase in the average biomass of large vulnerable fish compared to the reference period, whereas when the 5 year species list is used the indicator reports an approximately 20% decline in the average biomass of large vulnerable fish compared to the reference period.

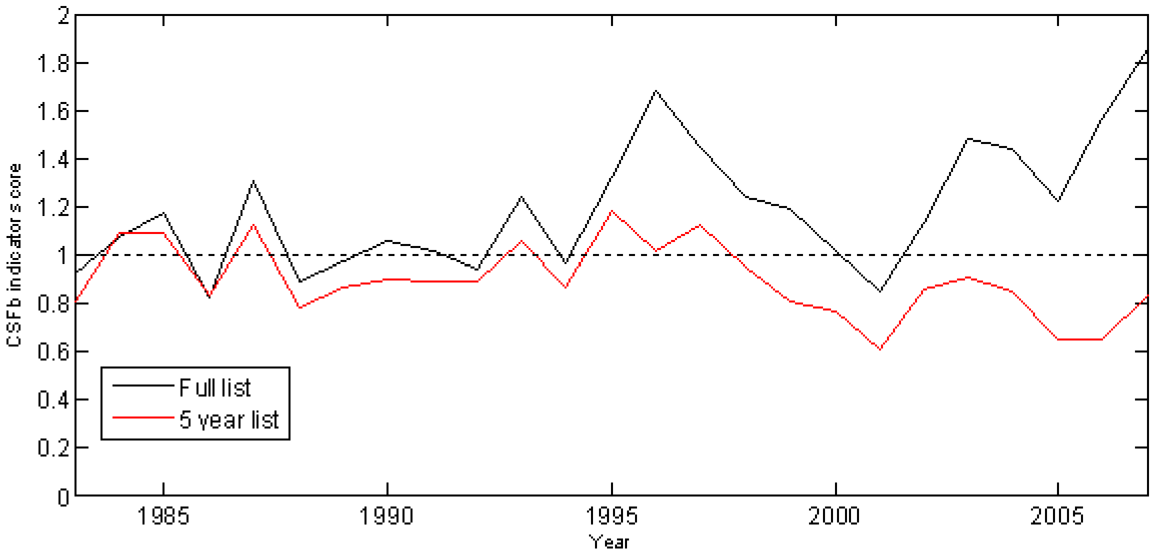

Figure 2.1.2: CSFb indicator values calculated with the full and 5 year species lists. The dashed line is a refernce line with a value of 1.

2.1.4 Discussion

The underlying cause of the variation in behaviour of CSFa and CSFb between the full list and 5 year list is apparent when the abundance trends of the individual species incorporated in the indicator are examined (Figure 2.1.3). Two species, *Anarhichas lupus* and *Squalus acanthias*, that were incorporated in the 5 year list were not included in the full list. Both these species started at low abundance and declined further over time. Whereas five species were included in the full list that were not included in the five year list. In each case these were species that were increasing over the survey time period. Their abundance over the first 5 years was insufficient to allow the species to be included on the basis of abundance, but their increased numbers over time meant that they do achieve the abundance threshold over the full time series. The increased abundance of some of these species may be climate driven, rather than a fishing effect.

The variation in behaviour of the CSF indicators, and the underlying explanation of this behaviour, found in this study indicates that the species list selection criteria developed in COM(2008) 187 should be reconsidered and potentially revised. The approach trialled in this report of basing the species list on the first five years of records holds merits. This method does have the drawback that the indicator could become anchored on a historic 'outdated' community description if climate leads to a change in the 'natural' community inhabiting the area of study. Despite this drawback anchoring the indicator has the merit of avoiding the shifting baseline problem that inherently besets the current species selection criteria.

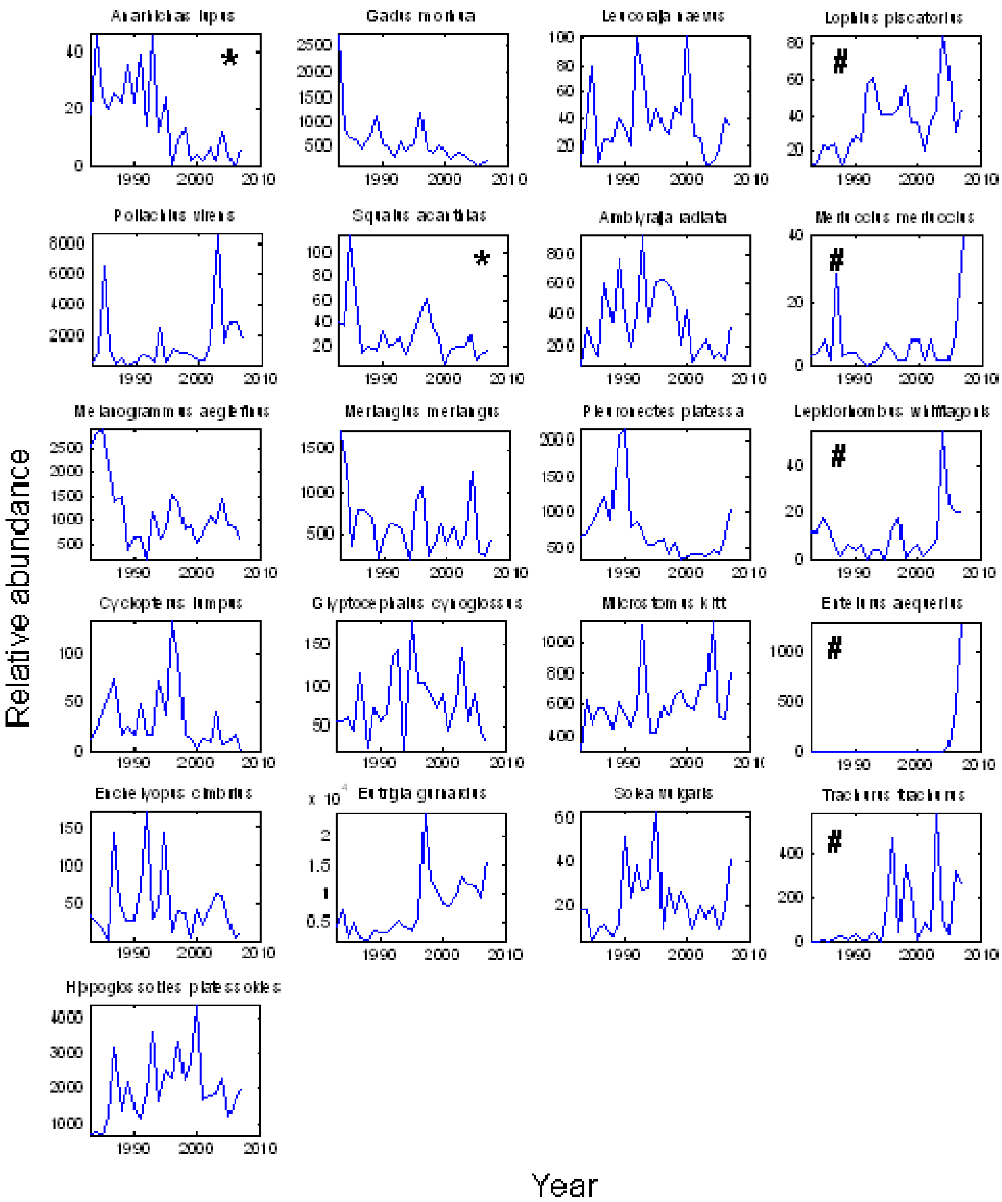

Figure 2.1.3: Relative abundance over time of all species included in the CSF species lists. All species co-occurred in both lists, apart those marked * which only occurred in the 5 year list and those marked # which only occurred in the full list.

