ICES WKIND REPORT 2013

ICES ADVISORY COMMITTEE

ICES CM 2013/ACOM:38

Report of the Workshop on DCF Indicators

21 – 25 October 2013

ICES Headquarters, Copenhagen, Denmark

ICES
International Council for the Exploration of the Sea
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Recommended format for purposes of citation:

ICES. 2013. Report of the Workshop on DCF Indicators, 21 - 25 October 2013, ICES Headquarters, Copenhagen, Denmark. ICES CM 2013/ACOM:38. 81 pp.

Contents

Executive Summary

The Workshop on update and calculation of the DCF indicators (WKIND), chaired by Leonie Dransfeld (Ireland) met in ICES HQ, Denmark 21–25 October 2013 to examine and report on the DCF indicators of fishing pressures/impacts, update their technical details and carry out the actual analysis for each indicator. The EU Data Collection Framework (EC 199/2008) supports the collection, management and analysis of data which underpins the scientific advice relating to the Common Fisheries Policy (CFP). In order to progress the implementation of the ecosystem-based approach to fisheries management, nine pressure and state indicators are included in the DCF, which aim to measure the performance of the CFP in relation to the objectives of 'minimising the impact of fishing activities on the marine ecosystem'.

The state indicators include three size based fish community indicators, namely the conservation status of fish, which monitors the change in biodiversity status of vulnerable fish species (**DCF1-CSF**); the proportion of large fish which reflects the size structure of the community **(DCF2-LFI**) and the mean maximum length, which reflects changes in life history composition **(DCF3-MML**). Analysis on the conservation status of fish revealed that the outcome of the indicator was highly sensitive to the decisions made by expert judgement. Issues were identified relating to reference periods in relation to exploitation history, tracking depleted species, masking signals of single species trends, and overall reproducibility. It was recommended that single species metric indicators based on life history characteristics should be developed as an alternative to the CSF. Using regional expertise, indicators **DCF-2 (LFI)** and **DCF-3 (MML)** were updated based on proposed protocols for the different ICES ecoregions Baltic Sea, Bay of Biscay, Celtic Sea (separated into west of Scotland and Celtic Sea proper), Iberia and North Sea using regional and inhouse data from DATRAS.WKIND also assessed the temporal correlation between the LFI and MML vs. fishing (based on relative fishing mortality) for the six ecoregions, to establish if significant pressure-state relationships could be demonstrated.

The fourth DCF state indicator **(DCF4-PMRN),** the "Size at maturation of exploited fish species" aims to measure the genetic or evolutionary effects of fishing on fish populations. The indicator and its data requirements were reviewed, existing studies summarised and the indicator was calculated for additional stocks using inhouse data from DATRAS. These included North Sea saithe, whiting and sprat as well as West of Scotland herring, haddock and whiting. Due to extensive data requirements and lack of suitable data in most ecoregions, it was concluded that the PMRNI is not suitable as a regional-wide DCF indicator to measure the genetic effects of fishing. The rate of evolutionary change estimated from PMRNI combined with information on the growth and mortality regime of the species, may have potential as an indicator of the evolutionary effects of fishing on selected species.

A set of three pressure indicators based on vessel monitoring data measure the spatial extent **(DCF-5)** and aggregation **(DCF-6)** of fishing and the area not impacted by mobile bottom gear **(DCF-7).** WGSFD, the working group on spatial fisheries data, reviewed and updated indicators 5 to 7. Due to limited data availability the update of the indicators was restricted to national data from the UK, Germany and Denmark. Spatial resolution of grid cells was increased to 0.05 degrees, new statistical procedures were applied to DCF6 and recommendations were made to express all three indicators as a proportion of sea floor area, preferably grouped into habitat types.

Pressure indicator **DCF-8** is the discarding rate of commercial species in relation to landings. Historically, evaluation of this indicator was hampered by a lack of data. Catch data split into discard and landings were provided to WKIND by STECF for the years 2003 to 2012. Data issues relating to ICES and STECF catch data were summarised and the indicator was updated using the STECF dataset. Analysis, based on the case study of bottom trawling in the Celtic Sea, indicated that adjustments to the protocol reduced variability and improved the signal, these include expressing discards as a proportion of catch rather than landings and not fixing time series to the mean of the first three years. Interpretation of the indicator needs to consider data quality issues especially in early years, the variability introduced by natural recruitment fluctuations and the forthcoming "obligation to land all catch", as agreed in the newly reformed CFP.

