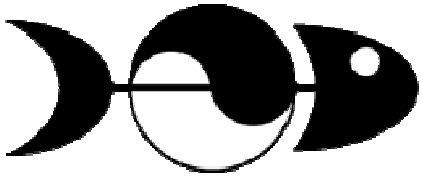

MEFEPO

Making European Fisheries Ecosystem Plans Operational

EC FP7 project # 212881

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 Western Waters

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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 Western Waters Regional Advisory Council (NWW 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 NWW 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 NWW 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. 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.

Contents

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

[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.

> *…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 been 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 $\geq$ SSBpa and F $\leq$ 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 $\geq$ 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 et 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 of 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 of 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.

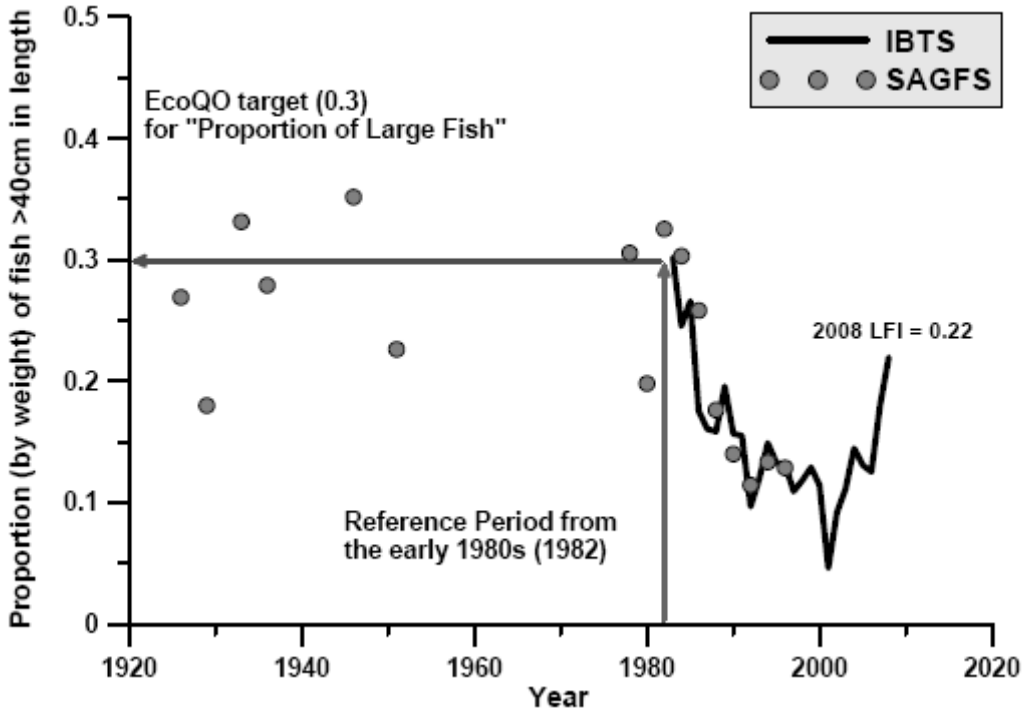

Figure 1.2.3.1: Time series of the LFI for the North Sea based on the Q1 North Sea IBTS and the Scottish August Groundfish Survey (SAGFS). Source: ICES 2009.

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., 2010) 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. (2010), 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 Western Waters 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 Western Waters 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 on fishery independent trawl survey data that reports catch per unit effort (CPUE) of species by length. This data is available from surveys conducted under the DCR. Table 2.1.1 presents a summary of the surveys available from the ICES online database of trawl surveys (DATRAS, http://datras.ices.dk) that can provide the information required to calculate the CSF indicators in this report. The indicators were calculated independently for each survey and using the method defined in COM (2008) 187 and the modifications listed in section one of this report. The following descriptions of the surveys conducted in NWW were taken from DATRAS.

Table 2.1.1 Surveys and data used in the estimation of the Conservation Status of Fish Species in the NWW region. The column 'Species Excluded' indicates the number of species excluded from analyses (if any) and the reason for exclusion. Years in brackets represent no survey.

Survey	ICES Divisions	Survey Type	Gear	Data Series	Species Excluded
ALT IBTS	VIa	Bottom trawl	GOV	1985-2008	1 (no catch first 3yrs)
BTS VIIa	VIIa	Bottom trawl	Otter	1993-2008	
EVHOE	VIIe-j	Bottom trawl	GOV	1997-2008	1 (no catch first 3yrs)
IGFS	VIa, VIIb, VIIj	Bottom trawl	GOV	2003-2008	1 (no catch first 3yrs)
Rockall	VIb	Bottom trawl	GOV	2001-2009 ('04)	2 (no catch first 3yrs)

Scottish Ground Fish Survey: ALT IBTS

The Quarter 1 Scottish Ground Fish survey started in 1981 and was initially intended to cover the fishing grounds on the continental shelf to the west of Scotland; in 1996 the survey area was extended to include the northern Irish Sea. The Scottish West Coast Surveys use a similar ICES rectangle based sampling strategy to that used in the North Sea. Trawl stations are selected at one tow per rectangle based on a library of clear tows. There is no explicit return to the same trawling position every year, although this is generally the case. The gear deployed on all the Scottish surveys is the 36/47 GOV trawl fitted with heavy ground gear 'C' and a 20 mm internal liner.

The survey covers Division VIa and extends into the northern part of the Irish Sea and North West of Ireland (Figure 2.1.1). The depth range covered has been 20 to 500m since 2000. The survey is usually carried out in March of each year. The target

species are cod, haddock, whiting, saithe and herring and age frequencies are constructed for these species. All other fish species encountered are also sampled for at least length frequencies.

Northern Irish Survey: BTS VIIa

In the Northern Ireland survey, the sampling design is stratified with fixed-position stations. Stratification is by depth and seabed type. Haul duration is 3 nautical miles at 3 knots over the seabed. Stations in the St George's Channel are 1 nautical mile at 3 knots and have only been surveyed since October 2001. Number of stations is 45 in northern Irish Sea and 12 in St George's Channel. Tows are during day time only.

The surveys have been carried out in March and October since 1992. From March 1992 to March 2001, the survey extended from 54° 43' N to 53° 22' N (Figure 2.1.1). From October 2001 the survey is extended into the St George's Channel to 52° 18' N. Depth range is from 20 to 120m. The surveys are carried out on the R.V. Lough Foyle, a 43.5m stern trawler of 880 kw and GRT 547 tonnes. The fishing gear is a rock-hopper otter trawl with a 17m footrope fitted with 250 mm non-rotating rubber discs.

French Survey: EVHOE

The French demersal survey began in 1987, but there was a change in vessel and sampling design in 1997, from this year onwards the whole area has been separated in 5 geographical strata or sectors: southern Bay of Biscay (GS) and northern Bay of Biscay (GN), southern Celtic Sea (CS), central Celtic sea (CC) and northern Celtic sea (CN). In each sector a depth-stratified sampling strategy has been adopted with 7 depth ranges: 0-30, 31-80, 81-120, 121-160, 161-200, 201-400 and 401-600 meters. Therefore only the time series from 1997 was used in this study, considering sectors GS and GN within the SWW area, and the Celtic Sea (sectors CS, CC and CN) in the NWW area (Figure 2.1.1). In these surveys catch in weight and catch in numbers were recorded for all species, but from 1987 to 1990 length was only measured for selected finfish and shellfish species. From 1991 onwards, all finfish and selected shellfish species (mainly Nephrops and squid) are measured.

Irish Ground Fish Survey: IGFS

The Irish West Coast Groundfish Survey started in 1990 and for the first two years consisted of circa 25 stations concentrated around the Irish coast in ICES Areas VIa South and VIIb. Adverse weather in 1992 limited station coverage to only 4 stations which effectively broke the time series. The survey was re-established in 1993 and consisted of circa 70 stations, for Parts A and B combined. Spatial coverage was extended west out to the 200m contour, but remained as VIa South and VIIb. The Irish West Coast Groundfish Survey is carried out in two parts: Part A covers ICES Division VIa (south) and VIIb (north); Part B covers ICES Division VIIb and VIIj. The survey is conducted from 15 to 300 m depths during the fourth quarter (October - November). Prior to 2002 the survey was carried out on chartered commercial fishing vessels. Whilst the same vessel (MFV Marliona, 224 gross tonnage and 30 m LOA) was normally used each year for Part A and Sionann for Part B, in 2001 Part B was conducted from the MFV Regina Ponti (34.5 m LOA). Both vessels used a Rockhopper net with 12 inch discs and 11 inch Thyboron doors.

However from 2003 onwards all Irish Surveys have been conducted on the new 65m research vessel, the R.V. Celtic Explorer, starting around mid October through to late November. Therefore for consistency the data used in this report is that from 2003 to present. The fishing gear used is a GOV 28.9/37.1 Trawl with Morgere Kite (0.85 by 0.85m). Mean vertical opening is 6 m and door spread 48 m. Morgere Polyvalent doors (Type AA4.5) are used and gear performance is monitored throughout the survey using the SCANMAR (RX400) net monitoring system (Headline height, Door spread).

Scottish Rockall Survey: Rockall

The Scottish Quarter 3 Rockall survey began in 1985 and was carried out annually until 1997. However, in 1998 it was decided to make the survey a bi-annual event; in 1998 a new survey of deep water stocks was completed, in the future the Rockall survey and a deep water survey will occur in alternate years.

The Rockall surveys will generally be in September during odd numbered years. The survey covers only a relatively small area, in the order of eight ICES rectangles. Trawl stations are on known clear tows and vary between 2 and 8 per rectangle depending on the proportion of the area within the 250m depth contour. The gear deployed on all the Scottish surveys is the 36/47 GOV trawl fitted with heavy ground gear 'C' and a 20 mm internal liner.

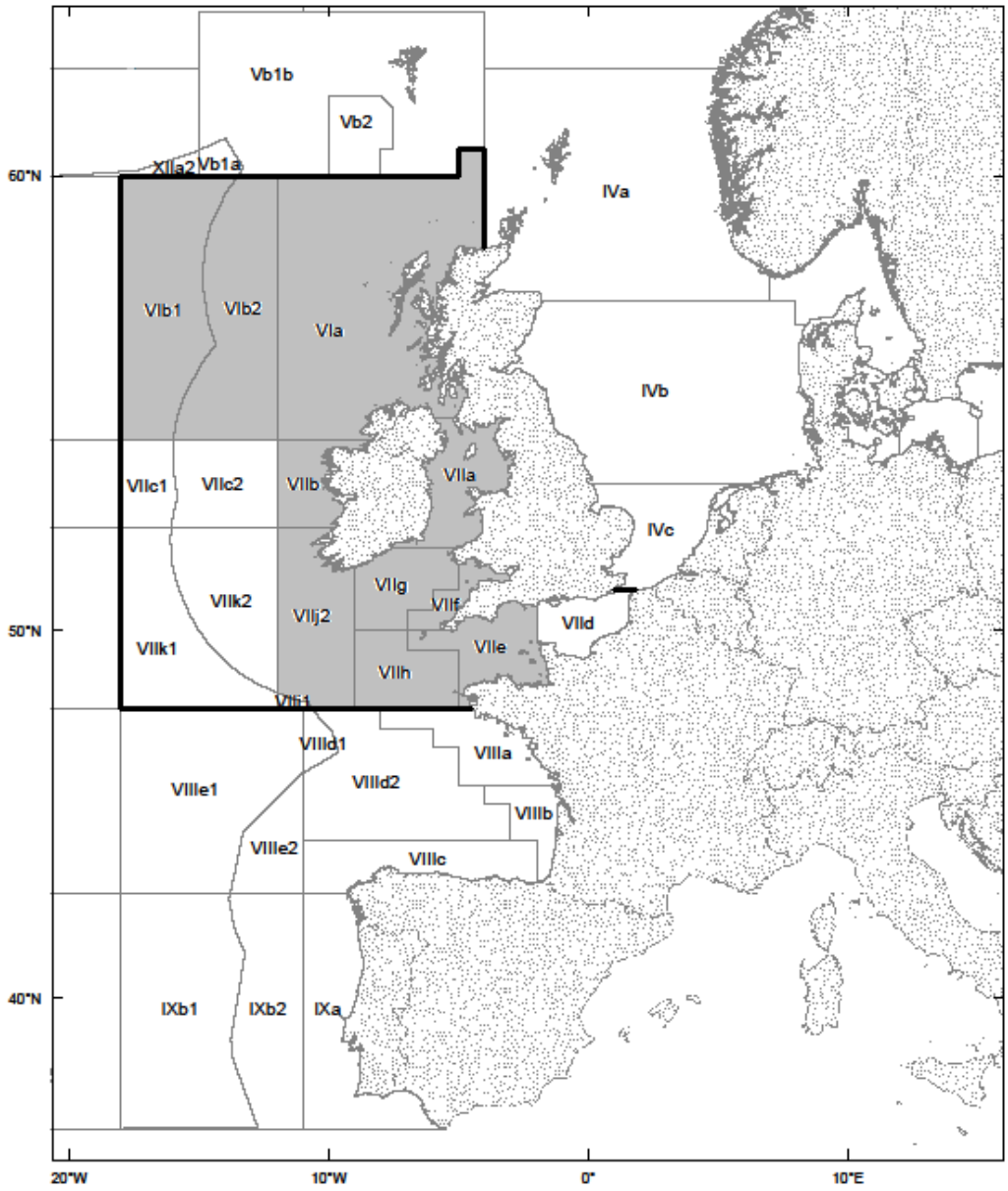

Figure 2.1.1 Map indicating ICES Divisions that are covered by the surveys included in the GES descriptor 1 indicator assessment (grey fill) in North Western Waters (bold border).