The result that the CSFa indicator has remained below the provisional threshold level of 1 over the full time period for which unified data across the whole North Sea is available suggests that the effect of fishing on the marine biodiversity with respect to GES descriptor 1 is well within acceptable limits. Using the selection criteria specified in COM(2008) 187 the CSFb indicator also indicates that effect of fishing on biodiversity is within acceptable levels. When the CSFb indicator is calculated using the 5 year species list there has been a decline in abundance of large vulnerable fish over the time series, and it could be considered that the conservation status of fish is not being maintained.

When interpreting the CSF indicators it is important to note that this indicator only considers a selected portion of the fish community. There are 29 species and 10 habitats listed on the OSPAR list of threatened and declining habitats and species that are considered under threat or in decline in the greater North Sea (OSPAR area II). Of the 29 species listed as threatened or declining in the North Sea 10 are fish species, and of these 10 fish species only one (*G. morhua*) is considered in the indicator based on the full list and two (*G. morhua* and *S. acanthias*) are included in the 5 year list. This indicates the limitations of the CSF indicators as indicators of the effect of fishing on biodiversity; they only incorporate very limited information on species that are known to be threatened or declining.

Incorporating information on the OSPAR threatened fish species in a survey based indicator is problematic, in many cases the majority of the declines will have occurred before the unified survey time series begins and hence the information on the less impacted stock sizes is not formally available in this form of analysis. Reducing the minimum abundance threshold would allow species at lower abundances to be incorporated in the analyses, however at very low abundances analysis of survey data has very little power and little confidence could be ascribed to the analyses. It has been suggested that analyses based on the spatial distribution of occurrence in the time series data could be applied as these methods can provide more power to analyses based on low numbers of observations. Whilst such an approach might add breadth to the species coverage it still does not get round the inherent problem of conducting biodiversity analyses on time series with only limited past reach.

2.2 GES Descriptor 3: Commercial species

2.2.1 Data requirements and availability

The data required to calculate the commercial species indicator is yearly assessment values of SSB and F for a stock and the reference values for SSB_{pa} and F_{pa} for the same stock. Ideally this would be known for all stocks, as this is practically unfeasible a target coverage of including stocks that made up 75% of the value of the landings was identified as desirable, albeit this level of representativity is currently unavailable.

The stocks that were selected to calculate the indicator for the North Sea are shown with the stock code used in table 2.2.1.

Table 2.2.1 Assessed stocks, and their codes, used to calculate the commercial species indicator for the North Sea.

Code	Stock
cod-347d	Cod in Subarea IV (North Sea), Divison VIId (Eastern Channel) and IIIa West (Skagerrak)
cod-scow	Cod in Division VIa (West of Scotland)
had-34	Haddock in Subarea IV (North Sea) and Division IIIa West (Skagerrak)
had-scow	Haddock in Division VIa (West of Scotland)
her-47d3	Herring in Subarea IV and Divisions IIIa and VIId (North Sea autumn spawners)
ple-eche	Plaice in Division VIId (Eastern Channel)
ple-nsea	Plaice Sub-area IV (North Sea)
sai-3a46	Saithe in Sub-area IV (North Sea) & Division IIIa (Skagerrak)
sol-eche	Sole in Division VIId (Eastern Channel)
sol-kask	Sole in Division IIIa (Skagerrak-Kattegat)
sol-nsea	Sole in Sub-area IV (North Sea)
whg-47d	Whiting Sub-area IV (North Sea) & Division VIId (Eastern Channel)

The years the selected stocks were assessed are shown in table 2.2.2. This shows that the suite of stocks on which the indicator is based has expanded considerably over time (see figure 2.2.1).

Table 2.2.2 Years for which assessments were available for stocks listed in table 2.2.1. Stock codes relate to codes in table 2.2.1.

Year	cod-347d	cod-scow	had-34	had-scow	her-47d3	ple-eche	ple-nsea	sai-3a46	sol-eche	sol-kask	sol-nsea	whg-47d
1957							X				X	
1958							X				X	
1959							X				X	
1960					X		X				X	
1961					X		X				X	
1962					X		X				X	
1963	X		X		X		X				X	
1964	X		X		X		X				X	
1965	X		X		X		X				X	
1966	X		X		X		X				X	
1967	X		X		X		X	X			X	
1968	X		X		X		X	X			X	
1969	X		X		X		X	X			X	
1970	X		X		X		X	X			X	
1971	X		X		X		X	X			X	
1972	X		X		X		X	X			X	
1973	X		X		X		X	X			X	
1974	X		X		X		X	X			X	
1975	X		X		X		X	X			X	
1976	X		X		X		X	X			X	
1977	X		X		X		X	X			X	
1978	X	X	X	X	X		X	X			X	
1979	X	X	X	X	X		X	X			X	
1980	X	X	X	X	X	X	X	X			X	
1981	X	X	X	X	X	X	X	X			X	
1982	X	X	X	X	X	X	X	X	X		X	
1983	X	X	X	X	X	X	X	X	X		X	
1984	X	X	X	X	X	X	X	X	X	X	X	
1985	X	X	X	X	X	X	X	X	X	X	X	
1986	X	X	X	X	X	X	X	X	X	X	X	
1987	X	X	X	X	X	X	X	X	X	X	X	
1988	X	X	X	X	X	X	X	X	X	X	X	
1989	X	X	X	X	X	X	X	X	X	X	X	
1990	X	X	X	X	X	X	X	X	X	X	X	
1991	X	X	X	X	X	X	X	X	X	X	X	
1992	X	X	X	X	X	X	X	X	X	X	X	
1993	X	X	X	X	X	X	X	X	X	X	X	
1994	X	X	X	X	X	X	X	X	X	X	X	
1995	X	X	X	X	X	X	X	X	X	X	X	X
1996	X	X	X	X	X	X	X	X	X	X	X	X
1997	X	X	X	X	X	X	X	X	X	X	X	X
1998	X	X	X	X	X	X	X	X	X	X	X	X
1999	X	X	X	X	X	X	X	X	X	X	X	X
2000	X	X	X	X	X	X	X	X	X	X	X	X
2001	X	X	X	X	X	X	X	X	X	X	X	X
2002	X	X	X	X	X	X	X	X	X	X	X	X
2003	X	X	X	X	X	X	X	X	X	X	X	X
2004	X	X	X	X	X	X	X	X	X	X	X	X
2005	X	X	X	X	X	X	X	X	X	X	X	X
2006	X	X	X	X	X	X	X	X	X	X	X	X
2007	X	X	X	X	X	X	X	X	X	X	X	X
2008	X	X	X	X	X	X	X	X	X	X	X	X