1 Introduction

1.1 Terms of Reference

The **Workshop on update and calculation of the DCF indicators** (WKIND), chaired by Leonie Dransfeld (Ireland) met in ICES HQ, Denmark 21–25 October 2013 to:

a) Based on the outcome of WGECO 2012 and the WKEID 2010 examine and report on the DCF indicators of fishing pressures/impacts and possible developments/ improvements in these

b) Update the indicators in terms of technical details of how to do it if required and then make the actual analysis/calculation thereby establishing timelines for each indicator.

The full Terms of Reference are presented in Annex 2.

1.2 Introduction to DCF indicators

The EU Data Collection Framework (DCF; Council Regulation (EC) No 199/2008 and EC Decision 2008/949/EC) is a legal framework and funding mechanism to support the collection, management and analysis of data which underpins the scientific advice relating to the Common Fisheries Policy (CFP). The DCF includes the support for the collection of biological and economic data relating to the fishing sector.

In order to progress the implementation of the ecosystem-based approach to fisheries management, the need was identified to include environmental indicators into the data collection (EC, 2006). These indicators should measure the performance of the CFP in relation to the objectives of 'minimising the impact of fishing activities on the marine ecosystem. A set of nine environmental indicators are included into the DCF, which comprise a combination of pressure and state indicators. These indicators are listed in Appendix 8 of the current DCF (2010/93EU), see table 1.1. Indicators were selected for which there was sufficient scientific justification and which can be quantified based on existing monitoring programmes. The state indicators should cover a broad range of ecosystem features and the pressure indicators should cover the most important aspects of how fishing impacts the ecosystem (EC, 2006).

The state indictors include three indicators to measure the effect of fishing on the wider fish community, including the change in biodiversity status of vulnerable fish species (DCF1-CSF), the size structure of the community (DCF2-LFI) and the life history composition (DCF3-MML). A fourth state indicator (DCF4-PMRN), the "Size at maturation of exploited fish species" aims to measure the genetic or evolutionary effects of fishing on fish populations. A set of pressure indicators (DCF5 to 7) based on vessel monitoring data is included to measure the spatial extent of fishing and DCF 8 "discarding rate of commercial species" aims to evaluate the proportion of discarding in relation to landings. DCF 9 "Fuel efficiency" is included to evaluate the contribution of the fishing sector (and different metiers within) to greenhouse gas emissions. The details on the rationale of the indicators, data requirements and calculations are published in SEC 2008.

Table 1.1) List of DCF environmental indicators to measure the effects of fisheries on the marine ecosystem (Appendix 8, 2010/93/EU)

DCF No	Indicator name Acronym*	Type	Indicator Definition
1	Conservation status of fish species **CSF**	State	Indicator of biodiversity to be used for synthesising, assessing and reporting trends in the biodiversity of vulnerable fish species
2	Proportion of large fish **LFI**	State	Indicator for the proportion of large fish by weight in the assemblage, reflecting the size structure and life history composition of the fish community
3	Mean maximum length of fishes **MML**	State	Indicator for the life history composition of the fish community
4	Size at maturation of exploited fish species **PMRN**	State	Indicator of the potential 'genetic effects' on a population
5	Distribution of fishing activities	Pressure	Indicator of the spatial extent of fishing activity, reported in conjunction with the indicator for 'Aggregation of fishing activity'
6	Aggregation of fishing activities	Pressure	Indicator of the extent to which fishing activity is aggregated, reported in conjunction with the indicator for 'Distribution of fishing activity'
7	Areas not impacted by mobile bottom gears	Pressure	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).
8	Discarding rates of commercially exploited species	Pressure	Indicator of the rate of discarding of commercially exploited species in relation to landings
9	Fuel efficiency of fish capture	Pressure	Indicator of the relationship between fuel consumption and the value of landed catch. It will provide information on trends in the fuel efficiency of different fisheries. This indicator was not reviewed in WKIND**.**

**(where applicable)*

1.3 WKIND approach to indicator review and update

The DCF indicators were divided into four categories based on data requirements and expertise:

- **Category 1** includes DCF indicators 1 to 3 which are fish community indicators based on IBTS data. Indicators were reviewed with particular focus on the outcome of ICES WGECO (2012) and STECF (2012). The outcomes of different methodological decisions were examined and recommendations made for calculations and protocol changes. Using regional expertise, indicators DCF 2 (LFI) and DCF 3 (MML) were updated based on proposed protocols for the different ICES ecoregions Baltic Sea, Bay of Biscay, Celtic Sea (separated into west of Scotland and Celtic Sea proper), Iberia and North Sea using regional and inhouse data from DATRAS. The outcome of the review and update of indicators 1 to 3 is summarised in report **sections 2 and 3**.
- **Category 2** comprises the indicator "Size at maturation of exploited fish species" which is based on the probability maturation reaction norm. The indicator was reviewed and the data needs documented. Existing studies were summarised and the indicator was calculated for additional stocks for which potentially sufficient data were available, using inhouse data from DATRAS. A synthesis on the utility and application of the indicator was based on this analysis. The outcome of the review and update of indicator 4 is summarised in **section 4.**
- **Category 3** includes the three spatial DCF indicators 5 to 7, which measure fishing distribution using VMS data. Within the ICES expert groups, WGSFD, the working group on spatial fisheries data, has developed the expertise to analyse fishing activity based on VMS data. As WGSFD met one month before WKIND 2013, it was agreed that WGSFD will carry out the review and update of indicators 5 to 7. Due to limited data availability the update of the indicators was restricted to national data from the UK, Germany and Denmark. The output was discussed in WKIND with the incoming chair of WGSFD and further recommendations were made based on these discussions. The review and update of indicator 5 to 7 is summarised in **section 5**. It includes an introduction to the indicators, the review and update of the indicators as a direct extract from the WGSFD2013 report and the recommendation from WKIND.
- **Category 4** is the rate of discarding. The data availability and quality of discard data was discussed at length. Using discard and landings data, provided by STECF, the indicator was reviewed and updated for each ecoregion and main fishing gear. The review and update process was demonstrated on one case study, bottom trawling in the Celtic Sea. The review, recommendations and issues are presented in **section 6.**

The main issues and recommendations for all eight indicators are summarised in section 7.

We thank the ICES Secretariat for their support in arranging and running this workshop and for their assistance with interrogating inhouse data bases and requesting discard data from the EC. We are grateful to the EC and member states for the provision of discard data. We also thank N. Graham (MI, Ireland), F. Velasco (IEO, Spain) and S. Shephard (QUB, UK) for their valuable contributions to this workshop.

2 DCF Indicator 1: Conservation status of fish species (CSF)

2.1 Background to indicator

The conservation status of fish indicator is an indicator of biodiversity to be used for synthesizing, assessing and reporting trends in the biodiversity of vulnerable fish species. It consist of two parts: 1) CSFa which responds to changes in the proportion of species being threatened also taking the severity of the threat to individual species into account according to an index based on the IUCN decline criteria, and 2) CSFb that tracks year-to-year relative changes in the overall abundance of the fish species defined as being vulnerable.

The indicator relies on the assumption that larger fish species are more vulnerable to fishing and use the maximum length of the fish species to select a suite of species for analyses. The indicator was originally developed for the North Sea (Dulvey *et al*. 2006), and has been most thoroughly tested in this ecoregion (LeQuesne *et al*. 2010; STECF 2012; ICES 2012).

Justification for indicator

Values of the CSFa indicator can be linked directly to the IUCN process for identifying critically endangered, endangered and vulnerable species. This makes the indicator consistent with other threat-based indicators used to report on the status of mammals, birds and amphibians and which are used to track progress in relation to biodiversity commitments. ICES assessed stocks that meet these simple but widely used threat criteria have been shown, without exception, to be exploited beyond safe biological limits (note that the decline associated with 'vulnerable' exceeds that which would be required to achieve MSY and that the declines associated with 'endangered' and 'critically endangered' would place stocks at risk of reduced reproductive capacity). It is also possible to set limit reference points and reference directions for this indicator. The proposed reference direction for indicator CSFa is a significant reduction in the rate of decline, which would be consistent with the WSSD target of achieving a significant reduction in the rate of biodiversity. An increase in the value of the indicator would show progress towards the CFP objective of ensuring that the impacts of fishing on marine ecosystem are sustainable (SEC 2008).

Values of the CSFb indicator track interannual changes in the catch rates of the larger, and therefore more vulnerable, species in a fish community. Reference directions can be set for this indicator (SEC 2008).

2.2 Data requirements

SEC 2008 gives the following requirements on data for calculating CSF: Species, length and abundance from fisheries-independent research survey(s) for relevant marine region. Accurate reporting of this indicator requires that all species that contribute to the indicator are consistently and reliably identified. Survey catches shall be fully sorted (not sub-sampled) to ensure that all individuals of every species that contributes to the indicator are recorded but sub-sampling is allowed in length measurements where duly justified.