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. The only further modification to the method described in COM (2008) 187 was the use of an alternative species list in calculating the indicators. This alternate list was based on the average abundance of species during the first three 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. The second method for

calculating the species list was applied to avoid a 'shifting baseline' as it was noted that species that declined 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 indicators were calculated using both species lists: the 'full list' and the 'three year list'.

2.1.3 Indicator assessment

The CSFa indicator is a measure of change in the average IUCN threat rating of species in the large fish community. The calculation of CSFa requires the actual catch of each species in each year to be compared to the predicted catch. The predicted catch is based on a model (least squares) fitted to the previous x years in the data series. Since x must be at least 10 years, CSFa cannot be calculated for surveys with less than 10 years data. Therefore CSFa is not presented for the Irish Ground Fish or Scottish Rockall surveys, and is limited to two points in the French EVHOE survey. A CSFa score of one indicates all species in the relevant list are considered threatened; a score of three indicates all species are endangered. Therefore a CSFa score less than one is the target.

CSFb is a comparison of the catch of each species, each year to a reference level (mean catch of first three years). Therefore there is no target CSFb score but an increasing trend indicates an improvement in the populations of large fish species.

2.1.3.1 CSF Scottish ALT IBTS

In this survey twenty species were included in the full list of large species and 17 in the three year list. One species, *Chimaera monstrosa*, was excluded from the analyses due to no catch in the first three years. CSFa, based on both the full and three year lists, remained below the target score of one for all years surveyed except 2008 (Figure 2.1.3.1.1). The cause of this increase can be seen when the species in the full (Figure 2.1.3.1.2) and three year (Figure 2.1.3.1.3) lists are plotted separately. In the final years the actual catch of many species dips below the predicted level causing a poor CSFa score. However most species in both lists are well above the reference level (the average catch of the first three years) and this is reflected in the large increase in CSFb score over the survey (Figure 2.1.3.1.4). Although there is a sharp decline in the final two years of the series, the individual plots confirm that the abundances of most species are still above reference levels.

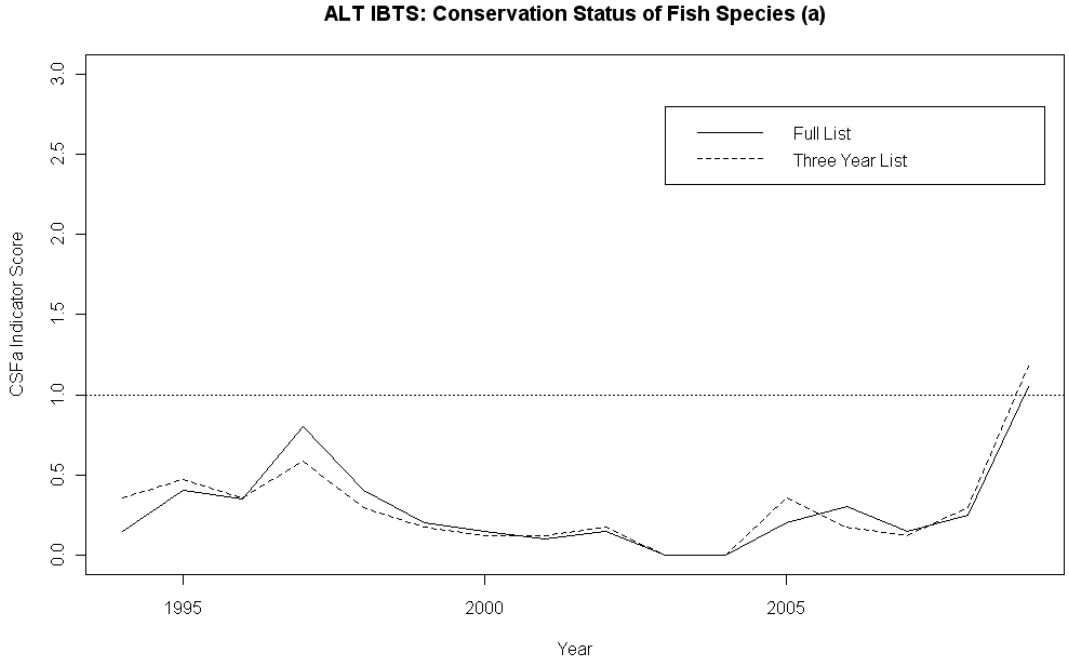

Figure 2.1.3.1.1 Conservation status of fish species (a) for the ALT IBTS using both the full and three year species lists.

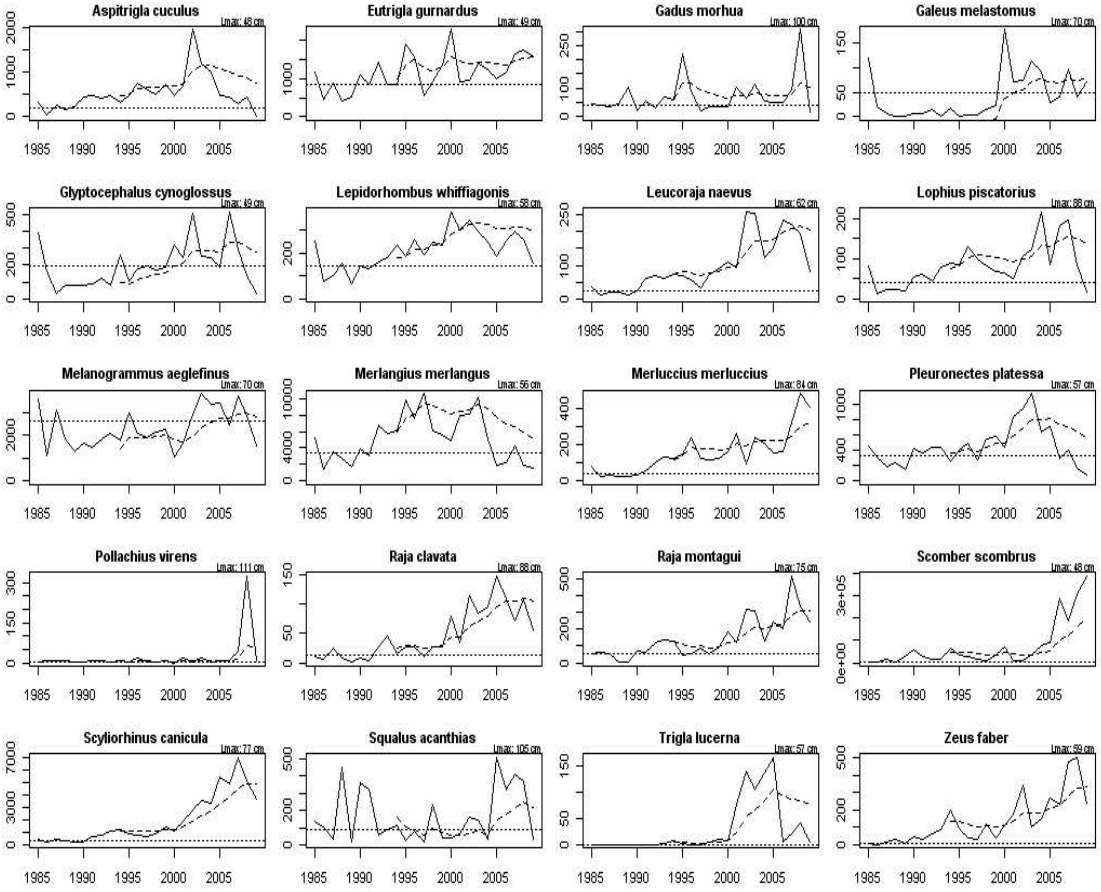

Figure 2.1.3.1.2 Actual (continuous line) and predicted (dashed line) catch for the 20 species included in the full list in the calculation of CSFa for the ALT IBTS. Abundance over 0.5 Lmax is on the y axis, year is on the x axis. Lmax is the max recorded length for that species over the entire survey. Horizontal dotted line represents the mean catch in the first three years, which is used in the calculation of CSFb.

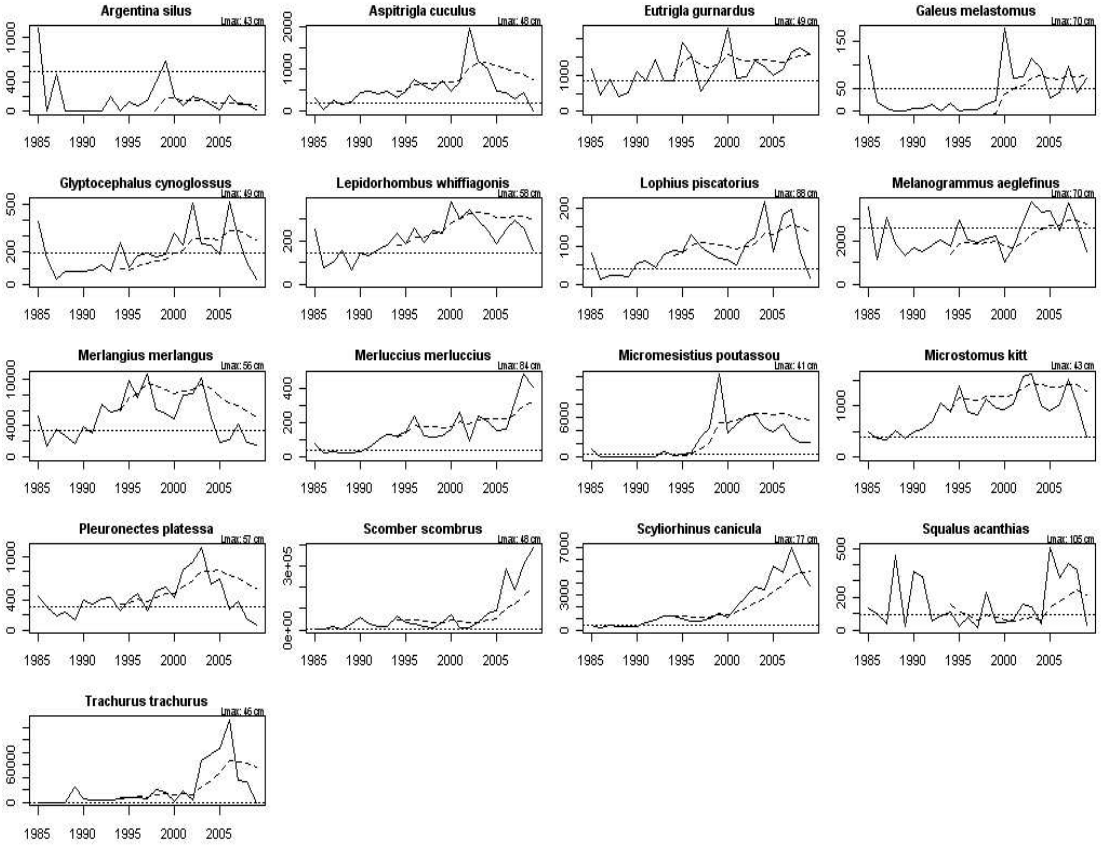

Figure 2.1.3.1.3 Actual (continuous line) and predicted (dashed line) catch for the 17 species included in the three year list in the calculation of CSFa for the ALT IBTS. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

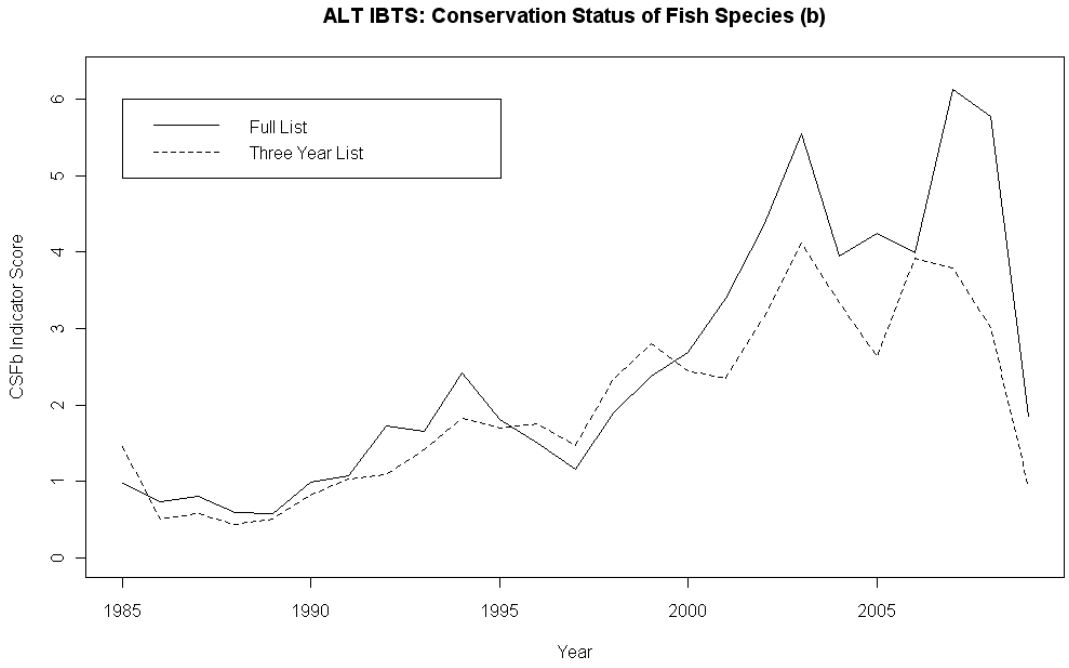

Figure 2.1.3.1.4 Conservation status of fish species (b) for the ALT IBTS using both the full and three year species lists.