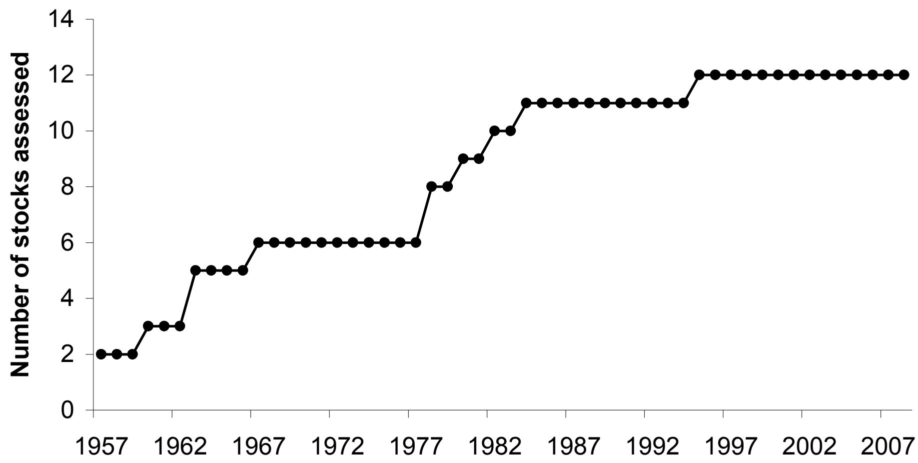

Figure 2.2.1. Number of North Sea stocks assessed over time.

To assess representativity of the indicator the proportion of total landings that came from assessed stocks was determined. This calculation was based on the ICES catch statistics 1973-2007 as they occur in the FAO Fishstat database. The Fishstat divisions listed in table 2.2.3 were attributed to the North Sea RAC region and landings per species were aggregated across the region.

Table 2.2.3 Divisions in the FAO Fishstat database attributed to the North Sea RAC region.

Area 27 Sub-area IIIa
Area 27 Sub-area IIIa+IVa+b
Area 27 Sub-area IV
Area 27 Sub-area IV a+b
Area 27 Sub-area IVa
Area 27 Sub-area IVb
Area 27 Sub-area IVc
Area 27 Sub-area VIa
Area 27 Sub-area VIId

Over the last 5 years (2003-2007) there were almost 300 different species or species-groups landed. The exact number was difficult to determine as there is overlap between groups (e.g. Anglerfish and Anglerfishes nei) as well as different species aggregated in one group (e.g. "Dogfishes and hounds" or "Cuttlefish, bobtail squids"). In the period 2003-2007 58 species (42 fish, 16 invertebrates) contributed more than 0.1% of the landings by weight (table 2.2.4). Together these species made up 99% of the landings (approximately 90% fish and less than 10% invertebrates).

About 30-40% of the landed species consists of assessed species for which both reference values are known (figure 2.2.2) and contributed to the indicator calculation. However, in a sense this is an understatement since several species that contribute an important part of the landings are assessed but they have wide ranges of distribution, and the core of the stocks lie outside the North Sea, so they were not considered representative of the state of the North Sea commercial stocks (i.e. Mackerel, Blue whiting and Horse mackerel). If these species were included the representativity would increase to about 65%. Alternatively if these species were not included in the total North Sea-specific landings the representativity would be about 56%.

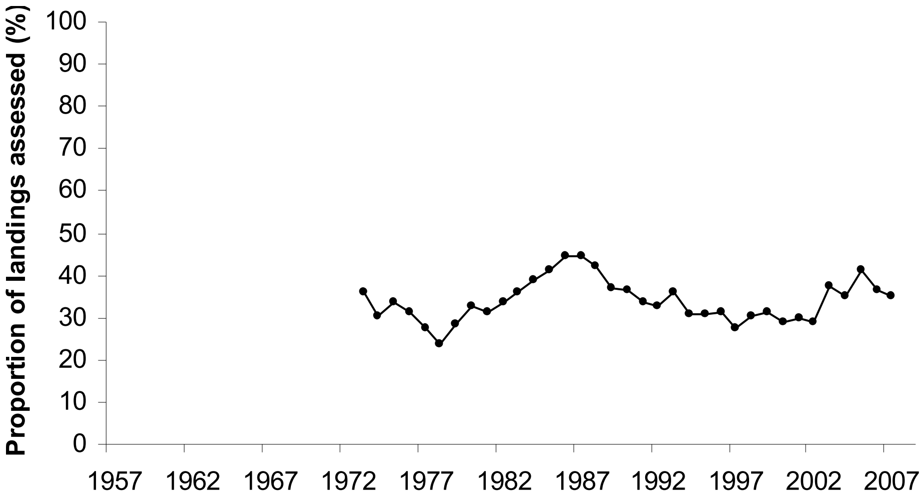

Figure 2.2.2 Proportion of the total landings in the North Sea region consisting of assessed species.

Table 2.2.4 All major species and species-groups (>0.1% of the total landings period 2003-2007), their total landings and relative contribution. Indicated is whether the species are assessed (A) or non-assessed (NA), and whether they are fish (F) or invertebrates (I).

Species	Assessed	Type	Total landings (t)	% landings
Atlantic herring	A	F	2783653	21.5
Blue whiting(=Poutassou)	NA	F	1899827	14.7
Atlantic mackerel	NA	F	1830193	14.1
Sandeels(=Sandlances) nei	NA	F	1445138	11.2
European sprat	NA	F	1052670	8.1
Saithe(=Pollock)	A	F	560699.5	4.3
Atlantic horse mackerel	NA	F	423721	3.3
European plaice	A	F	348293	2.7
Blue mussel	NA	I	297343	2.3
Haddock	A	F	217233	1.7
Common shrimp	NA	I	194042	1.5
Norway lobster	NA	I	180636.5	1.4
Atlantic cod	A	F	153572	1.2
Edible crab	NA	I	121705	0.9
Great Atlantic scallop	NA	I	117624	0.9
Norway pout	NA	F	115552	0.9
Common sole	A	F	106008	0.8
Whiting	A	F	89451	0.7
Northern prawn	NA	I	69692	0.5
Common edible cockle	NA	I	63178	0.5
European pilchard(=Sardine)	NA	F	60875.5	0.5
Angler(=Monk)	NA	F	58165.5	0.4
Common dab	NA	F	54997	0.4
Ling	NA	F	54926	0.4
Roundnose grenadier	NA	F	46192.5	0.4
Whelk	NA	I	35895	0.3
European hake	NA	F	33450.5	0.3
Cuttlefish,bobtail squids nei	NA	I	24767	0.2
European flounder	NA	F	23637	0.2
Lemon sole	NA	F	22877	0.2
Raja rays nei	NA	F	20896	0.2
Various squids nei	NA	I	19579	0.2
Greater argentine	NA	F	19347	0.1
Turbot	NA	F	19025	0.1
Red mullet	NA	F	16075	0.1
Tusk(=Cusk)	NA	F	15434.5	0.1
Witch flounder	NA	F	15161	0.1
Blue ling	NA	F	14746.5	0.1
Pouting(=Bib)	NA	F	14314	0.1
Picked dogfish	NA	F	13748	0.1

Black scabbardfish	NA	F	13674.5	0.1
Pollack	NA	F	12571	0.1
Argentine	NA	F	12435	0.1
Tub gurnard	NA	F	12044.5	0.1
European flat oyster	NA	I	10184	0.1
Atlantic surf clam	NA	I	9666	0.1
Portunus swimcrabs nei	NA	I	9409	0.1
European seabass	NA	F	9315	0.1
Small-spotted catshark	NA	F	9248	0.1
Megrim	NA	F	8538.5	0.1
Brill	NA	F	8450	0.1
European lobster	NA	I	7796	0.1
Razor clams nei	NA	I	7764	0.1
European anchovy	NA	F	7569.5	0.1
Monkfishes nei	NA	F	7395.5	0.1
Red gurnard	NA	F	7317	0.1
Black seabream	NA	F	6770	0.1
Queen scallop	NA	I	6673.5	0.1

2.2.2 Modifications to indicator calculation method

The only modification to the criteria developed by Piet & Rice (2004) was that the indicator was calculated for the North Sea RAC region (ICES area IIIa, IVa, b & c), whereas the original work by Piet & Rice (2004) was based on the Greater North Sea that also included the eastern Channel (ICES VIId).