WGECO points out that changes in the spatial coverage of surveys over time may in itself affect community indicators (ICES, 2012). A standard survey area therefore needs to be defined to ensure that the temporal signals investigated are not confounded by spatial heterogeneity in distribution patterns within the fish community.

As spatial heterogeneity in the underlying fish community can drive variations in the indicator, in surveys with randomly stratified sampling design, fishing stations should be selected that ensure suitable sampling of each strata and abundance data from the largest proportion of the marine region over the longest available time period (consistent through time). The area of each stratum must be estimated to compute stratified means in abundance data.

2.3 Review of CSF calculation protocol

This section recapitulates the critical parts of the protocol given for the Conservation Status of Fish species indicators CSFa and CSFb in SEC (2008). Where needed, the protocol is interpreted and clarified, including suggestions from WGECO (ICES 2012).

2.3.1 Creating a vulnerable species list

The criteria for creating a list of vulnerable species are made in a two-step process. The following criteria apply for excluding species:

1) They have morphology, behaviour or habitat preferences that are expected to lead to low and variable catchability in the survey gear (this does not exclude species that should, in theory, be effectively sampled by the gear but which have become so scarce that they are now caught infrequently- unless excluded under '2' below)

2) Mean annual catch rates of the species in the entire survey area over the entire survey period are less than 20 individuals (of any length)

3) They have an asymptotic total length (Linf) and/or maximum recorded total length of <40 cm

4) They cannot be identified reliably (although all practicable effort should be made to ensure species-level identification)

Criterion 1 requires good ecological knowledge of local fish fauna and catchability in the relevant survey. Fish species to be removed will be based on expert judgement. There is a risk that species, which have declined before the time series started are excluded as sporadic species in areas where there is little information on the fish fauna before the survey started.

The surveys, from which the time series are obtained, most commonly started before the legislation on DCF-indicators came into effect in 2008. It may therefore be challenging to verify both the accuracy of species identification and that rare species have been consistently sampled in older data.

After the initial exclusion of species the following process should be used to select species and size-classes when calculating the indicator:

5) Compile a list of species recorded in the history of the survey and their mean asymptotic total length (L_{inf}) and/or maximum recorded total length (if ≥ 40 cm). Asymptotic total length or maximum recorded total length are ideally determined from total length and age data collected on the same survey. A mean value for the survey period should be used when there are multiple estimates of L_{inf}, but the highest recorded value of maximum total length should be used.

6) Rank the species listed under '5' from high to low asymptotic total length (L_{inf} and/or maximum recorded total length (use maximum total length on-

ly in those cases when L_{inf} cannot be calculated from available size at age data)

7) Select the 20 largest species by total length (or all the species in the list if <20) from the rankings produced in '6'. Once this list has been defined it should be used for calculating indicator values in all subsequent years.

8) For each of the species identified in '7' calculate mean catch rates, standardised to account for any changes/ differences in tow duration (e.g. number per hour) for individuals of length ≥0.5 L_{inf} only.

Criterion 7 implies that the size threshold for inclusion (> 40 cm) should always be applied even if less than 20 species are retained in the vulnerable species list. We recommend that the size threshold should be adjusted on a regional basis so that 20 species are included.

Two indicators of the biodiversity of vulnerable fish species can be calculated from the resulting list containing 20 vulnerable species: (CSFa) an indicator of the biodiversity of vulnerable fish species that responds to changes in the proportion of contributing species that are threatened, and (CSFb) an indicator of the biodiversity of vulnerable fish species that tracks year-to-year changes in the abundance of contributing species. Both indicators assume that the survey catch rate provides an index of abundance. CSFa should be calculated and evaluated according to the following protocol:

9) For each species, catch rates in the first year of the survey are compared with catch rates 10 years later. To achieve this a linear model is fitted to the first x years of data, $t_1 - t_x$ and to each successive year, i.e. $t_1 - t_{x+1}$, $t_1 - t_{x+2}$,…, $t_1 - t_{maximum}$, where $t_{maximum}$ is the final year for which data are available. The percent change in catch rate of the species is then calculated from the initial (t_1) and final (t_x to $t_{maximum}$) catch rate as predicted from the least squares linear model fit. Species that meet any one of the decline criteria in any year of the time series are categorised as threatened; unless their numerical catch rate subsequently increases above a preset catch rate threshold. This should be taken as the mean catch rate over the first 3 years of the time series. The composite threat indicator is then calculated for each year as the average of the species threat scores (critically endangered if ≥ 90% decline- score =3, endangered if ≥70% decline- score=2, vulnerable if ≥50% decline- score=1) and allocated to the final year of the period over which the decline was measured. The indicator value is readily interpreted because the scores can vary from 0 to 3, such that a score of 0 is equivalent to no species meeting any of the threat criteria and a score of 3 is equivalent to each species being critically endangered.