2.1.3.2 BTS VIIa

Twelve species met the criteria for inclusion in the full list and 14 for the three year list. No species were excluded. CSFa remained below the target value of one for the entire survey for both full and three year lists (Figure 2.1.3.2.1). Looking at species separately, actual catch remains close to predicted catch for both full (Figure 2.1.3.2.2) and three year ((Figure 2.1.3.2.3) lists for most species. However actual catch is below the reference level for many species in the latter years, resulting in the declining trend of CSFb scores (Figure 2.1.3.2.4).

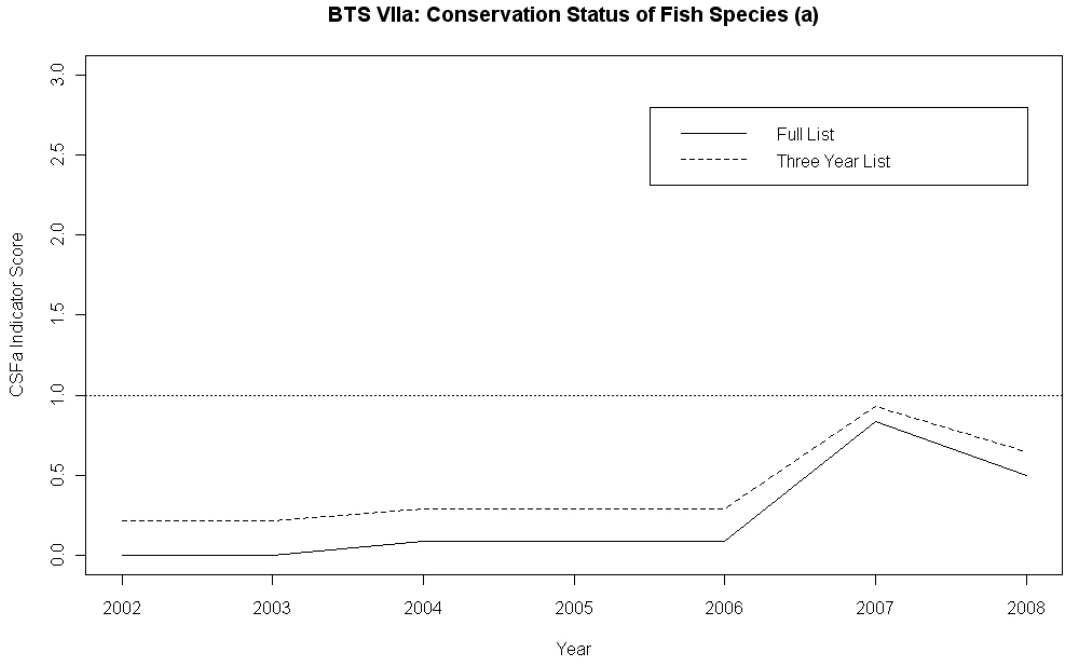

Figure 2.1.3.2.1 Conservation status of fish species (a) for the BTS VIIa using both the full and three year species lists.

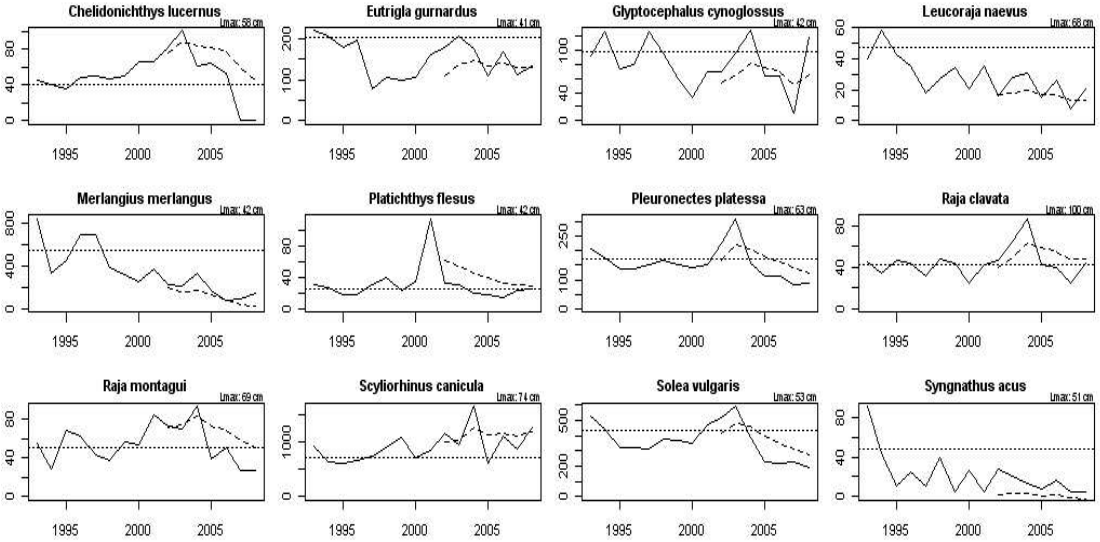

Figure 2.1.3.2.2 Actual (continuous line) and predicted (dashed line) catch for the 12 species included in the full list in the calculation of CSFa for the BTS VIIa. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

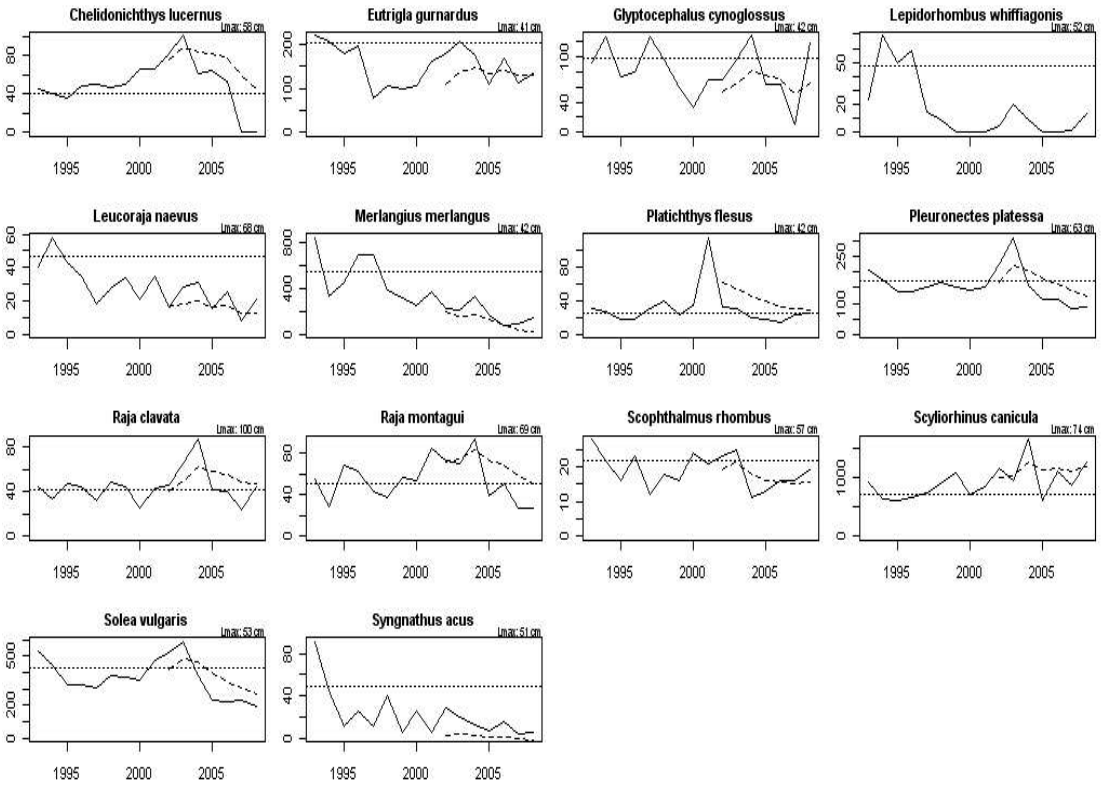

Figure 2.1.3.2.3 Actual (continuous line) and predicted (dashed line) catch for the 17 species included in the three year list in the calculation of CSFa for the BTS VIIa. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

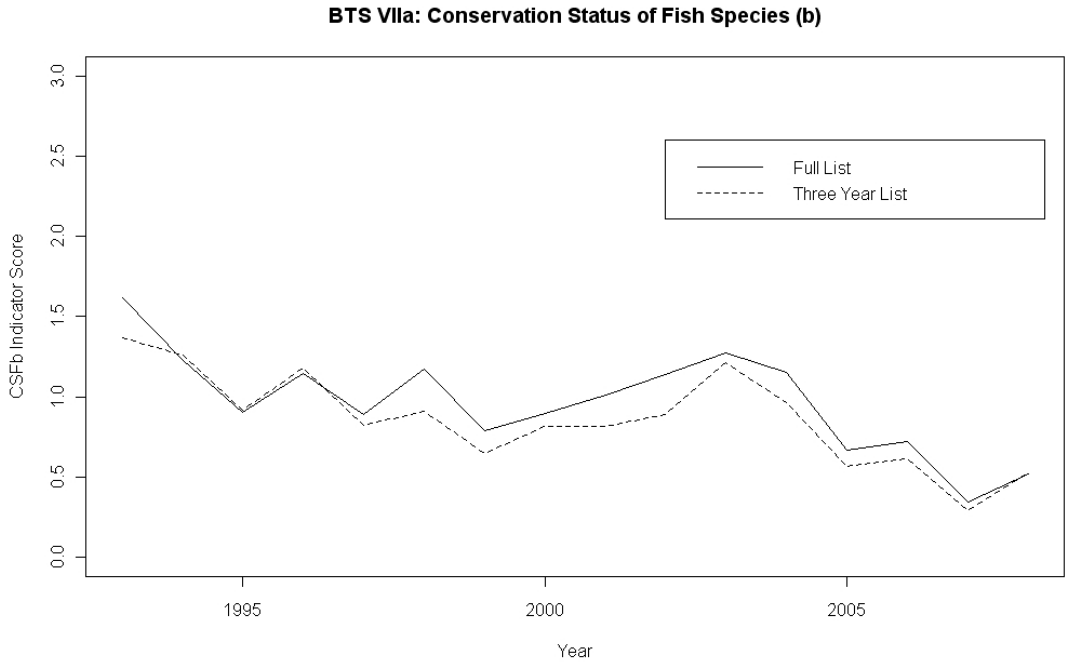

Figure 2.1.3.2.4 Conservation status of fish species (b) for the BTS VIIa using both the full and three year species lists.

2.1.3.3 EVHOE

Twenty species were included in the full species list and 13 in the three year list. *Galeus melastomus* was excluded due to no catch in the first three years. Due to the number of years available in the time series only two points could be calculated for the CSFa for each list. These four points were below the target value (Figure 2.1.3.3.1) however such a short data series provides limited information. Plotted separately the actual catch shows a mix of increasing and decreasing abundances for both the full (Figure 2.1.3.3.2) and three year (Figure 2.1.3.3.3) species lists. This mix produces a variable CSFb score (Figure 2.1.3.3.4). CSFb for the three year list fluctuates around one but the full list score increases in the latter half of the survey to around twice its initial level.

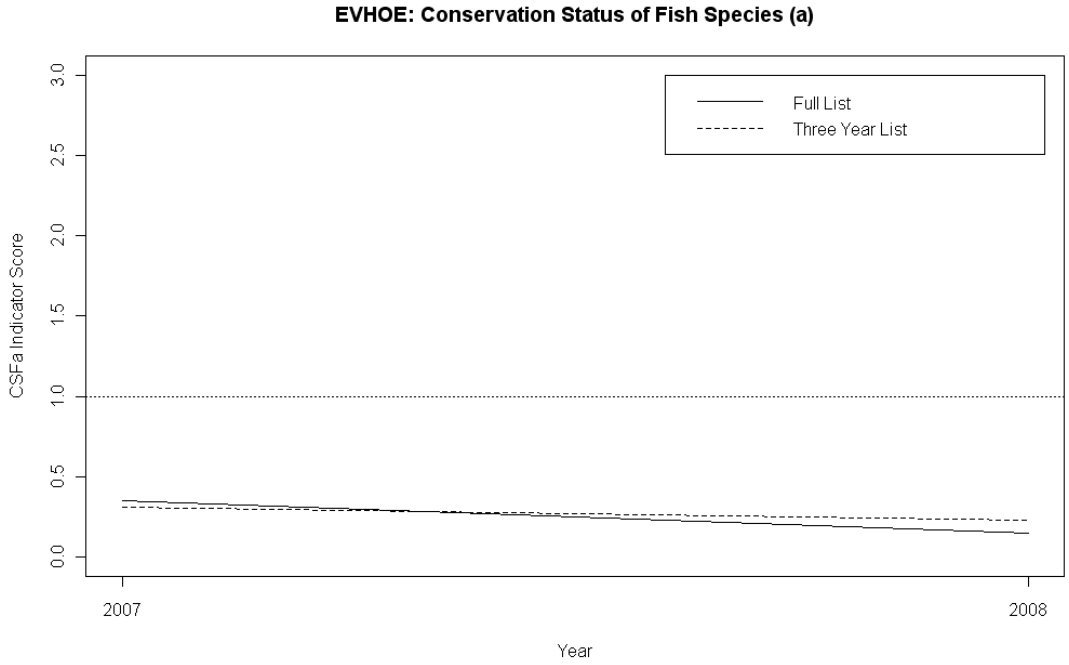

Figure 2.1.3.3.1 Conservation status of fish species (a) for the EVHOE survey using both the full and three year species lists.