2.2.3 Indicator assessment

The time-series of the proportion of stocks within SBL indicator shows a strong decrease from 100% at the start in 1957 when only based on two stocks (plaice and sole) to about 20% in the early 1970s to about 10% in the 1990s (figure 2.2.3). In recent years there appears to be a slight increase to about 30%. A comparable trend is observed for the linked indicator, "proportion of landings within SBL" which also decreases strongly over the 1960s remaining mostly below 20% and showing a slight increase in recent years (figure 2.2.4).

The decrease at the beginning of the time-series may be caused by the change in the composition of the suite of stocks on which the indicator is based. As the indicator was based on a consistent suite of stocks from 1995 onwards the increase in recent years appears to be genuine.

The target reference point to achieve GES for the commercial species descriptor is 100% of stocks are within SBL. The 2008 indicator value of just over 40% is well below the target level.

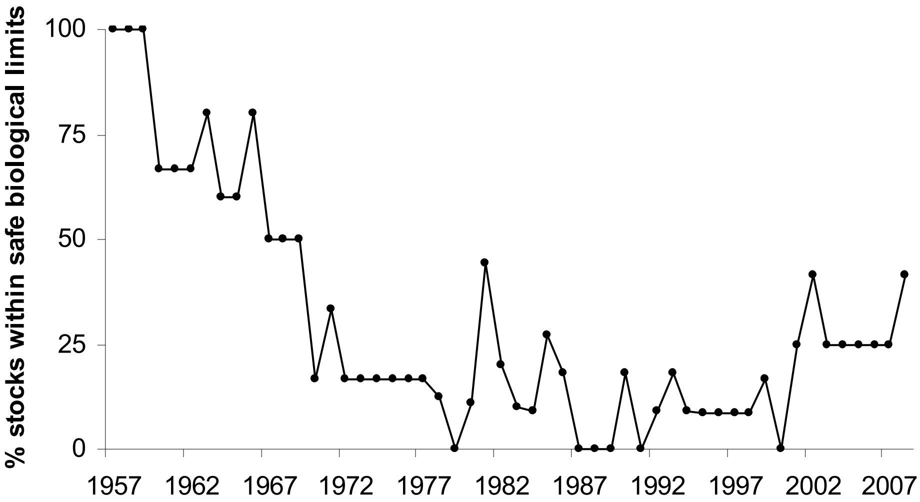

Figure 2.2.3 Proportion of North Sea stocks within safe biological limits.

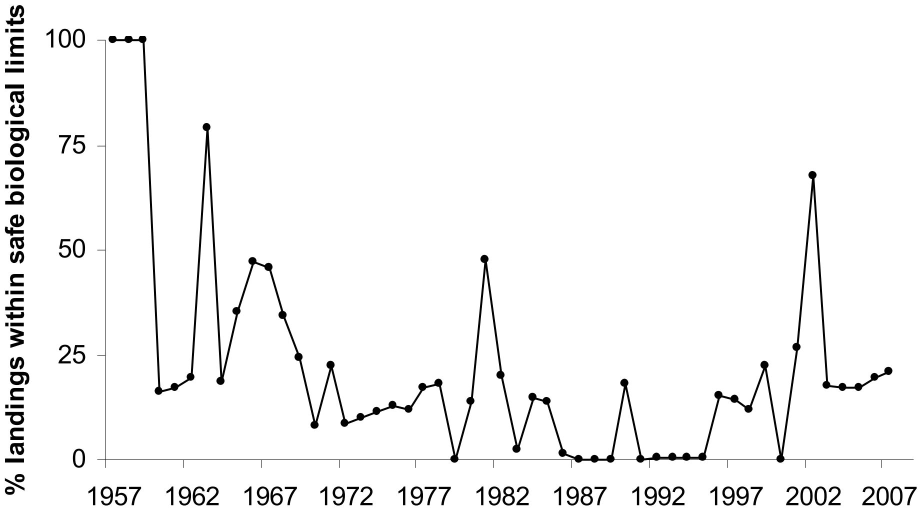

Figure 2.2.4 Proportion of landings from assessed North Sea stocks that are within safe biological limits.

2.2.4 Discussion

For this indicator the reference value should be 100% (i.e. 100% of the stocks should have SSB ≥ SSBpa and F ≤ Fpa in order to achieve GES). This was also confirmed in the London workshop. However the target may be set lower if politicians/society so desire. Should other indicators or reference values (e.g. MSY) be included in the GES assessment then this may have consequences for the 100% value as it is known that it is not possible to achieve MSY for all stocks simultaneously.

The representativity of 30-40% is not very high although there are issues pertaining to how this should be calculated. It becomes clear, however, that the target of 75% set at the London expert meeting is not currently realistic and would require considerable additional resources to achieve unless a reliable assessment method requiring less intensive data becomes available.

2.3 GES Descriptor 4: Food Web Structure

2.3.1 Data requirements and availability

Calculation of the "large fish indicator" (LFI) is based upon fishery independent trawl survey data that reports CPUE of species by length. This data is available from surveys conducted under the DCR. The North Sea IBTS survey provides coverage of the whole North Sea area as a single co-ordinated survey and can provide the information required to calculate the CSF indicators. The North Sea IBTS survey data were available from DATRAS to calculate the indicator in this report. The time period used was all data from 1983 until 2007. 1983 was chosen as the first year in the time series to use as this was the first year in which all component parts of the IBTS survey were conducted with a GOV trawl; 2007 was the latest available data at the time of this work.