10) The proposed reference direction for indicator (a) is a significant reduction in the rate of increase, consistent with the WSSD target of achieving a significant reduction in the rate of biodiversity loss (by 2010). A decrease in the value of the indicator would also show progress towards the CFP objective of ensuring that the impacts of fishing on marine ecosystem are sustainable. A limit reference point for this indicator would be 1 (when all species are listed as 'vulnerable' on average).

WGECO (2012) has interpreted this protocol and gives the following guidelines:

Using the list of species sensitive to fishing, the abundance index of individuals with lengths ≥L0.95/2 (as a proxy for size at maturity) are calculated for each species.

On a ten years gliding window, calculate a decline index: the slope of a linear model; if the species is not rebuilt since (≥average abundance first three years): score the decline index according to the IUCN A1 criterion as follows:

- • Min(decline) ≤90% 'critically endangered' CR 3
- • Min(decline) ≤70% 'endangered' EN 2
- • Min(decline) ≤50% 'vulnerable' VU 1
- • Otherwise 'least concern' LC 0

The indicator is the average decline score across sensitive species; it varies from 0 (no species threatened) to 3 (all species critically endangered).

Each step in the indicator protocol described in the EC decision (EC 2008) are given by the following equations:

1) $y_{i,l}(t)$ catch of the population i by size class l, $t=t_1\ldots t_f$
S total number of species

2) SV: N_{SV} sensitive populations = $\{L_{0.95,i}>40\text{ cm}\ \&\ L_{0.95,i}>L_{0.95,j}\ \forall j\in(S-SV)\}$;
N_{SV} = max(20, number of populations >40 cm)

3) $a_i(t)=\sum_{l>L_{0.95,i}/2} y_{i,l}(t)$

4) $t_k=t_1\ldots(t_f-10)$:

$$a_i(t)/a_i(t_k)=\beta_{1,k}t+\beta_{2,k},\quad t=t_k\ldots t_k+10$$

$\mathrm{Id}_i=\mathrm{score}(\min_k(\beta_k))$ (*Cf* tableau)

$R_i=\mathrm{I}\{\exists t>t_{kmin}+10\ \ a_i(t)>A_i\}$ avec

$$A_i=\sum_{t=1}^{3}a_i(t)/3 \quad \text{ou} \quad A_i=\sum_{j=1}^{5}\max(a_i(t))/5$$

5) $I=\sum_{i=1}^{N_{SV}}(1-R_i)Id_i \Big/ N_{SV}$

The next criterion refers to the calculation and evaluation of CSFb

Broken down into a workflow the calculation of CSFb entails:

11) Catch rates in a given year are expressed as a proportion of the mean catch rate in the first 3 years of any given survey (for which the mean catch rate is defined as 1). In any given year, the indicator is calculated as the geometric mean of relative adult numerical abundance. When calculating the geometric mean, proportions are log transformed as log(x + a), where x is the proportion and a is 0.5 times the minimum non-zero proportion in the time series.

The proposed reference direction for indicator (b) is a significant reduction in the rate of decline, which would be consistent with the WSSD target of achieving a significant reduction in the rate of biodiversity loss (by 2010). An increase in the value of the indicator would show progress towards the CFP objective of ensuring that the impacts of fishing on marine ecosystem are sustainable.

1. Calculation of annual abundance (standardized by haul duration or swept-area) for each of the vulnerable species;
2. Calculation of the average abundance during the first three years of the time series (“reference period”)
3. Compute the ratio between log-transformed annual species abundance and reference species abundance, log(x+a), where x is the relative abundance and a = 1/2 the minimum non-zero species abundance in the time-series;
4. The indicator is then calculated as the geometric mean of the proportions for the vulnerable species for each year.

2.3.2 Problems with calculation and interpretation of the indicator

Both WGECO (ICES 2012) and STECF (2012) report that there are problems in reproducing the indicator calculations. For example, the species list used by MEFEPO and WGECO to calculate the CSF indicators for the North Sea only have 9 species in common out of the 16 and 18 species selected respectively. The complex process of defining the species list for CSF contains several steps where alternative approaches and expert judgement will influence the final species list.