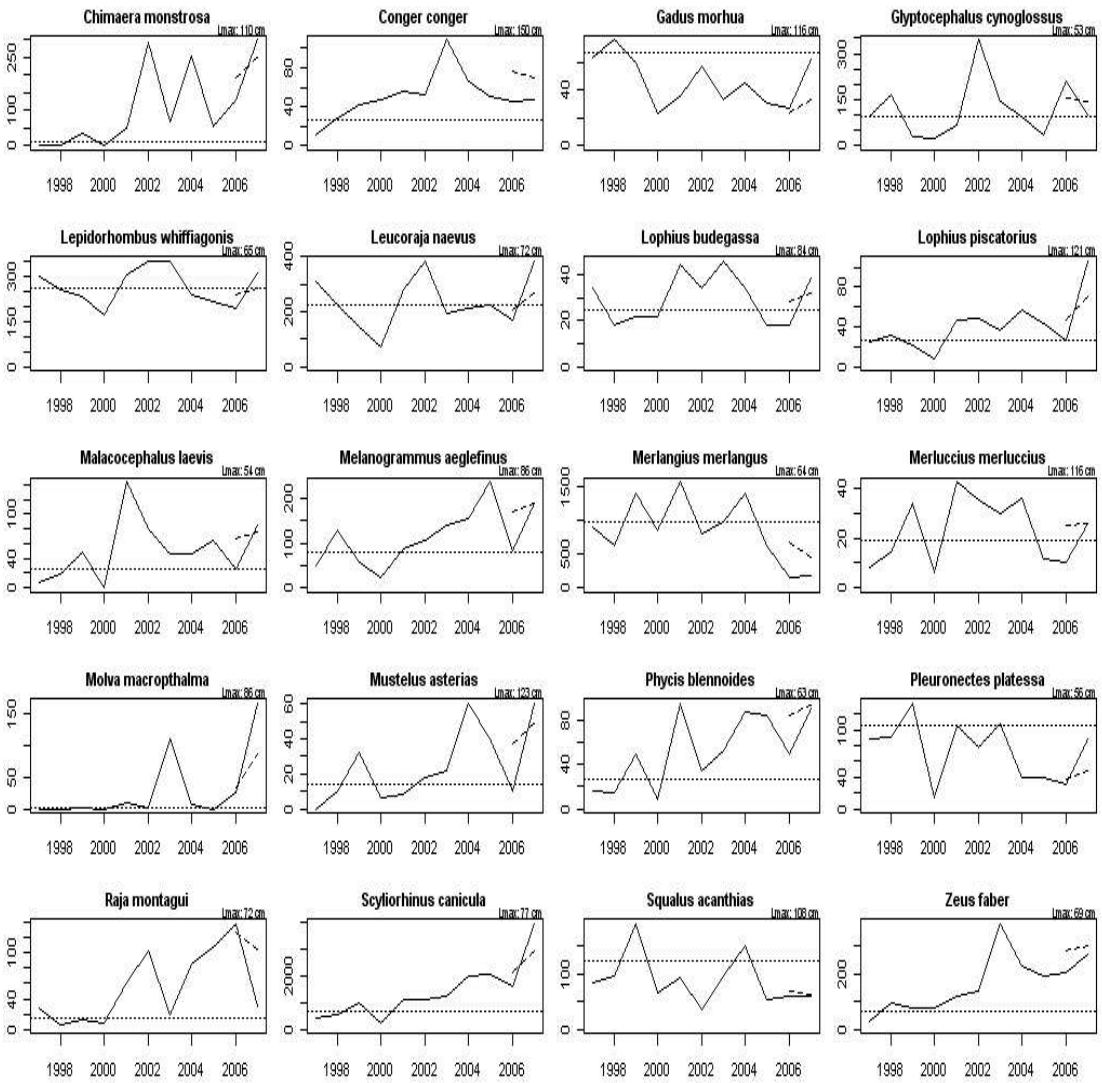

Figure 2.1.3.3.2 Actual (continuous line) and predicted (dashed line) catch for the 20 species included in the full list in the calculation of CSFa for the EVHOE survey. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

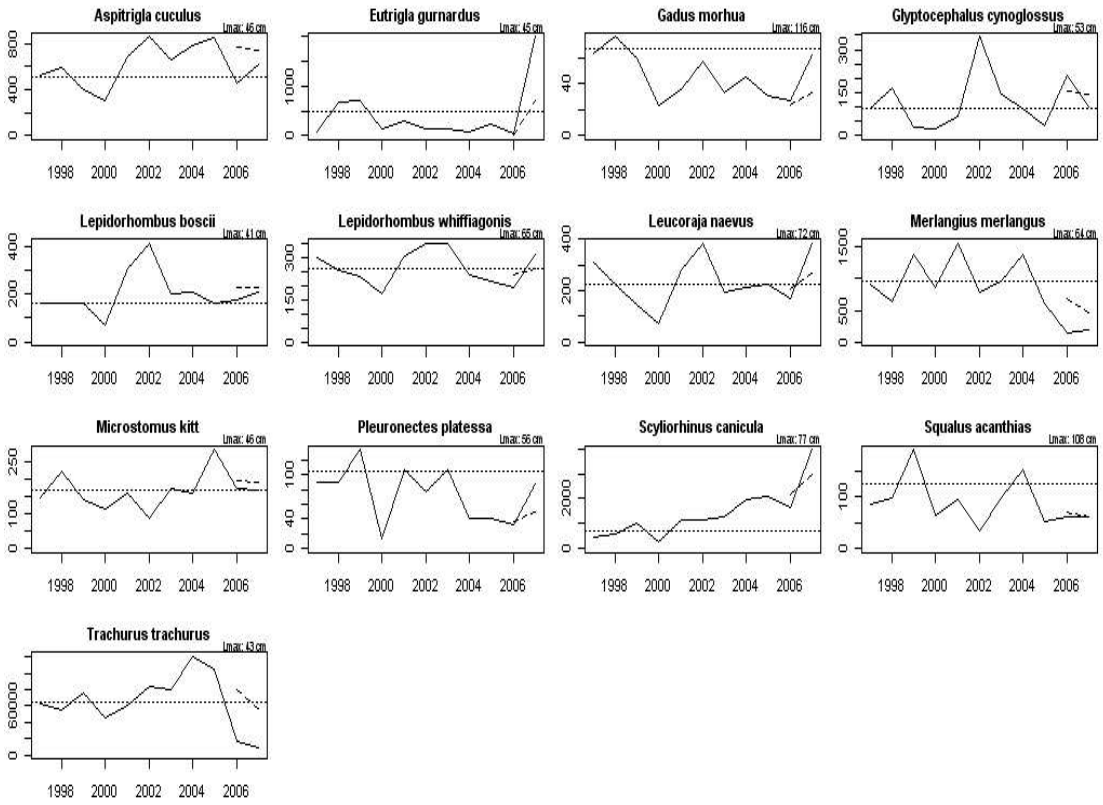

Figure 2.1.3.3.3 Actual (continuous line) and predicted (dashed line) catch for the 13 species included in the three year list in the calculation of CSFa for the EVHOE survey. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

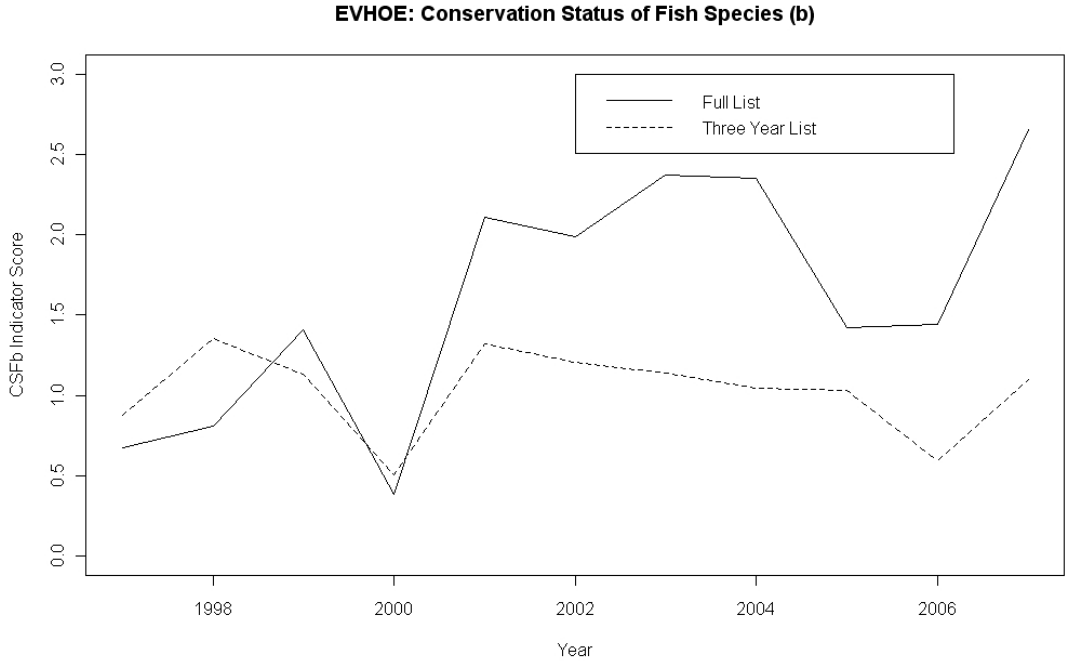

Figure 2.1.3.3.4 Conservation status of fish species (b) for the EVHOE survey using both the full and three year species lists.

2.1.3.4 IGFS

Seventeen species were included in both the full and three year lists. One species, *Syngnathus acus*, was excluded due to no catch in the first three years of the data series. The CSFa indicator could not be calculated due to the number of years in the time series. There was a peak in the abundance of many species in the full (Figure 2.1.3.4.1) and three year (Figure 2.1.3.4.2) lists around 2005 and 2006. This resulted in a peak in CSFb score in those years, with a subsequent decline to the initial level (Figure 2.1.3.4.3).

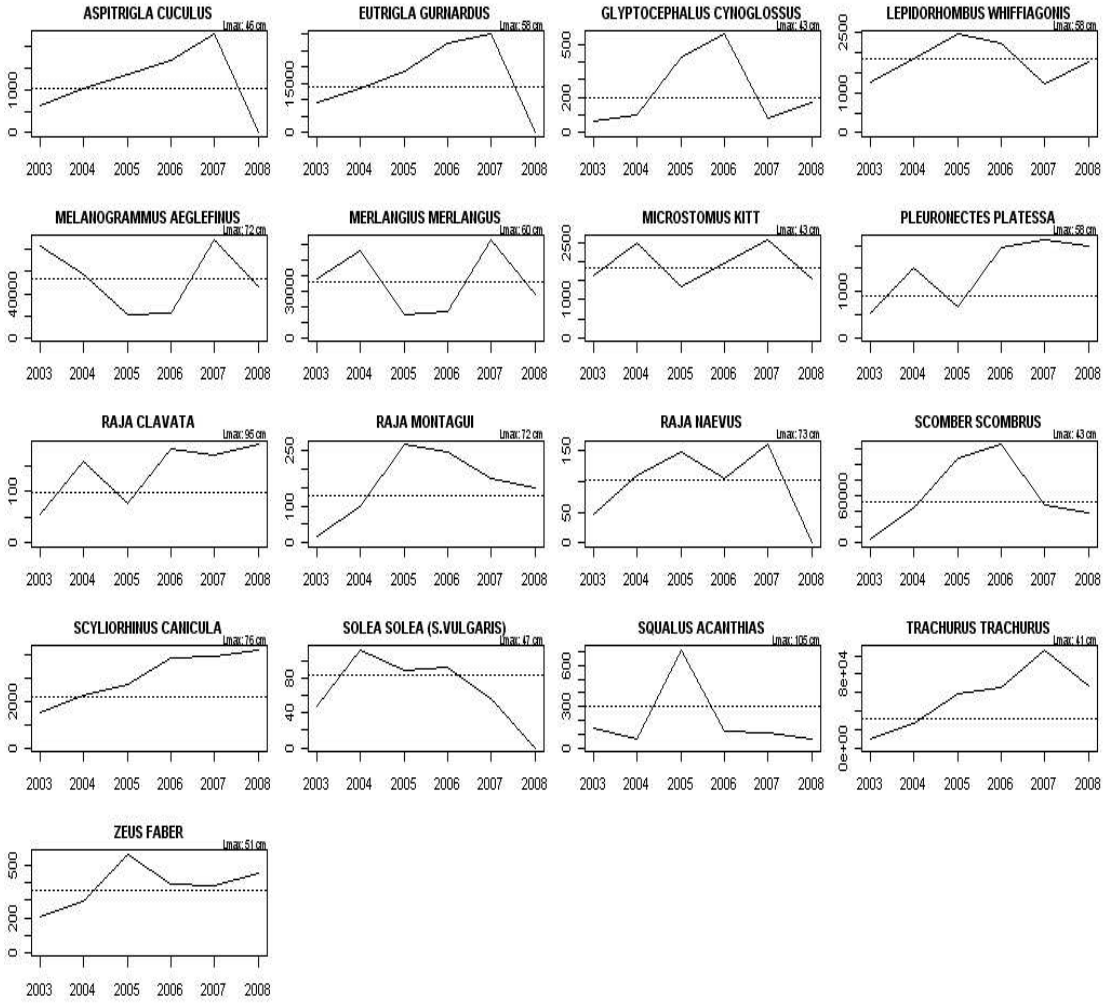

Figure 2.1.3.4.1 Actual (continuous line) and predicted (dashed line) catch for the 17 species included in the full list in the calculation of CSFa for the IGFS. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