2.3.2 Modifications to indicator calculation method

The indicator values presented in this report, and subsequently the method used, was taken from ICES (2009)

2.3.3 Indicator assessment

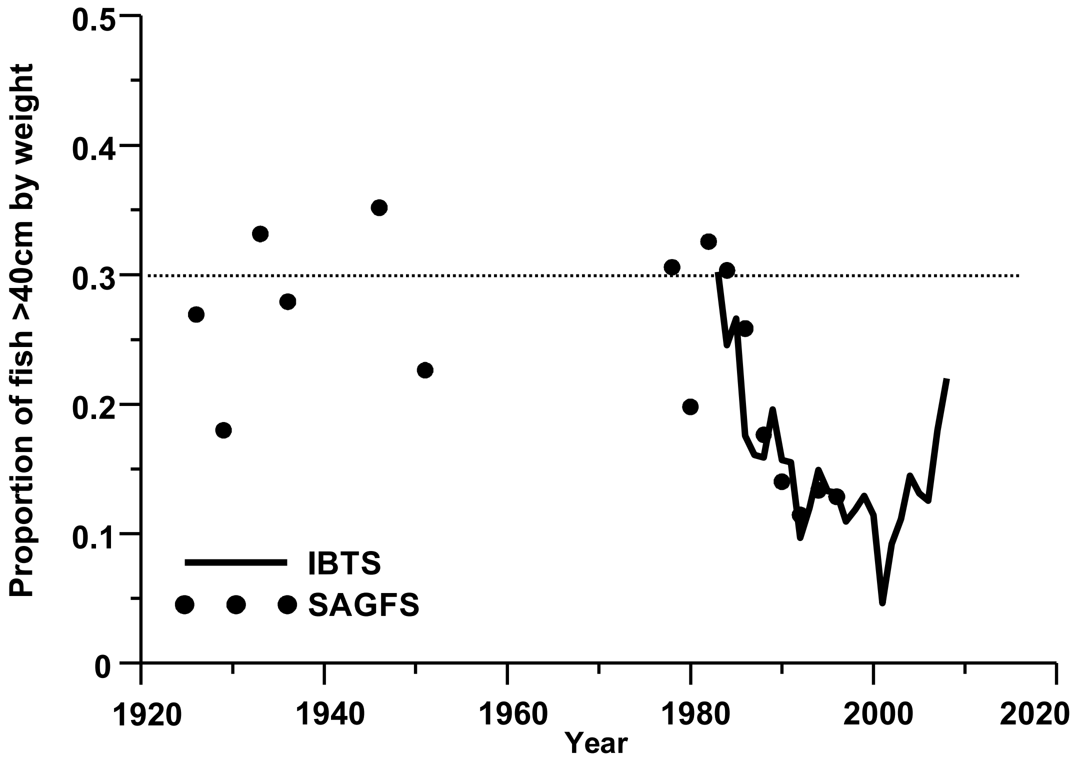

Figure 2.3.1 LFI calculated for the North Sea IBTS shown alongside historic data from the Scottish August Groundfish Survey (SAGFS). The dashed line indicates the value of 0.3 which is the target level for the OSPAR EcoQo for large fish. Modified from ICES 2009.

The LFI calculated for the North Sea IBTS has been below the OSPAR target value of 0.3 since the early 1980s (Figure 2.3.1). Although the indicator is still below the target value of 0.3 it has risen considerably from its low point in the early 2000's.

The North Sea is not considered to be attaining GES in relation to qualitative descriptor 4 as monitored by the LFI indicator with a target value set at 0.3.

2.3.4 Discussion

GES descriptor 4 relating to food web integrity refers to "*all elements of the marine food webs*" in defining GES with respect to food webs. The indicator applied here to assess the impact of fishing on food web integrity only considers a selected portion of the fish community. Is this sufficient to report the effects of fishing on the integrity of whole food webs? Two points need to be considered here; firstly the work presented in this report specifically attempted to assess the impacts of fishing on GES, not the condition of the marine environment with respect to GES generally. Secondly, although the LFI does not report on the status of elements of the marine environment, other than a selected portion of the fish community, it is worth considering the extent to which achieving the target value for the LFI would also lead to satisfactory status for other elements of the marine environment even though they are not monitored.

The need for a food web indicator that is reports the effects of fishing constrains the range of indicators that can be used; all indicators will be driven by a variety of factors but some are more strongly driven by fishing than others. The selection of the LFI for this work was made on the pragmatic basis that it is well documented to respond to fishing in a consistent manner, and is considered to be more sensitive to fishing than other drivers (see discussion in section 1.2.3.1). An indicator employed to report on the condition of food webs in relation to GES in general need not be constrained by this consideration. With regards to the second point (namely, would achieving the target value for the LFI lead to other ecosystem elements also achieving GES?) this question is being actively considered by ICES. However it is worth noting that although there is general agreement that food web integrity is important for ecosystem processes there is less consensus on what food webs should look like and how far they can depart from their current status before they can be considered to no long achieve GES (see discussion in section 1.2.3.1).

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

2.4 GES Descriptor 6: Benthic Habitats

2.4.1 Data requirements and availability

The only way to get a complete picture of the distribution of fishing effort from VMS is for VMS to be fitted to all vessels, and for the vessel locations to be recorded on a semi-continuous basis. Currently within the EU VMS is only fitted to vessels over 15m, and VMS records are only sent every 2 hours. The provision of VMS data could be improved for reporting this indicator if VMS coverage was extended to a greater proportion of the fleet, and if VMS position records were sent more frequently.

Individual nations receive the VMS data for nationally registered vessels in all waters and all vessels in national waters. Creating a complete map effort by mobile bottom gears for the North Sea RAC region requires raw or processed VMS outputs to be submitted by each nation with national waters in the North Sea RAC region. In the MEFEPO project VMS data was only requested for the nations that had national partners in the MEFEPO project. Therefore no attempt was made to access the VMS records for Belgium, Germany and Sweden. Of the countries for which the VMS outputs were requested, outputs were received from England, Holland, Norway and Scotland. The requests to access the VMS records for France and Denmark were rejected by the relevant ministries.

The VMS records for England and Scotland were processed according to the method specified in the MEFEPO VMS processing instruction document (Appendix 1). In the cases of Holland and Norway slight alterations to the method were required due to the format in which the data is available. These modifications are presented below (Section 2.4.2).

The VMS data is used to create a map of effort by mobile bottom gears, to calculate the indicator this needs to be linked to bathymetry data or a sea floor habitat map. The only available seafloor habitat map with complete coverage of the North Sea RAC area is the sediment map contained in the United Kingdom Digital Marine Atlas, freely available from the BODC (www.bodc.ac.uk). This habitat map was combined with the bathymetry to allow the indicator to be reported for seafloor habitat type by depth band. The indicator was also calculated just using the DCR specified depth bands.

The origin of the seabed sediment map on the UKDMAP CD is unclear, the attribution states BGS 1:250,000 seabed sediment map but the version on the CD bears no resemblance to the BGS version. It also covers a much wider area than the BGS map extending beyond where the BGS have mapped or even have data (e.g. eastern North Sea). It may be that the map has been generalised and extrapolated from BGS maps but if that is the case then it has little or no use as a means of delimiting seabed habitats. Even on a very broad scale and its use is likely only to detract from the understanding of the environment as the boundaries are incorrect and the variation within each mapped area is likely to be as large as the differences between areas. The shortcomings of the existing maps are recognised both by BGS and by stakeholders, with a new level of detail being required for modern marine management. There are currently plans to initiate more detailed surveys across large areas of the European seas, however the cost is in the order of hundred's of millions of Euros and will require a significant amount of political backing to be achieved.