WKIND performed preliminary analyses of the CSF for a few ecoregions, but encountered similar problems with reproducing time series of the indicators as presented by WGECO. The preliminary analyses also revealed that the outcome of the indicator was highly sensitive to the decisions that had to be made by expert judgement, otherwise strictly following protocol. It was therefore decided not to present the results for the CSF indicator in this report and instead list the critical issues associated with this indicator:

Defining the species list of vulnerable species

For surveys that do not stretch back in time to cover the pre-exploitation period, there is a risk that already depleted species are excluded from this indicator although they are the very ones that the indicator aims to track. Thus when going through the steps of eliminating species with < 20 individuals (criterion 2), species known to have been depleted by fisheries before the time series started should be retained in the vulnerable species list.

Using L_{inf} or L_{max}

The use of L_{inf} or L_{max} may affect which fish species is included in the list of vulnerable species, especially where L_{max} is supressed by high fishing mortality. L_{inf} and L_{max} may differ among ecoregions and even surveys. It is therefore advised in SEC (2008) that that L_{inf} data from the survey in question is used where there is information on size and age of the fish and that L_{max} from the survey is used otherwise. Our recommendation is to use $L_{0.95}$ from the survey data to reduce the risk of having erroneous length measurements (outliers) influencing the selection process, and given that data is lacking to calculate L_{inf} for all species.

Indicator can mask strong signals of single species abundance

The CSFa indicator has the advantage of translating the status of vulnerable fish species into a single metric with direct reference to the IUCN protocol for identifying critically endangered, endangered and threatened species. There is, however, a risk that individual species may decline or disappear from the dataset without being picked up by the indicator, since the indicator is based on the average decline score across sensitive species. Variability caused by natural fluctuations in the remaining species could mask the signal from single declining species.

History of exploitation and definition of reference period

For several of the ecoregions, survey time series are short in relation to the exploitation history of the fish assemblage. The first three years of the time series, may well reflect a time after peak exploitation where the abundance of vulnerable species are very low. Under such conditions, even a small positive change will result in indicator (CSFb) values larger than 1 suggesting recovery. From conservation perspective the species may, however, still be considered as critically endangered. The same reasoning holds true for the CSFa indicator. There is a risk that already depleted species are excluded from the indicator calculation although they are the very ones that the indicator aims to track. Furthermore, SEC (2008) suggests that a limit reference point for the CSFa indicator would be 1 (when all species are listed as 'vulnerable' on average). Under conditions where the survey starts during a period with a heavily exploited fish community, adopting 1 as a reference point could produce indicator values that suggest recovery beyond the reference limit, but where the individual species are still endangered. Even when its known that surveys are too short to cover the pre-exploitation period, these properties of the indicators will make them harder to communicate to managers and policymakers.

Indicator resolution in relation to policy needs

The CSF indicators give composite measures of the impact of fisheries on vulnerable fish species in terms of trends in catches. Changes in the indicator values will many times be caused by changes in the abundance and status of threatened species and commercial species. It is therefore likely that users would also request species by species information on catch rates to identify the species responsible for reported trends in either of the CSF indicators.

2.4 Recommendations

The problems of reproducing the indicator calculations even with a detailed protocol together suggest that less complicated indicators should be developed. As an alternative to the present CSF indicators, single species metric indicators could be developed. Approaches to select species vulnerable to fishing based on life history traits have been developed (see below). Even though this approach will result in a larger number of indicators the evaluation of the status of vulnerable species will be more transparent. The approach of retaining information on single species will also make it possible to look at groups of species which may have different management options such as protected species or commercial species. Furthermore, the most sensitive species can be included even if present day densities are very low.

Looking at single species will also make it possible to relate changes in abundance to changes in catches (commercial species) and bycatch to inform management on the best ways to reduce the effect of fishing on the biodiversity of vulnerable fish species.

To support the recommendation on the need to consider the conservation status of endangered species at the species level, alternative methods to identify especially vulnerable species to fishing could be based on Le Quesne *et al.*, 2012:

(i) Identify the species and their maximum body sizes (L_{max}) as large-bodied species are especially vulnerable to fishing in mixed fisheries.

(ii) Develop an age-structured population model based on life-history invariants to establish conservation reference points and thus the sensitivity of the selected species to the realized fishing mortality.

(iii)The comparison of the conservation- and yield-based fishery reference points is used to identify especially vulnerable species. The assessment of sensitivity to fishing mortality does not provide a complete assessment of vulnerability, but it does highlight species of conservation concern.