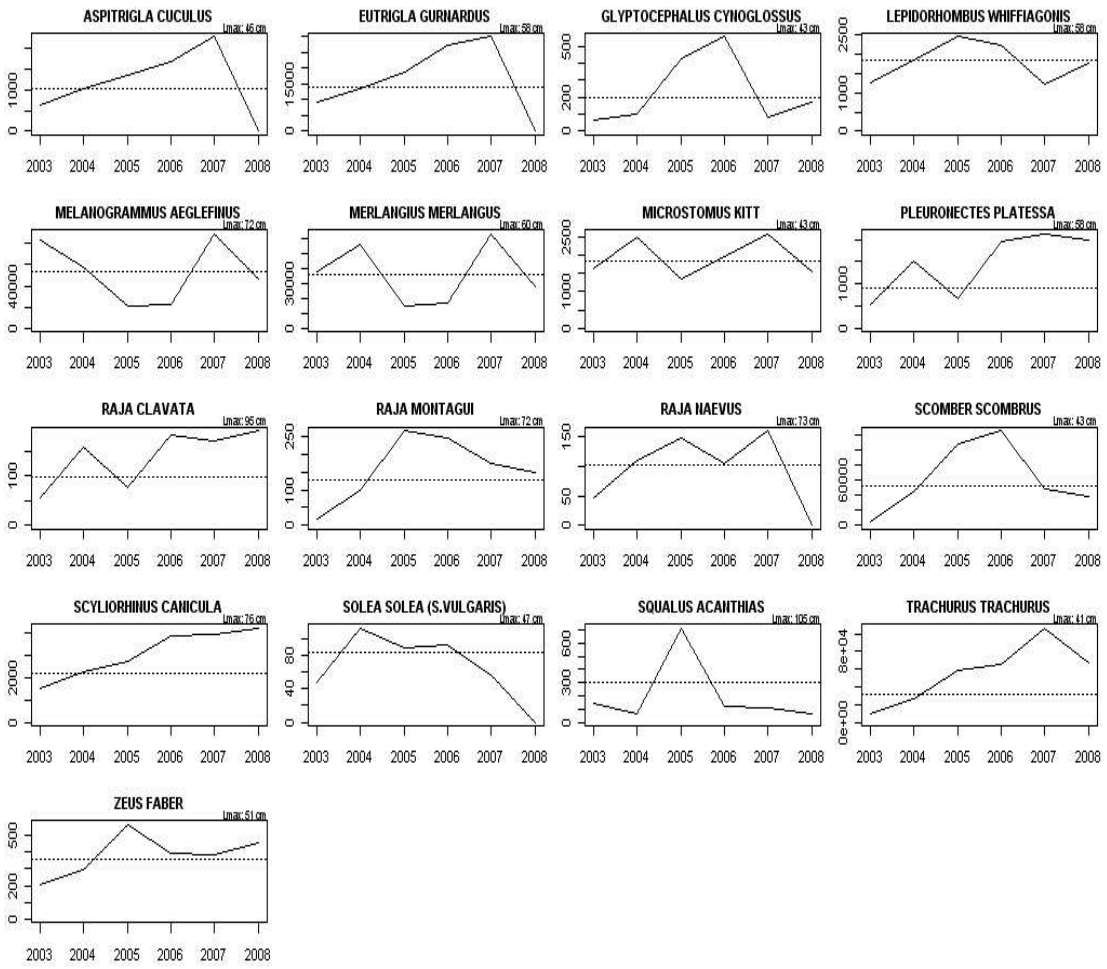

Figure 2.1.3.4.2 Actual (continuous line) and predicted (dashed line) catch for the 17 species included in the three year list in the calculation of CSFa for the IGFS. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

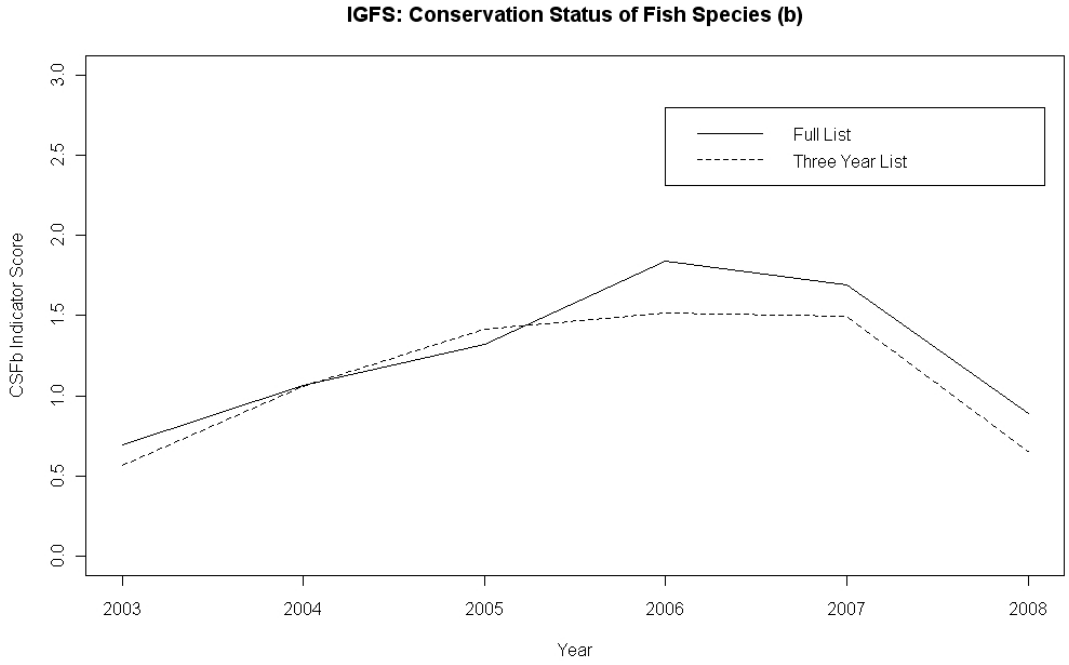

Figure 2.1.3.4.3 Conservation status of fish species (b) for the IGFS using both the full and three year species lists.

2.1.3.5 Rockall

Two species were excluded from analyses due to no catch in the first three years: *Gymnammodytes semisquamatus* and *Entelurus aequoreus*. Six species were included in the full species list and only three in the three year list. Abundances varied widely for these species, some increasing and some decreasing (Figures 2.1.3.5.1 and 2). There was a general increasing trend in the CSFb score (Figure 2.1.3.5.3), however considering the low number of species meeting the criteria for inclusion in the indicator care should be used in the interpretation of this result.

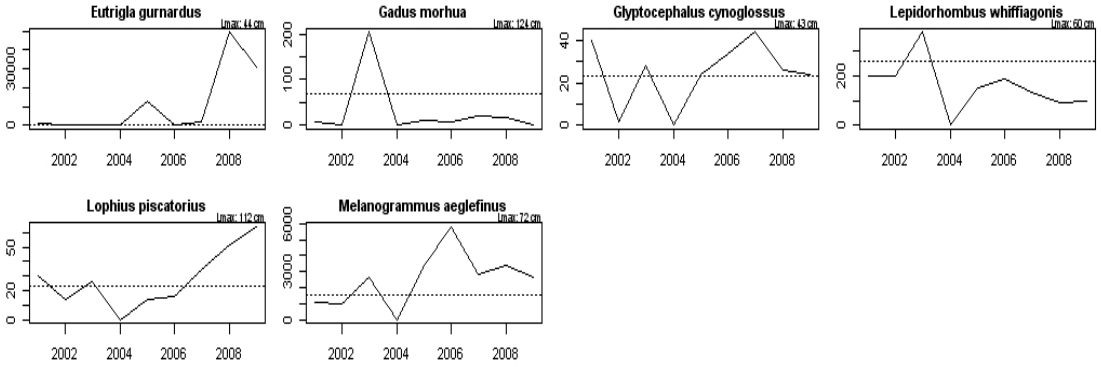

Figure 2.1.3.5.1 Actual (continuous line) and predicted (dashed line) catch for the 6 species included in the full list in the calculation of CSFa for the Rockall. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

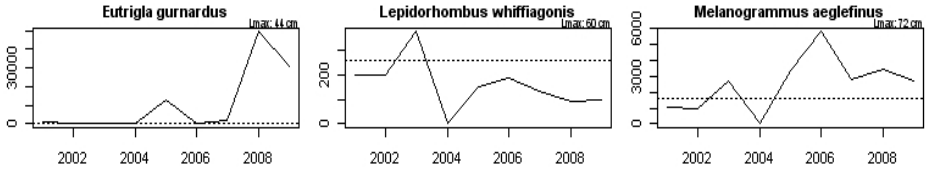

Figure 2.1.3.5.2 Actual (continuous line) and predicted (dashed line) catch for the 17 species included in the three year list in the calculation of CSFa for the Rockall survey. Horizontal dotted line and Lmax: see Figure 2.1.3.1.2 description.

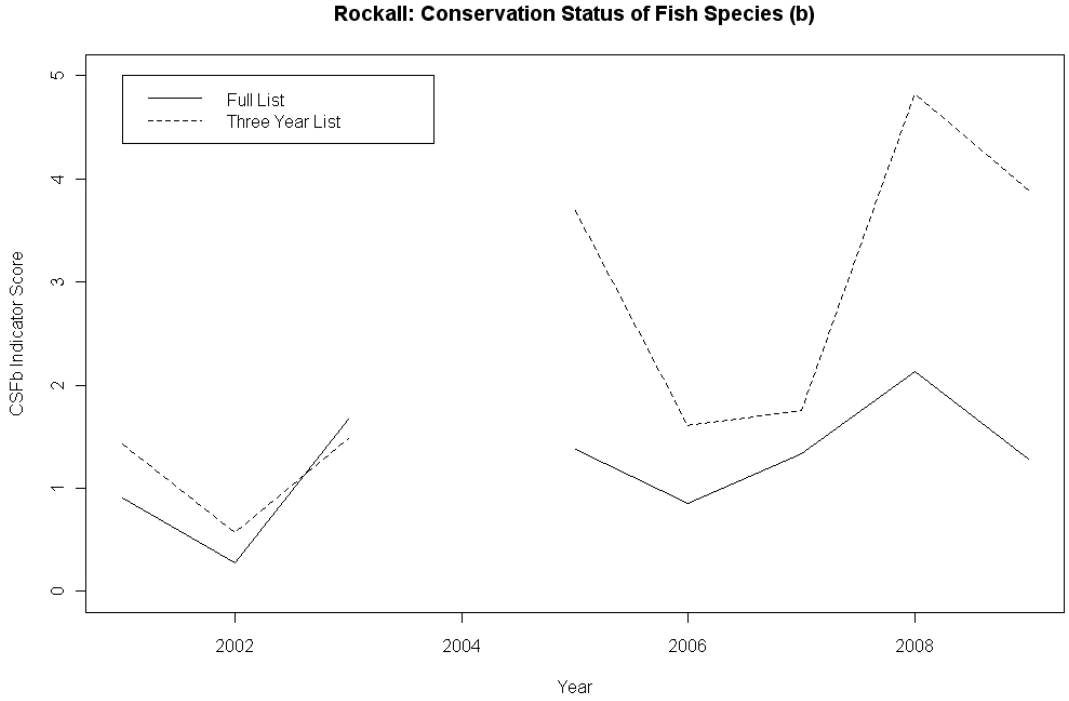

Figure 2.1.3.5.3 Conservation status of fish species (b) for the Rockall survey using both the full and three year species lists.

2.1.4 Discussion

For all three surveys for which it could be calculated, CSFa remained below the threshold for the vast majority of surveyed years. Similarly, CSFb showed a constant or increasing trend in all but the BTS VIIa data. Although this is a positive result, which suggests fishing pressure is having a limited effect on the threat status and relative abundance of fish species, it should be interpreted carefully. By excluding species caught in low numbers over the course of the survey the indicator may be disregarding the most threatened species. The inclusion of an alternative species list based on the initial three years of catch goes some way toward alleviating this concern; avoiding the shifting baseline. However, due to the relatively short time series of consistent surveys, the baseline used is probably an already degraded reference status. This is particularly relevant to the EVHOE, IGFS and Rockall surveys where data is available from DATRAS only as far back as a decade. The recent reference period could be the reason so few species met the selection criteria for inclusion in the species list of the Rockall survey. With a minimum average yearly catch of 20 individuals for a species to be included, it is possible that most populations of large species have been fished to low levels in this area prior to the initiation of the survey. Particular care should be taken when using the CSFa and b results of surveys that could only produce 6 species over 40cm in max length with an average annual catch above 20 individuals.

The CSF indicators perform well at summarising the fluctuations in threat and abundance of large fish species in the majority of surveys in the NWW region. Although it is possible for a species to become extinct while the overall CSF score remains below the target value, this is the case with most indicators and is the reason for the inclusion of the individual species plots. For future use it would appear that the three year list method, as described here and in the other MEFEPO regional WP2

reports, would be the most appropriate. A minimum length of time series and/or number of species meeting the inclusion criteria could also be considered when applying this indicator.

2.2 GES Descriptor 3: Commercial species

Over the last 5 years there have been over 350 different species or species-groups landed in the NWW. This calculation was based on the ICES catch statistics 1973-2008 as they occur in the FAO FishStat database. The FishStat divisions attributed to the NWW RAC region were Area 27 Sub-areas VIa+b, VIIa-k, and landings per species were aggregated across the region. 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 2003-2008 72 species (56 fish, 12 invertebrates and 4 algae) contributed more than 0.1% of the landings by weight (Table 2.2.4). Together these species made up 99.4% of the landings (approximately 90% fish, 8% invertebrates and 1% algae).