2.4.2 Modifications to indicator calculation method

Data is not available for the whole Dutch fleet, so the data was raised to reflect whole fleet effort levels. Gear specific speed thresholds were used to filter out fishing from non-fish records, this was based on gear specific speed profiling conducted by IMARES. In the case of Norwegian VMS data, only Norwegian vessels over 24m are required to carry VMS and VMS records are sent on an hourly basis. The vessels included in the analysis all have permission for one of the following gear types; North Sea trawl, limited North Sea trawl, Pollock trawl, cod trawl, and prawn trawl above 65 feet. Only the VMS data for Norwegian vessels in Norwegian waters was received, the VMS records for foreign vessels in Norwegian waters were not received.

The indicator assessment is based up VMS data for 2006 and 2007.

2.4.3 Indicator assessment

The proportion of area not trawled, by depth and habitat types, was calculated from the map of effort by mobile bottom gears compiled within this project (Figures 2.4.1 & 2.4.2). The lower reported effort in Norwegian waters compared to the other areas for which data is available can mainly be attributed to data collection. The Norwegian data is only based on Norwegian vessels over 24m, whereas for the other areas the data includes all vessels, national and foreign, over 15m.

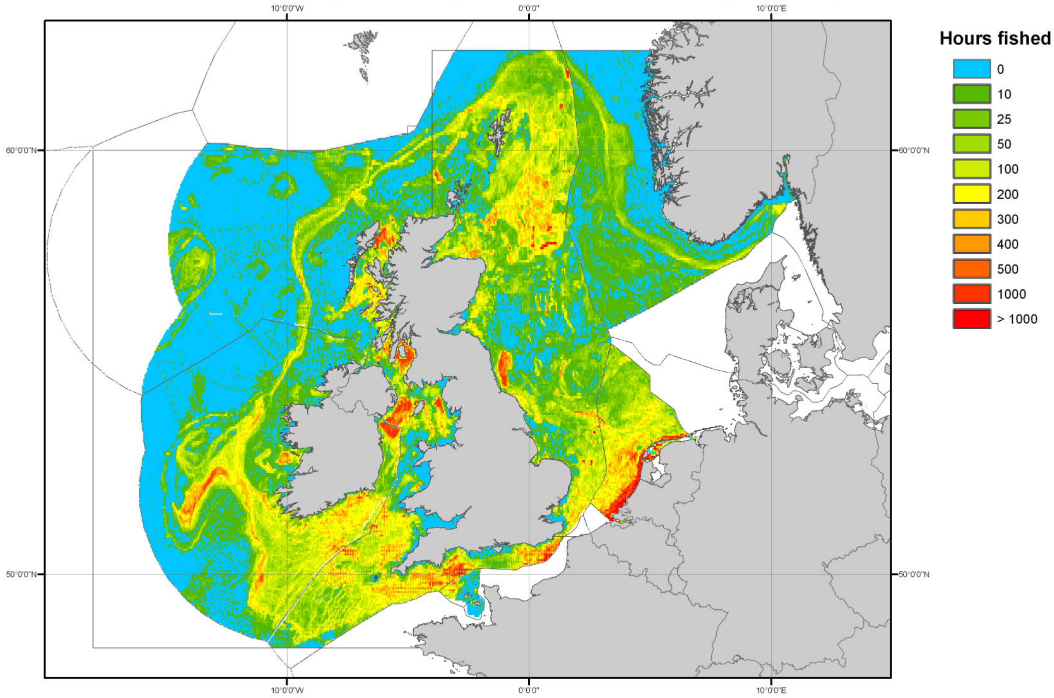

Figure 2.4.1 Distribution of fishing effort by mobile bottom gears for 2006 by 3'x3' cells based on VMS records from submitting nations. The VMS data were processed using the point estimation method described above.

The proportion of area not trawled indicator was calculated for 2006 and 2007 by depth band and sediment type (Table 2.4.1 and 2.4.2).

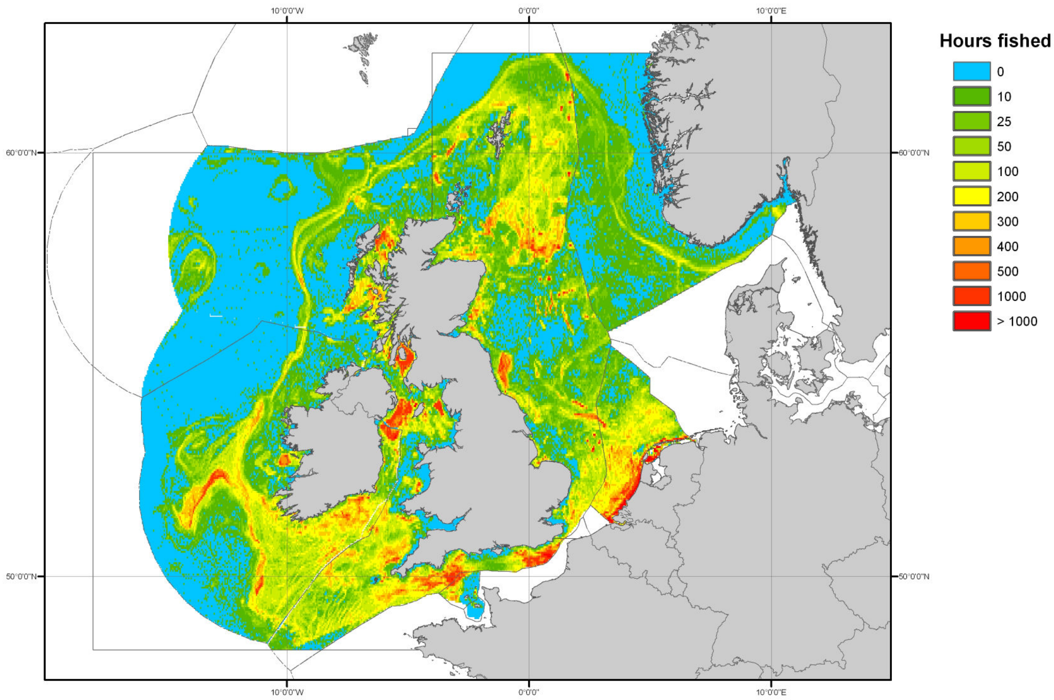

Figure 2.4.2 Distribution of fishing effort by mobile bottom gears for 2007 by 3'x3' cells based on VMS records from submitting nations. The VMS data were processed using the point estimation method described above.

Table 2.4.1 Percent of area not impacted by mobile bottom gears by combined depth band and sediment type For the North Sea RAC region for 2006. Blank cells for areas where the sediment type did not occur in that depth band. See text for details.

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

Table 2.4.2 Percent of area not impacted by mobile bottom gears by combined depth band and sediment type For the North Sea RAC region for 2007. Blank cells for areas where the sediment type did not occur in that depth band. See text for details.

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

2.4.4 Discussion

A primary concern with an indicator based on VMS records is that this takes no account of the <15m fleet. This is likely to be of particular importance in inshore and coastal areas. The high proportion of <20m and 20-50m waters reported as not trawled for some sediment types (Table 2.4.1 & 2.4.2) could be a biased estimate. Further work needs to be developed on assessing the distribution of fishing effort by the <15m fleet and integrating this information with the VMS records from the >15m fleet.