Greenstreet *et al*., 2012 proposes to identify vulnerable species based on life-history traits. In general, "slowest-type" species with large-body, slow growing, late age, large size at first maturity and low fecundity were considered the most sensitive and species with the "fastest-type" traits were deemed the most resilient.

For sensitive species, a suite of species-level metrics explicitly directed to fish communities and based on the indicator classes proposed for Descriptor 1 "Biological diversity is maintained" in the Marine Strategy Framework Directive (EC, 2010) can be computed (e.g. biomass, proportion of biomass larger than length-at-first–maturity). Trend-based targets can be set for the species-level metrics using an alternative non-parametric approach. The entire duration of each species-specific time-series metric can be treated as the "reference period". The last year in the time-series can then be considered the "current assessment year". A target position relative to the "reference period" can be set for the "current assessment year". Greenstreet *et al*., 2012 proposes that the "current assessment year" value should be in the upper 25 percentile of all values in the full time-series "reference period". The indicator is then the number (or proportion) of sensitive species "population abundance" meeting their specified upper-percentile range.

A method is also proposed for setting an indicator-level target, knowing the number of sensitive species analysed and the probability of any individual species-specific metric achieving its trend-based target, observing if such an indicator value represents a statistically significant (e.g. less than 5% chance) departure from the binomial distribution, leads to the conclusion that the target had been met.

3 DCF Indicators 2 & 3 – The Large Fish Indicator & the Mean Maximum length of Fishes

3.1 Introduction

The DCF-indicator suite includes two indicators (DCF-indicators 2&3) which aim to assess the size structure of fish communities (EU-COM, 2008). Indicators based on size information of fish are commonly referred to as size-based indicators (SBI) (Shin *et al*., 2005) and can be based on information on single species or fish communities.

One of the best known community SBI is the Large Fish Indicator (LFI) for the North Sea. It has been developed as an univariate indicator of the effects of fishing on fish community "state". The North Sea LFI describes the proportion (by weight) of the demersal fish community that is larger than a specified length threshold. The LFI has been adopted as a general "fish community" EcoQO for OSPAR regions and as a "foodweb indicator" in the EU Marine Strategy Framework Directive (MSFD) (EU-COM 2010) and has been adjusted to the Celtic Sea (Shephard *et al*., 2011). For other marine ecoregions, the adaptation of the LFI concept is still pending, as the technical protocol for calculating the LFI requires several prerequisites (Fung *et al*., 2012; Greenstreet *et al*., 2011).

The mean maximum length of fishes (MML) is an indicator of the life history composition of the fish community. Contrary to the LFI, the MML is sought to identify fisheries induced changes in the species composition instead of changes in the actual size composition (ICES, 2012). The MML therefore is based on a life-history trait rather than on actual size distribution and strictly speaking may not be considered as SBI. However, previous studies indicate some redundancy between the LFI and MML (Greenstreet *et al*., 2012a) and hence the MML is referred to as SBI hereafter.

The pressure-state relationship (PSR) between community SBI and fishing has been confirmed for the North Sea and Celtic Sea LFI, even with long temporal lags of several years. For the MML and the LFI of other regions, a significant PSR has not yet been demonstrated. As a first approach therefore WKIND calculated time series of averaged community fishing pressure according to Greenstreet *et al*. (2011) to assess the temporal correlation between the LFI and MML vs. fishing. The following sections provide guidelines and considerations on how to calculate the community SBI and the results for six marine ecoregions.

3.2 Procedures to calculate size-based (SBI) community indicators (LFI, MML)

1) Prepare survey data database:

   a) Check for spatial coverage i.e. if all rectangles/subareas/strata have been sampled representatively over time. Examples are provided by ICES (2012) and Greenstreet *et al*. (2012c). For the North Sea and Western Scottish Waters all rectangles which were sampled at least in 50% of all survey years were included. For surveys in Celtic Sea, Bay of Biscay and the Baltic Sea the distribution of sampling stations is not based on ICES rectangles but on depth strata. Therefore no data from the EVHOE and the BITS surveys were excluded.

b) Select for appropriate gear according to the survey protocol. In the North Sea the standard gear is the "Grande Overture Vertical" (GOV) (ICES, 2010).

c) Check naming of species (be aware of synonyms) (Daan 2001).

d) Estimate weight per length class using length-weight regression ($W=aL^b$). Weight-length regression parameters (a,b) may be derived from surveys or literature. Careful checking of length code types is strongly recommended.