Table 2.2.4 All major species and species-groups (>0.1% of the total landings period 2003-2008), their total landings and relative contribution. Indicated is whether the species are assessed (X) or not (blank) for the purposes of this indicator, and whether they are fish (F), invertebrates (I) or algae (A).

Species	Assessed	Type	Total Landings (t)	% Landings
Blue whiting		F	5,634,995	54.1
Atlantic mackerel		F	943,963	9.1
Atlantic herring		F	598,618	5.7
Atlantic horse mackerel		F	581,050	5.6
Great Atlantic scallop		F	247,376	2.4
Norway lobster		I	166,786	1.6
Whelk		I	162,969	1.6
Edible crab		I	158,928	1.5
European pilchard(=Sardine)		F	116,145	1.1
Haddock	X	F	92,508	0.9
Cuttlefish, bobtail squids nei		I	89,003	0.9
Whiting		F	86,932	0.8
Monkfishes nei		F	78,852	0.8
Tangle		A	72,890	0.7
Blue mussel		I	63,528	0.6
Queen scallop		I	63,466	0.6
Raja rays nei		F	55,155	0.5
Ling		F	52,384	0.5
European hake		F	50,323	0.5
Common sole	X	F	48,423	0.5
Saithe(=Pollock)		F	46,888	0.5
Atlantic cod	X	F	42,545	0.4
European plaice	X	F	40,763	0.4
Angler(=Monk)		F	34,489	0.3
Com. European bittersweet		F	33,207	0.3
Pouting(=Bib)		F	32,792	0.3
Megrims nei		F	32,107	0.3
European sprat		F	31,370	0.3
Red gurnard		F	28,297	0.3

Pollack		F	26,231	0.3
Small-spotted catshark		F	26,211	0.3
Spinous spider crab		I	26,047	0.3
Roundnose grenadier		F	23,510	0.2
European conger		F	23,210	0.2
Common edible cockle		F	22,895	0.2
Red mullet		F	22,661	0.2
Various squids nei		I	20,877	0.2
Witch flounder		F	19,211	0.2
Blue ling		F	19,098	0.2
Seaweeds nei		A	18,836	0.2
Black seabream		F	17,231	0.2
Black scabbardfish		F	17,006	0.2
Greater argentine		F	16,882	0.2
Picked dogfish		F	16,560	0.2
Lemon sole		F	16,188	0.2
European seabass		F	15,928	0.2
North European kelp		A	15,383	0.1
Anglerfishes nei		F	12,897	0.1
European lobster		F	11,217	0.1
John dory		F	10,848	0.1
Argentine		F	10,039	0.1
Tusk(=Cusk)		F	9,888	0.1
Smooth-hounds nei		F	9,702	0.1
Common cuttlefish		I	9,110	0.1
Megrim		F	9,028	0.1
Gurnards, searobins nei		F	9,001	0.1
Scallops nei		I	8,737	0.1
Norway pout		F	8,729	0.1
Cuckoo ray		F	8,728	0.1
Dogfish sharks nei		F	8,191	0.1
Common dab		F	7,739	0.1
Greater forkbeard		F	7,688	0.1
Turbot		F	6,915	0.1
Groundfishes nei		F	6,801	0.1
Tub gurnard		F	6,689	0.1
Inshore squids nei		F	6,440	0.1
European flat oyster		I	6,299	0.1
Brill		F	6,136	0.1
Mytilus spp		I	5,683	0.1
North Atlantic rockweed		A	5,637	0.1
Marine fishes nei		F	5,619	0.1
Portuguese dogfish		F	5,555	0.1

Clearly there are many more stocks in the region on which assessments are made. However many of these did not fit the criteria outlined in Section 1.2.2.1 (p. 21) of this report. The reasons for their exclusion are explained below.

2.2.1 Data requirements and availability

The data required to calculate the commercial species indicator is yearly assessment values of spawning stock biomass (SSB) and fishing mortality (F) for a stock and the reference values for spawning stock biomass precautionary ($SSB_{pa)}$ and fishing mortality precautionary (F_{pa}) for the same stock. In total 38 fish stocks listed in the ICES stock assessment summary database

(http://www.ices.dk/datacentre/StdGraphDB.asp) were identified as occurring in, or mostly within, the NWW waters (ICES divisions VI and VII). Of these, 17 had set limits for SSBpa and Fpa. And of these 17 only 7 stocks had annual estimates of SSB and F in the FishData table of the database. These stocks were selected to calculate the indicator for the NWW and are shown with the stock code used in Table 2.2.2.

Table 2.2.2 Assessed stocks, and their codes, used to calculate the commercial species indicator for the NWW.

Code	Stock
cod-scow	Cod in Division VIa (West of Scotland)
had-scow	Haddock in Division VIa (West of Scotland)
ple-echw	Plaice in Division VIIe (Western Channel)
ple-iris	Plaice in Division VIIa (Irish Sea)
sol-celt	Sole in Divisions VIIf and g (Celtic Sea)
sol-eche	Sole in Division VIId (Eastern Channel)
sol-iris	Sole in Division VIIa (Irish Sea)

The years the selected stocks were assessed are shown in Table 2.2.3. The suite of stocks on which the indicator is based has expanded over time and the longest time series is currently 45 years.

Table 2.2.3. Number of NWW stocks assessed over time.

	Stock							
Year	ple-iris	sol-iris	sol-celt	ple-echw	cod-scow	had-scow	sol-eche	Assessed
1964	X							1
1965	X							1
1966	X							1
1967	X							1
1968	X							1
1969	X							1
1970	X	X						2
1971	X	X	X					3
1972	X	X	X					3
1973	X	X	X					3
1974	X	X	X					3
1975	X	X	X					3
1976	X	X	X	X				4
1977	X	X	X	X				4
1978	X	X	X	X	X	X		6
1979	X	X	X	X	X	X		6
1980	X	X	X	X	X	X		6
1981	X	X	X	X	X	X		6
1982	X	X	X	X	X	X	X	7
1983	X	X	X	X	X	X	X	7
1984	X	X	X	X	X	X	X	7
1985	X	X	X	X	X	X	X	7
1986	X	X	X	X	X	X	X	7
1987	X	X	X	X	X	X	X	7
1988	X	X	X	X	X	X	X	7
1989	X	X	X	X	X	X	X	7
1990	X	X	X	X	X	X	X	7
1991	X	X	X	X	X	X	X	7
1992	X	X	X	X	X	X	X	7
1993	X	X	X	X	X	X	X	7
1994	X	X	X	X	X	X	X	7
1995	X	X	X	X	X	X	X	7
1996	X	X	X	X	X	X	X	7
1997	X	X	X	X	X	X	X	7
1998	X	X	X	X	X	X	X	7
1999	X	X	X	X	X	X	X	7
2000	X	X	X	X	X	X	X	7
2001	X	X	X	X	X	X	X	7
2002	X	X	X	X	X	X	X	7
2003	X	X	X	X	X	X	X	7
2004	X	X	X	X	X	X	X	7
2005	X	X	X	X	X	X	X	7
2006	X	X	X	X	X	X	X	7
2007	X	X	X	X	X	X	X	7
2008	X	X	X	X	X	X	X	7
2009	X	X	X	X	X	X	X	7

To assess the representativity of the indicator the proportion of total landings that came from assessed stocks was determined. Less than 10% of the landed weight

consists of assessed species for which both reference values are known and contributed to the indicator calculation (Figure 2.2.1). However, this is an understatement as several species that contribute an important part of the landings are assessed but have been omitted from the calculation of this indicator. Their omission was due to their wide ranges of distribution (the core of the stocks lie outside the NWW) so they were not considered representative of the state of the NWW commercial stocks (i.e. Blue whiting, Mackerel and Horse mackerel). If these species were included the representativity would increase to about 75% (Figure 2.2.1 dashed line).

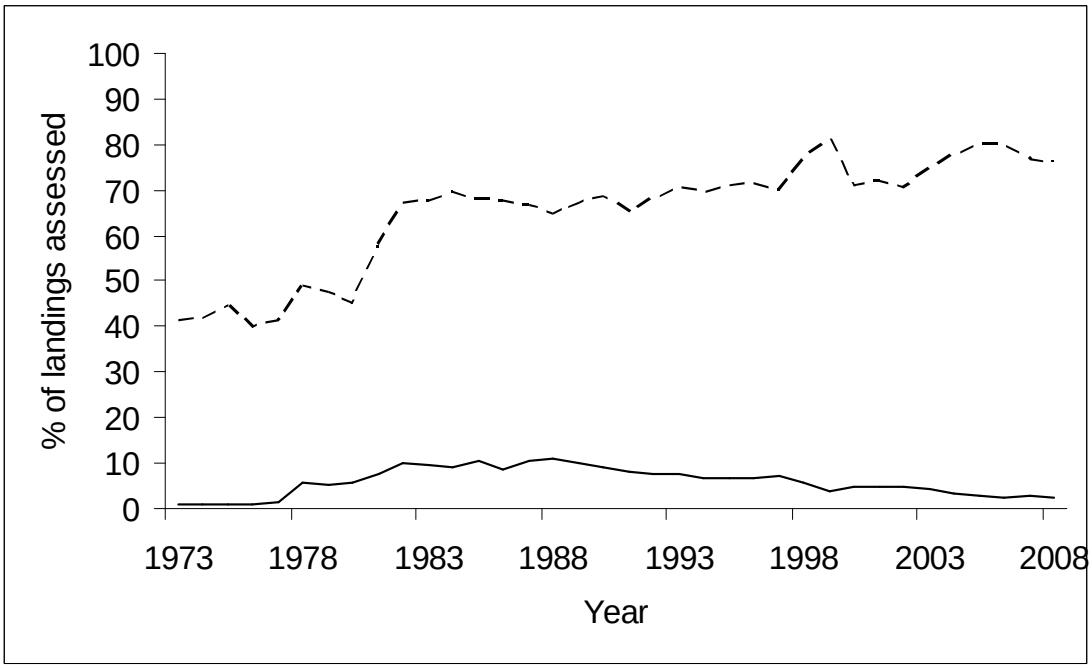

Figure 2.2.1 Proportion of the total landings in the NWW region consisting of assessed species. The continuous line represents the species included in the analysis of the indicator. The dashed line represents the representativity if the mobile pelagic species were to be included.

2.2.2 Modifications to indicator calculation method

No additional modifications to the criteria developed by Piet & Rice (2004) were made.

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 1964 when only based on one stock (plaice) to about 20% in the 1980s and 1990s (Figure 2.2.2). In recent years there appears to be a slight increase to about 35%. A comparable trend is observed for the linked indicator, "proportion of landings within SBL" which also decreases strongly over the 1970s remaining mostly below 20% and showing a slight increase in recent years (Figure 2.2.3).

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 1982 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 within SBL. The 2009 indicator value of 43% is well below the target level.

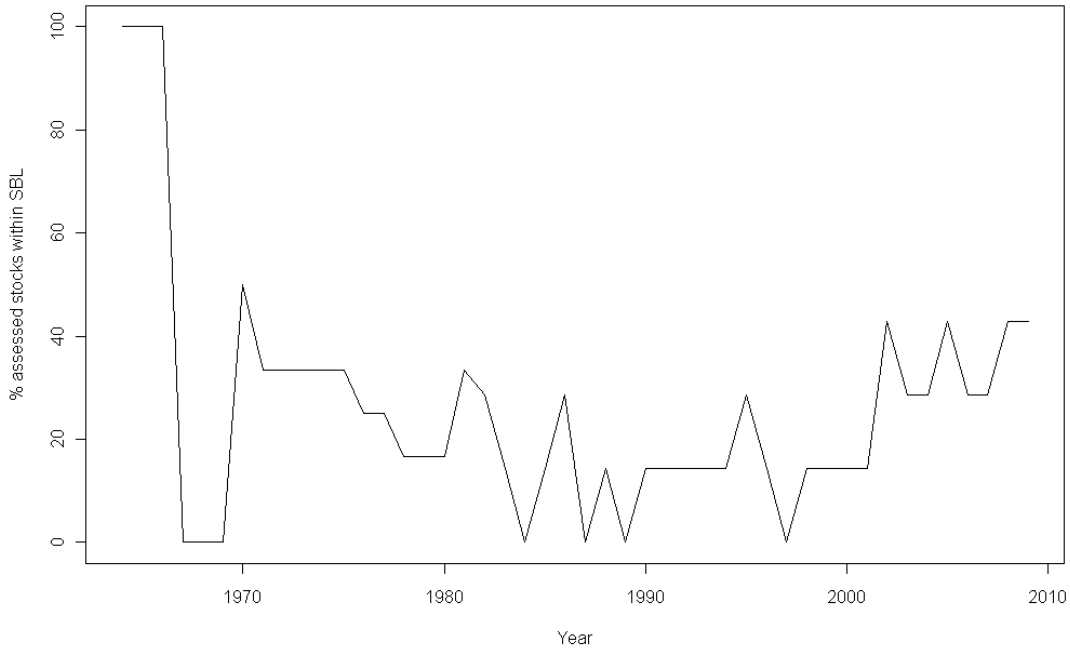

Figure 2.2.2 Proportion of assessed NWW stocks within safe biological limits.