It is important to consider the issue of spatial scale of analysis when interpreting the indicator results, and the implications this has for sea floor integrity. The spatial scale of analysis can significantly alter conclusions as to the proportion of area not trawled (Piet & Quirijns, 2009). A smaller spatial scale of analysis results in increased perceived patchiness of trawl impacts, and thus lowers the proportion of area not impacted. In this analysis it should be noted that the result that 100% of an area is impacted by bottom trawls does not in imply that 100% of the areas was actually impacted. To fully determine the impact of mobile bottom gears on seafloor integrity it is important to develop better understanding of the spatial of sea floor processes and the scale of impact. Furthermore the current regulations that VMS position records are only reported every 2 hours limits the level of spatial accuracy that can be achieved. Similarly the temporal scale of analysis also effects the level of perceived impact (Piet & Quirijns, 2009). In this study the indicator was calculated over 1 year periods, ideally the temporal scale of analysis should be tied to recovery time following impact.

No reference limits have been set or proposed for the proportion of area not trawled indicator when used as a pressure indicator to report on the MSFD GES descriptor 6: sea-floor integrity. Some limits have been suggested for protected area coverage of rare and threatened habitats. However it is important to distinguish at this point between concern for rare and threatened benthic habitats, such as OSPAR listed habitats, and the aims of GES descriptor 6 which is concerned with benthic ecosystem processes as a whole. The focus of GES descriptor 6 on functioning of benthic ecosystems as a whole leads to a focus on the state of the widespread and dominant benthic habitats. Thus limit reference points developed for protecting habitats of conservation concern are not necessarily applicable. Concern for rare and threatened habitats falls under GES descriptor 1. So far this report has only discussed the use of VMS data to report against GES descriptor 6, but VMS data could also be used as a pressure indicator to examine the impact of fishing on rare and threatened habitats for GES descriptor 1. However rare and threatened habitats tend to occupy limited areas making the spatial resolution of the point summation method potentially inappropriate to examine the impact of mobile bottom gears on these habitats.

As discussed in section 1.2.4.1 there is currently much debate over the relationship between the state of benthic systems and the delivery of ecosystem functions. Until this is more clearly resolved it will be hard to set reference levels on a sound theoretical and evidential basis. Furthermore the extent and frequency of impact that different benthic habitats can withstand before becoming functionally degraded will vary between habitat types and the type of bottom gear used. Given the uncertainties involved it would seem likely that for the next few years management decisions relating to maintaining benthic habitat functioning will have to be based on informed opinion. Once these limitations are accepted VMS data can play an important role in understanding, and monitoring, the distribution of fishing effort by vessels deploying mobile bottom gears.

Understanding the impact of fishing on benthic ecosystems requires not only knowledge of the distribution of fishing effort, but also the composition and distribution of benthic habitats. Currently there are no reliable seafloor habitats maps that cover whole RAC areas, let alone the whole European shelf seas. Improved mapping of European seafloor habitats is an essential activity to allow GES to be defined and monitored. Improving the coverage of vessels required to carry VMS, and increasing the VMS position reporting frequency, would both act to improve assessment of impact of mobile bottom gears on benthic ecosystems. The protocols for sharing VMS data outputs across nations need to be developed to allow calculation of the indicator to occur on a regular basis.

Section 3: Summary.

3.1 Ecosystem component coverage

The purpose of the work contained in this report is to develop a minimum necessary set of environmental objectives for the marine environment on the basis of the MSFD definitions for GES, and to develop a set of (almost) immediately operational indicators to report against the objectives. The ability of the selected indicators to report on the status of the marine is examined in table 3.1 which compares coverage of ecosystem components by the indicators with the ecosystem components identified as being notably impacted by fishing in Van Hal & Piet (2009)

Of the seven ecosystem components identified as impacted by fishing only four are covered by the indicators, although not all the ecosystem components need to be covered by each of the indicators. In the case of the commercial species descriptor only the commercial species need to considered, and only commercial fish and benthic invertebrate species need to be considered. Both of these components are covered by this indicator (although see section 2.2.1 for discussion of representivity). Similarly in the case of GES descriptor 6, benthic processes, only components that are part of 'sea-floor ecosystems' need be considered. This includes the seafloor habitats and protected habitats (where the benthic features are protected), which are covered by the indicator. But this could also include benthic invertebrates and demersal fish, which are not covered by the indicator. Despite the noted limitations of ecosystem component coverage by the selected indicators they can be considered to provide adequate ecosystem component coverage.

Table 3.1 Ecosystem components impacted by fishing (red), and coverage of these components by the selected indicators (green).

		Habitats				Plants		Inverts		Vertebrates			Other Groups
	Ecosystem components	Seafloor	Water column	Protected habitats	Special cases	Phyto-plankton	Macroalgae	Zoo-plankton	Benthos	Fish	Mammals & Reptiles	Seabirds	Non-indigenous & Invasive
Impacted by Fishing		[red]		[red]			[red]		[red]	[red]	[red]	[red]	
GES 1: Biodiversity	Conservation Status of Fish Species									[green]			
GES 3: Commercial species	Commercial Stocks								[green]	[green]			
GES 4: Food webs	Food Web Structure									[green]			
GES 6: Benthic processes	Seafloor Processes	[green]		[green]									

In the case of GES descriptors 1 and 4 the requirements for ecosystem component coverage are much wider and include '*biological diversity*' including species and habitats in GES descriptor 1, and '*all elements of marine food webs'* in GES descriptor 4. In both cases the selected indicators only consider part of the fish community, this may be considered to significantly restrict the ability of these indicators to report on the effects of fishing on the marine environment with respect to GES descriptors 1 and 4. In the case of GES descriptor 1, the lack of coverage of rare and threatened habitats, benthic invertebrates and the seabird and mammal community are significant gaps to current coverage. In the case of GES descriptor 4 the lack of coverage of invertebrates, seabirds and mammals could be seen as a significant gap to indicator coverage.

Do these gaps in ecosystem component coverage inhibit the ability of the selected indicators report on GES with respect to descriptors? As noted in section 1.2.3.1 key functional groups within a system can provide good characterisation of whole system status with respect to a given driver. In this report we are specifically interested in the effects of fishing. Other than invertebrate fisheries, fisheries target fish and thus the fish community is the ecosystem component expected to be most directly and immediately impacted by fishing. Therefore using indicators based on the fish community may not be as limiting as it first seems. It may be found that, apart from special cases, the fish community is the most sensitive part of the community to the impacts of fishing, and that by managing fishing operations to maintain GES for the fish community may lead to the other ecosystem components also attaining GES. Further research is required to establish whether this is the case, and although this may hold in many cases it is unlikely to hold in the case of rare and threatened habitats with respect to GES descriptor 1.

It was noted at the beginning of the report that this work was intended to develop a set of environmental objectives that could be operationally implemented in the short term, and that this constraint would undoubtedly lead to limitations in the coverage of the indicators. Indeed limitations to coverage have become manifest during the work, nonetheless following logic developed above starting with a set of indicators that are predominantly based on the fish community provides a rational starting point for developing a set of indicators to monitor the effects of fishing on marine environmental status.

3.2 Assessment of environmental status

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

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

and

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

In response to the first question, the results of the individual GES descriptor assessments in relation to the specified reference limits are presented in table 3.1. A first order assessment shows that for the four GES descriptors identified for analysis GES is not demonstrated as achieved for any descriptor, GES is compromised for two of the descriptors (GES 3 & 4) and can not be clearly assessed for the other two descriptors (GES 1, 6).

Table 3.1 Assessment of the North Sea RAC region with respect to impacts of fishing on Good Environmental Status as defined by the MSFD. A 'x' indicates that GES is not achieved, a'?' that status is uncertain or can not be assessed. See text for important caveats and comments.

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

Should these indicators be considered satisfactory for reporting on the GES descriptors to which they are associated? In each case limitations in indicator ecosystem component coverage has been noted, however as discussed in section 3.1 this is of most concern in relation to GES descriptor 1, furthermore in the case of the conservation status of fish species indicator used to report against GES descriptor 1 there are notable concerns about the ability of this indicator to monitor the status of the fish species of most conservation concern (see section 1.2.1.1). Therefore the impact of fishing on objectives for biodiversity in the North Sea RAC region should be prioritised for further indicator development.

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

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

The second question was whether fishing compromises GES in the North Sea RAC region as part of a unified assessment of GES. When considering a unified assessment of GES it is interesting to consider what is required for GES to be achieved; does GES have to be achieved for all of the descriptors, or is it sufficient for GES to be achieved ‘on average’ across all the descriptors? There is no specific guidance on this point within the text of the MSFD; the initial assumption is that GES needs to be achieved for all descriptors and that failing on one single point is sufficient for the whole system to be considered to be below GES. However it is interesting to consider this point and further specification on how to combine individual GES descriptors into a unified assessment could clarify future assessments.

In the case of the current assessment the North Sea RAC region fails to achieve GES for two of the four descriptors examined, and GES is only achieved for one descriptor (but see comments above). Therefore, irrespective of whether attainment of GES is based on an ‘average’ of descriptors or on the basis that GES needs to be achieved across the board, the current assessment indicates that fishing negatively impacts GES in the North Sea RAC region.

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Appendix 1:

Instructions for MEFEPO partners explaining the process for calculating the proportion of area not trawled indicator within the MEFEPO project.

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This document describes the process we will use under the MEFEPO project to calculate the proportion of area not trawled indicator. This document provides a brief background of the method and the steps require process the VMS data. This document dose not provide a detailed description of the method or justification for the method.

Calculating the proportion of area not trawled indicator
The proportion of area not trawled is a pressure indicator to report against MSFD GES descriptor 6: maintenance of sea floor integrity.

This indicator can be calculated for the >15m fleet using VMS data and an associated gear code. If the VMS data are not available, or can not be linked to gear codes it will not be possible to apply this indicator for that area.

To calculate the indicator for whole RAC areas we will need to combine VMS data from the national waters of each country in the RAC. This requires a combined analysis. This document briefly describes the method we are applying within the MEFEPO project to conduct this analysis and the data required.

VMS Processing
VMS data provides information on the location of fishing boats on a periodic basis (every 2 hours or more frequent), this is not a complete picture of the distribution of fishing activities. The VMS data needs subsequent processing to provide a predicted map of the location of fishing activities.

There are several different ways that VMS data can be processed to try and fill in the gaps, i.e. predict where the boats were between the VMS position records. None of the processing methods are perfect, and a method for processing VMS data designed for one fleet may not be appropriate for a different fleet or in a different area.

Calculating the area not trawled indicator at the scale of RAC areas or sub-regional areas will require combining data across a number of different fleets. The method of VMS processing that we are applying in MEFEPO is a simple but robust approach. It will not give an absolutely accurate measure of the proportion of area trawled, but it will give a robust relative measure of proportion of area trawled.

There are more complex methods available for analysing VMS data, however with many of these methods they will be no more accurate when applied to 2 hourly position data or if applied to fleets other than the one used to calibrate the method. Unnecessarily complex methods can give a false impression of accuracy.

Point Summation Method
The method we will apply is the 'point summation method to estimate number of hours fished'. The point summation method is based on dividing the area in to cells and calculating the estimated number of hours trawled per cell.

We will use a 3 minute by 3 minute grid of cells. The grid is based on minutes, rather than a fixed distance so that there are a consistent number of cells per ICES rectangle. (ICES rectangles are based on longitude and latitude, so their size varies with latitude.)

The basic concept behind this method is that the VMS data are filtered to select only the vessels that are using mobile bottom gears, and then further filtered on the basis of speed to separate out the VMS records associated with fishing. It is assumed that all the remaining VMS records are associated with vessels actively engaged in trawling. For each of these remaining VMS records a 'trawling time' is associated with the VMS record. The trawling time is the amount of time since the previous VMS position record. The trawling time associated with a VMS record is then assigned to the cell on the grid where the VMS record is located. The number of trawl hours per cell is summed across all VMS records over a complete year.

The analysis uses all VMS records from both national boats and foreign boats.

Preliminary analyses of this method show that when the data are combined over a whole year they provide a realistic representation of distribution of trawling activities, and the relative distribution of trawling effort is consistent with other VMS processing approaches.

Data Required
To calculate the proportion of area not trawled indicator within the MEFEPO project we will need to combine data from across several nation's EEZs. This will require us to pool information so it can be combined across regions.

Below the procedure for working up the VMS data is outlined for the analysis that we want to conduct for the MEFEPO assessment of proportion of area not trawled

We will aim to calculate this indicator for 2007 and 2006. VMS was installed on all vessels over 15m for these years. Please conduct the processing for each year separately. If you can only access or process data from a single year please use 2007.

<u>VMS data processing</u>
The output that you will release will be gridded data of the 'number of hours' trawled for each 3 minute x 3 minute cell.

The steps required to create this output are described below.

1) Assign gear codes to each VMS record, for national boats you should be able to link to log book records. For foreign boats use the primary gear listed on the EU fleet register :

   http://ec.europa.eu/fisheries/fleet/index.cfm?method=Download.menu

2) Keep all records associated with mobile bottom gears (bottom trawls and dredges).

3) For each VMS record calculate the time since the previous position record by that vessel, and assign it to the VMS record.

4) Filter out all VMS records where the time since the previous record is more than 4 hours.

5) Keep all records where the speed is between 1 and 6 knots.

6) Create a grid of 3 minute by 3 minute cells aligned with latitude and longitude degree boundaries.

7) For each VMS position record assign the time since the previous position record to the cell on the grid where the position record is located. Sum the 'trawling time' associated with each cell for all VMS records for the whole year.

8) Complete; at this stage you should have a gridded data set, where each cell on the grid has a number of hours 'trawling' associated with it.

The gridded number of hours 'trawling' per cell is not the final calculation of the indicator. There are different options of how to get from the gridded data of hours trawled per cell to a final indicator as a single value; once we have the gridded data we can explore the effect of different options on the final indicator value. The simplest way to calculate the indicator will be to set a cut-off value (e.g. 50 hours per year). Then all cells with more than 50 hours trawling per year will be classified as 'completely trawled', and all cells with less than 50 hours trawling per year will be classified as 'not trawled'.

As well as calculating the indicator for whole areas we also want to try and report the indicator for different habitat types or depth areas. Once we have the gridded data of hours trawling per cell we can overlay this on habitat maps later.