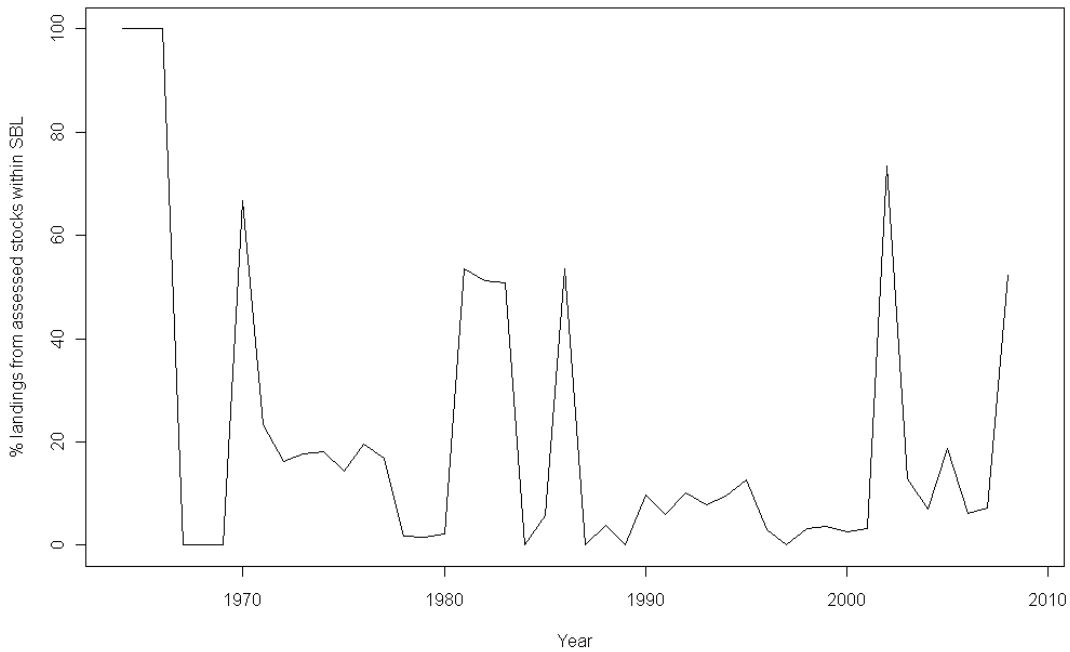

Figure 2.2.3 Proportion of landings from assessed NWW stocks that are within safe biological limits.

2.2.4 Discussion

The strict criteria for including a stock in the calculation of this indicator means that only a fraction of the stocks managed in the NWW can be considered. As a result less

than 10% of the landings in the RAC region are represented by the indicator as it is. Figure 2.2.1 illustrates that this representation could be upped to roughly 75% with the inclusion of pelagic stocks whose core areas overlap other regions. When the analysis is run including these species similar percentages of stocks within SBL are found. This result is not presented as it does not conform to the criteria for stock inclusion detailed in Section 1.2.2.1. However it does go some way towards confirming that the true percentage of stocks in NWW that are within SBL is indeed 45%.

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 MEFEPO 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. The surveys and data used for this indicator are the same as those described in section 2.1 of this report. The formula used to calculate the LFI for each year was:

$$\text{Weight of fish} \geq 40\text{cm} / \text{Total weight of fish}$$

As weight was not recorded for most fish species in the five surveys examined, length-weight (L-W) relationships were used to estimate individual fish weight. The L-W formula used was:

$$\text{Weight} = a\,(\text{Length}^{\wedge} b)$$

The a and b values used for each species were obtained from FishBase (www.fishbase.org).

As this indicator is sensitive to changes in numbers of fish both above and below the large fish threshold, the length that determines a large fish needs to be carefully set. Previous studies in the North Sea have shown 40cm to be an appropriate large fish threshold. Ongoing studies in the Celtic Sea indicate that this is most likely also an appropriate threshold for the NWW (S. Shephard and D. Reid, pers. comm.).

2.3.2 Modifications to indicator calculation method

To remove the effect of the highly variable catch of certain species, the LFI for each survey was also calculated excluding pelagic species. The species included as pelagic

were: blue whiting (*Micromesistius poutassou*), herring (*Clupea harengus*), Horse mackerel (*Trachurus trachurus*), mackerel (*Scomber scombrus*), anchovy (*Engraulis encrasicolus*), pilchard (*Sardina pilchardus*) and sprat (*Sprattus sprattus*).

2.3.3 Indicator assessment

LFI scores for all five surveys are presented in figure 2.3.1. The LFI scores for the ALT IBTS, BTS VIIa and Rockall surveys consistently fell below the target level for the OSPAR EcoQo for large fish of 0.3. The IGFS performed well with the majority of surveyed years exceeding the target value (except for one year where pelagic species were included in the analysis). The results for the EVHOE survey show the merit in excluding the pelagic species. When these species are included in the analysis the majority of the scores fall below the target value, although the increasing trend is positive. However, when excluding the highly variable pelagic species the LFI scores are mostly above the target value and the increasing trend is still evident.

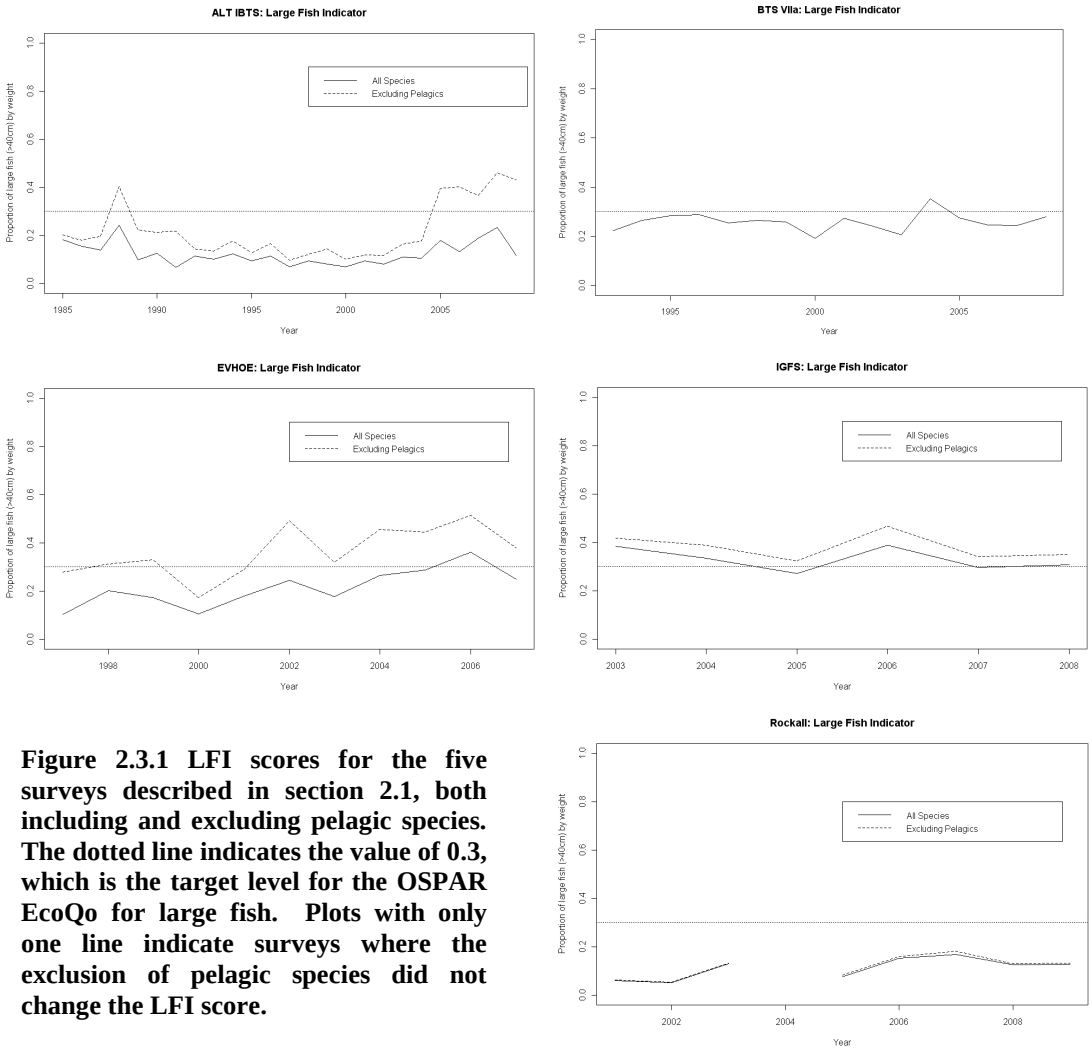

Figure 2.3.1 LFI scores for the five surveys described in section 2.1, both including and excluding pelagic species. The dotted line indicates the value of 0.3, which is the target level for the OSPAR EcoQo for large fish. Plots with only one line indicate surveys where the exclusion of pelagic species did not change the LFI score.

2.3.4 Discussion

If pelagic species are included in the analysis, the NWW as a whole is not considered to be attaining good environmental status in relation to qualitative descriptor 4 as four out of five surveys scored below the target LFI value of 0.3 in the final year. However if pelagic species are excluded as described in Section 1.2.3.1, three out of five surveys exceeded the LFI target. Does having three fifths of the surveyed areas in

GES mean GES for the entire region or should GES be met for all surveys? This will be discussed further in Section 3.

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 of effort by mobile bottom gears for the NWW RAC region requires raw or processed VMS outputs to be submitted by each nation with national waters in the NWW 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 and North Western Waters RAC areas 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 on 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).

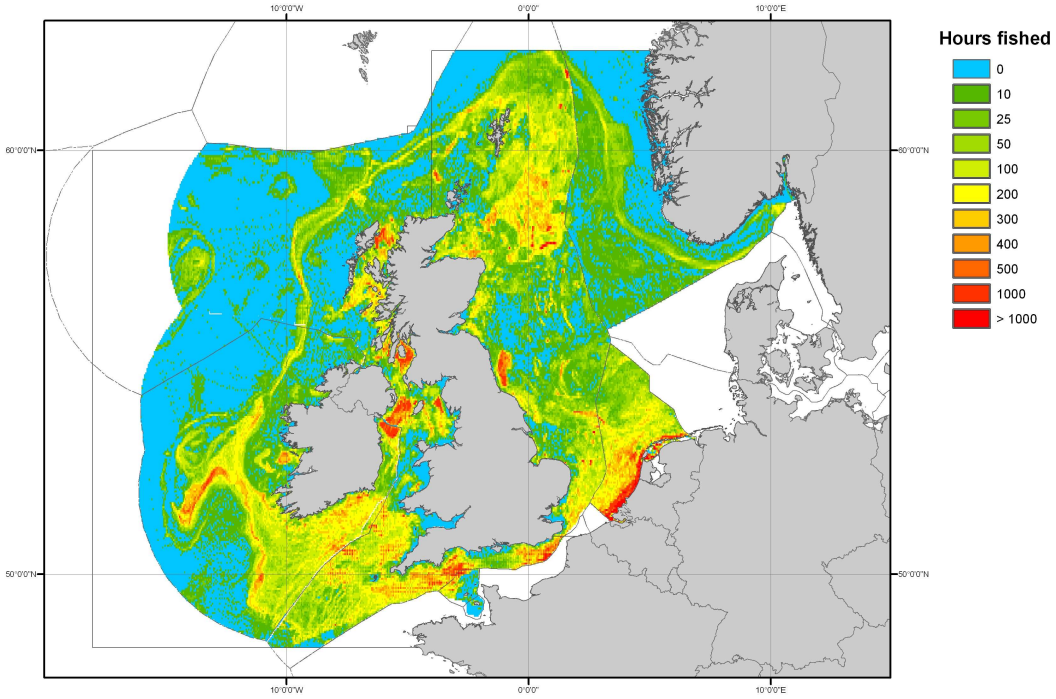

Figure 2.4.1 Distribution of fishing effort by mobile bottom gears for 2006 by 3'x3' cells based on VMS records from submitting nations. The VMS data were processed using the point estimation method described above.

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).

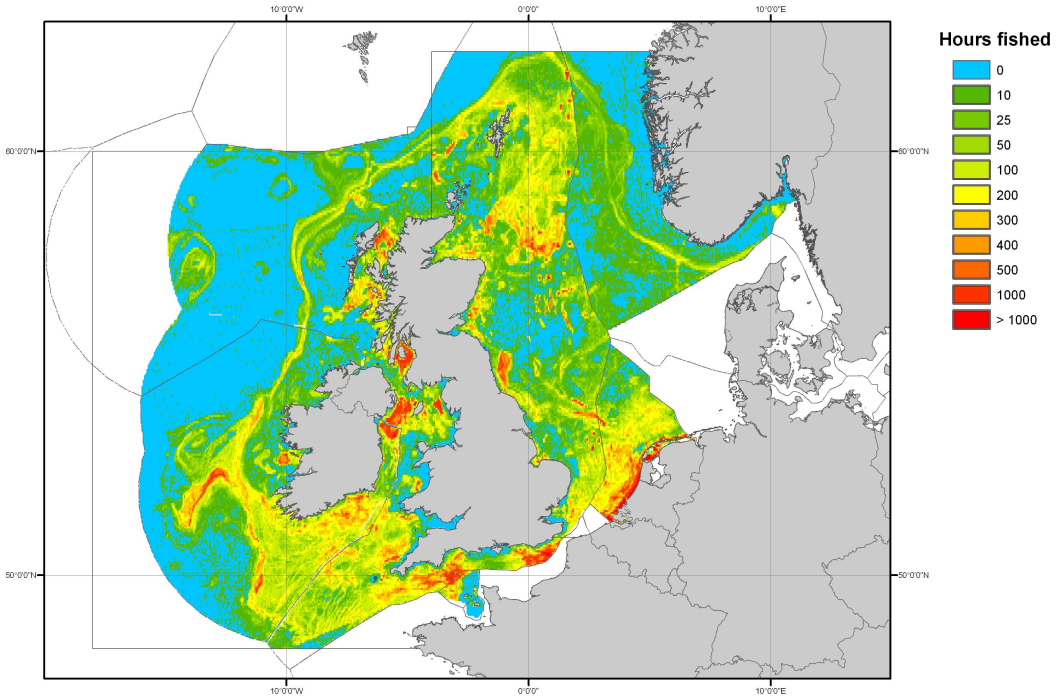

Figure 2.4.2 Distribution of fishing effort by mobile bottom gears for 2007 by 3'x3' cells based on VMS records from submitting nations. The VMS data were processed using the point estimation method described above.

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

		Depth					
		0 to 20m	20 to 50m	50 to 80m	80 to 130m	130 to 200m	>200m
Habitat	Gravel		0.9	17.8	1.2		100.0
	Mud	85.9	16.0	12.6	13.1	100.0	98.1
	Sand	93.0	77.8	44.4	59.5	57.1	53.5
	Mud and Sand				52.3	28.7	82.5
	Mud and Gravel						90.8
	Sand and Gravel	60.9	47.0	29.6	34.5	65.5	77.4
	Mud, Sand and Gravel	78.0	42.7	41.2	21.9	66.6	91.9
	Rock, Gravel and Sand	62.7	60.9	57.7	68.7	74.7	73.1

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

		Depth					
		0 to 20m	20 to 50m	50 to 80m	80 to 130m	130 to 200m	>200m
Habitat	Gravel		0.5	17.5	1.2		100.0
	Mud	59.9	16.2	14.4	10.5	98.7	97.7
	Sand	98.7	78.3	48.2	62.0	48.0	52.3
	Mud and Sand				54.2	26.0	83.5
	Mud and Gravel						93.1
	Sand and Gravel	58.7	47.0	31.9	38.6	63.8	78.7
	Mud, Sand and Gravel	81.1	43.7	36.7	26.7	64.3	98.1
	Rock, Gravel and Sand	63.0	59.7	55.6	69.2	71.4	64.2

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 affects 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 commercial fish and benthic invertebrate species need to be considered. Both of these components are covered by this indicator (although see section 2.2 for discussion of representativity). Similarly in the case of GES descriptor 6, benthic processes, only components that are part of 'sea-floor ecosystems' need to 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).

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

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 to 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 NWW RAC region two separate questions can be asked:

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

ii) Does fishing compromise GES in the NWW 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 3.2. 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).

Table 3.2 Assessment of the NWW RAC region with respect to impacts of fishing on Good Environmental Status as defined by the MSFD. An '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	?

GES 1: Biodiversity

As already noted, the interpretation of this indicator is difficult. As well as the issues already discussed, decisions must be made about which method to use to choose the list of species for inclusion in indicator assessment, whether to include surveys where such lists are very short, whether to include surveys with limited time series, whether GES should be achieved for both CSFa and CSFb, and whether GES is required for the majority or all of the surveys. For these reasons over-all GES could not be assessed for this descriptor in the NWW, however when the indicators and surveys are considered individually they do display mostly encouraging results.

GES 3: Commercial Species

Only 45% of assessed stocks fell within safe biological limits in the NWW region. Although only seven stocks qualified for inclusion in the indicator (representing less than 10% of landings) this percentage was relatively unchanged even if other wide ranging, pelagic stocks were included in the analyses (upping representation to 70-75%). Fishing compromises GES for this descriptor in the NWW.

GES 4: Food Webs

When the LFI was calculated excluding variable pelagic species (as described in Section 1.2.3.1) fishing in the NWW did not appear to impact GES for three out of five survey areas in the region. The question now becomes should GES be based on an average score when multiple surveys are involved or should GES be met for all surveys? Given that GES is not met for 40% of the surveys it is probably most appropriate to view the entire NWW region as not achieving GES for this descriptor. However explicit rules will need to be established to avoid this problem with the future use of this indicator.

GES 6: Benthic Processes

In the case of this descriptor 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 Western Waters 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 impact of fishing in the NWW RAC region could not be satisfactorily assessed for two of the four descriptors examined, and GES is not achieved for the other two descriptors (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 NWW RAC region.

References:

Beddington J.R. & May, R.M. 1977 Harvesting natural populations in a randomly fluctuating environment. *Science* **197**, 463-465.

Bianchi, G., Gislason, H., Graham, K., Hill, L., Jin, X., Koranteng, K., Manickchand-Heileman, S., Payá, I., Sainsbury, K., Sanchez, F. & Zwanenburg, K. 2000 Impact of fishing on size composition and diversity of demersal fish communities. *ICES Journal of Marine Science* **57**, 558-571.

Blanchard, J. L., Dulvy, N. K., Jennings, S., Ellis, J. R., Pinnegar, J. K., Tidd, A. & Kell, L. T. 2005 Do climate and fishing influence size-based indicators of Celtic Sea fish community structure? *ICES Journal of Marine Science* **62**, 405-411.

Bremner, J., Rogers, S. I. & Frid, C. L. J. 2006 Matching biological traits to environmental conditions in marine benthic ecosystems. *Journal of Marine Systems* **60** 302–316.

Brown, J. & Macfadyen, G. 2007 Ghost fishing in European waters: Impacts and management responses. *Marine Policy* **31**, 488-504.

Charlesworth, B. & Leon J.A. 1976 Relation of reproductive effort to age. *American Naturalist* **110,** 449-459

COM(2008) 187 The role of the CFP in implementing an ecosystem approach to marine management. Communication from the Commission to the Council and the European Parliament. [SEC(2008) 449].

Cury, P.M., Mullon, C., Garcia, S.M. & Shannon, L.J. 2005 Viability theory for an ecosystem approach to fisheries. *ICES Journal of Marine Science* **62**, 577-584.

Dulvy, N.K., Jennings, S., Rogers, S.I. and Maxwell, D.L. 2006 Threat and decline in fishes: an indicator of marine biodiversity. *Canadian Journal of Fisheries and Aquatic Sciences* **63** 1267-1275

Essington, T. E., Beaudreau, A. H. & Wiedenmann, J. 2006 Fishing through marine food webs. *Procedings of the National Academy of Sciences of the United States of America* **103**, 3171-3175.

Frid, C.L.J., Paramor, O.A.L., Brockington, S. & Bremner, J. 2008 Incorporating ecological functioning into the designation and management of marine protected areas. *Hydrobiologia* **606** 69–79

Fulton, E. A., Smith, A. D. M. & Punt, A. E. 2005 Which ecological indicators can robustly detect effects of fishing? *ICES Journal of Marine Science* **62**, 540-551.

Gall, G.A.E 1974 Influence of size of eggs and age of female on hatchability and growth in rainbow trout. *Calif Fish Game* **60**,26-35

Green, B.S, & David, W.S. 2008 Maternal Effects in Fish Populations. *Advances in Marine Biology* **54**, 1-105

Greenstreet, S. P. R. & Rogers, S. I. 2006 Indicators of the health of the North Sea fish community: identifying reference levels for an ecosystem approach to management. *ICES J. Mar. Sci.* **63**, 573-593.

ICES 2005. Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO), 12-19 April 2005, ICES Headquarters, Copenhagen. ACE:04. 146 pp.

ICES 2009 Report of the Working Group on the Ecosystem Effects of Fishing Activities (WGECO) ICES CM 2009/ACOM:20, Copenhagen, Denmark 190pp.

Jennings, S.J. 2005. Indicators to support an ecosystem approach to fisheries. *Fish and Fisheries*, **6**, 212-232.

Jennings, S.J. & Kaiser, M.J. 1998 The effects of fishing on marine ecosystems. Advances in Marine Biology **34**: 201-352

Jennings, S.J., Pinnegar, J. K., Polunin, N. V. C. & Boon, T. W. 2001 Weak cross-species relationships between body size and trophic level belie powerful size-based trophic structuring in fish communities. *Journal of Animal Ecology* **70**, 934-944.

Jennings, S. J., Greenstreet, S. P. R., Hill, L., Piet, G. J., Pinnegar, J. K. & Warr, K. J. 2002 Long-term trends in the trophic structure of the North Sea fish community: evidence from stable-isotope analysis, size-spectra and community metrics. *Marine Biology* **141**, 1085-1097.

Kell, L.T., & Fromentin J.M. 2007 Evaluation of the robustness of maximum sustainable yield based management strategies to variations in carrying capacity or migration pattern of Atlantic bluefin tuna (Thunnus thynnus). *Canadian Journal of Fisheries and Aquatic Sciences* **64**:837-847.

Kerr, S.R. & Dickie, L.M. 2001 *The biomass spectrum: a predator prey theory of aquatic production.* New York: Columbia University Press.

Koops, M.A., Hutchings, J.A., & McIntyre, T.M. 2004 Testing hypotheses about fecundity, body size and maternal condition in fishes. Fish and Fisheries **5**:120-130.

Larkin, P.A. 1977 Epitaph for Concept of Maximum Sustained Yield. *Transactions of the American Fisheries Society* **106**, 1-11.

Lee, J., South, A.B. & Jennings, S. (2010) Developing reliable, repeatable and accessible methods to provide high-resolution estimates of fishing effort distribution from Vessel Monitoring Systems (VMS) data. *ICES Journal of Marine Science 67: 1260–1271*

Longhurst, A. 2002 Murphy's law revisited: longevity as a factor in recruitment to fish populations. *Fisheries Research* **56**:125-131.

Mace, P.M. 2001 A new role for MSY in single-species and ecosystem approaches to fisheries stock assessment and management. *Fish and Fisheries* **2**, 2-23.

Marshall, C.T., Kjesbu, O.S., Yaragina, N.A., Solemdal, P. & Ulltang, O. 1998 Is spawner biomass a sensitive measure of the reproductive and recruitment potential of northeast Arctic cod. *Canadian Journal of Fisheries and Aquatic Science* **55**:1766-1783

Marteinsdottir, G. & Thorarinsson, K. 1998 Improving the stock-recruitment relationship in Icelandic cod (Gadus morhua) by including age diversity of spawners. *Canadian Journal of Fisheries and Aquatic Sciences* **55**,1372-1377

May, R. & McLean, A. 2007 Theoretical Ecology: principles and applications. Third Edition. OUP, Oxford. pp.272.

Naeem, S., Loreau, M. & Inchausti, P. 2004 Biodiversity and ecosystem functioning: the emergence of a synthetic ecological framework. In: M. Loreau, S. Naeem and P. Inchausti (Editors), Biodiversity and Ecosystem Functioning. Oxford University Press, Oxford, pp. 3-11.

Nikolskii, G.V. 1962 On some adaptations to the regulation of population density in fish species with different types of stock structure. . In: Holdgate EDLCaMW (ed) The Exploitation of Natural Animal Populations. Blackwell Oxford, p 265-282

Ostrovsky, I. 2005 Assessing mortality changes from size-frequency curves. *Journal of Fish Biology* **66,** 1624-1632.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. & Torres, F. (1998). Fishing down marine food webs. *Science* **279**, 860-863.

Piet, G.J. & Rice, J.C. 2004 Performance of precautionary reference points in providing management advice on North Sea fish stocks. *ICES Journal Of Marine Science* **61**, 1305-1312

Piet, G. J. & Jennings, S. 2005 Response of potential fish community indicators to fishing. *ICES Journal of Marine Science* **62**, 214-225.

Piet, G. J. & Quirijns, F. 2009 Spatial and temporal scale determine our perspective of the impact of fishing. *Canadian Journal of Fisheries and Aquatic Sciences* **66**: 829-835.

Pilling, G.M., Kell, L.T., Hutton, T., Bromley, P.J., Tidd, A.N. & Bolle, L.J. 2008 Can economic and biological management objectives be achieved by the use of MSY-based reference points? A North Sea plaice (Pleuronectes platessa) and sole (Solea solea) case study. *ICES Journal of Marine Science* **65,** 1069-1080

Roff, D.A. 1991 The evolution of life-history parameters in fishes, with particular reference to flatfishes. *Netherlands Journal of Sea Research* **27,** 197-207

Shiganova, T. A. & Bulgakova, Y. V. 2000 Effects of gelatinous plankton on Black Sea and Sea of Azov fish and their food resources. *Ices Journal of Marine Science*, **57,** 641-648.

Shin, Y.J. & Cury, P. 2004 Using an individual-based model of fish assemblages to study the response of size spectra to changes in fishing. *Canadian Journal of Fisheries and Aquatic Sciences* **61**, 414-431

Shin, Y.J., Rochet, M.J., Jennings, S., Field, J.G. & Gislason, H. 2005 Using size-based indicators to evaluate the ecosystem effects of fishing. *ICES Journal of Marine Science* **62,** 384-396

Sissenwine, M.P. 1978 Is MSY an adequate foundation for optimum yield? *Fisheries* **3,** 22-42

Trenkel, V. M. & Rochet, M. 2003 Performance of indicators derived from abundance estimates for detecting the impact of fishing on a fish community. *Canadian Journal of Fisheries and Aquatic Science* **60**, 67-85.

van Hal, R. & Piet, G. (Eds) 2009 Ecological, social and economic characteristics and status of the North Sea RAC region. Edited by van Hal & Piet, IMARES IJmuiden.

Van Franeker, J. A., Meijboom, A. & de Jong, M. L. 2004 Marine litter monitoring by Northern Fulmars in the Netherlands 1982-2003. Alterra-rapport 1093, pp. 48pp. Wageningen, Alterra.

Walters, C.J., Christensen, V., Martell, S.J. & Kitchell, J.F. 2005 Possible ecosystem impacts of applying MSY policies from single-species assessment. *ICES Journal of Marine Science* **62,** 558-568

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.

VMS data processing
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.