2) Define species list for LFI & MML:

a) Define a list of species that should be included into the calculation of the SBI and create a subset of the survey data including these species. For the North Sea only demersal species are included into the LFI, but for other marine regions pelagic species may need to be included. Generally, only species that are caught representatively by the survey gear should be included.

3) Define length threshold for the LFI:

e) For some marine regions LFI thresholds have been specified (Greenstreet *et al*., 2011; Shephard *et al*., 2011) or are under discussion (Oesterwind *et al*., 2013), whereas for other regions an appropriate threshold for the weight proportion of large fish has yet to be defined. For regions without any known definition of a LFI-threshold WKIND used the 90%-percentile of the weight-at-length distribution as a first approach. Other approaches have been proposed by Shephard *et al*. (2011). This 90%-percentile corresponded well to predefined LFI-thresholds in the North Sea and Celtic Sea.

4) Calculate the annual LFI:

$$LFI_y = \frac{W_{>thr,y}}{W_{Total,y}}$$

thr: size-threshold for large fish
$W_{>thr,y}$: the weight fraction of the total annual catch which is larger than *thr*
$W_{Total,y}$: the total catch weight in year *y*

5) Calculate MML as weighted mean of species' L_{max} (by number or weight) (ICES, 2012):

$$MML_N = \frac{\sum_{j=1}^{S} L_{max,j} N_{j,y}}{N_y}$$

$$MML_W = \frac{\sum_{j=1}^{S} L_{max,j} W_{j,y}}{W_y}$$

$L_{max,j}$: Maximum observed size in the survey data (as proxy for L_∞)
$N_{j,y}$: The number of caught individuals of species j in year y

$W_{j,y}$: The weight of species j caught in year y
N_y: the total number of individuals caught in year y
W_y: The total weight caught in year y

The MML can be calculated either by caught weight or number. When calculating the MML by numbers more emphasis is given to the L_{max} of small species. Therefore MML_N is generally smaller than MML_W.

6) Test SBI against pressure indicators e.g. community fishing pressure (F_{com}):

a) Calculate F_{com} according to Greenstreet *et al*. (2011):

$$F_{com,y} = \frac{\sum_{i=1}^{S} F_{i,y}/F_{i,RF}}{S}$$

S: The number of assessed stocks,
$F_{i,y}$: the fishing mortality for stock S in year y
$F_{i,RF}$: F-reference value for stock S (either F_{pa} or F_{MSY} depending on data availability of reference points)

b) Cross-correlate time series of LFI and MML against Fcom. Cross-correlations can be performed on the original or the prewhitened time series. The latter removes temporal trends of the input or pressure time series (Fcom) which may not be related to the output or state time series (LFI, MML) (Probst *et al*., 2012).

Table 3.1: Meta-information on data to calculate pressure (Fcom) and state indicators (LFI, MML) of fish communities.

Region	Data source	LFI/MML species	LFI threshold	F_{com} stocks	F_{com} period	F_{ref}
Baltic Sea	Datras BITS	*Gadus morhua* *Platichthys flesus* *Pleuronecte platessa* *Scophthalmus rhombus* *Scophthalmus maximus* *Limanda limanda* *Solea solea* *Merlangius merlangus*	30 cm	cod-2224 cod-2532	1970-2011	F_{MSY}
Bay of Biscay	Datras EVHOE (ICES Div. VIII)	According to Greenstreet *et al.* (2011)	49 cm	sol-bisc	1984-2011	F_{MSY}
Celtic Sea	Datras EVHOE (ICES Div. VII)	According to Shephard *et al.* (2011)	50 cm	cod-7e-k had-7b-k ple-celt ple-echw sol-iris sol-celt sol-echw whg-7e-k	1993-2011	F_{MSY}
North Sea	Datras IBTS-NS	According to Greenstreet *et al.* (2011)	40 cm	cod-347d had-34 nop-34 ple-nsea sai-3a46 sol-nsea whg-47d	1967-2011	F_{pa}
Portuguese waters	IPMA (PT-IBTS) (ICES Div. IX a&b2)	According to Portuguese MSFD Initial Assessment Report (2012)	30 cm	anp-8c9a whb-comb mac-nea hom-soth mgw8c9a mgb-8c9a hke-soth	1989-2012	F_{MSY}
Western Scottish Waters	Datras SWC	According to Shephard *et al.* (2011)	45 cm	cod-scow had-scow had-rock sai-3a46 whg-scow	1981-2011	F_{pa}

3.3 The Baltic Sea

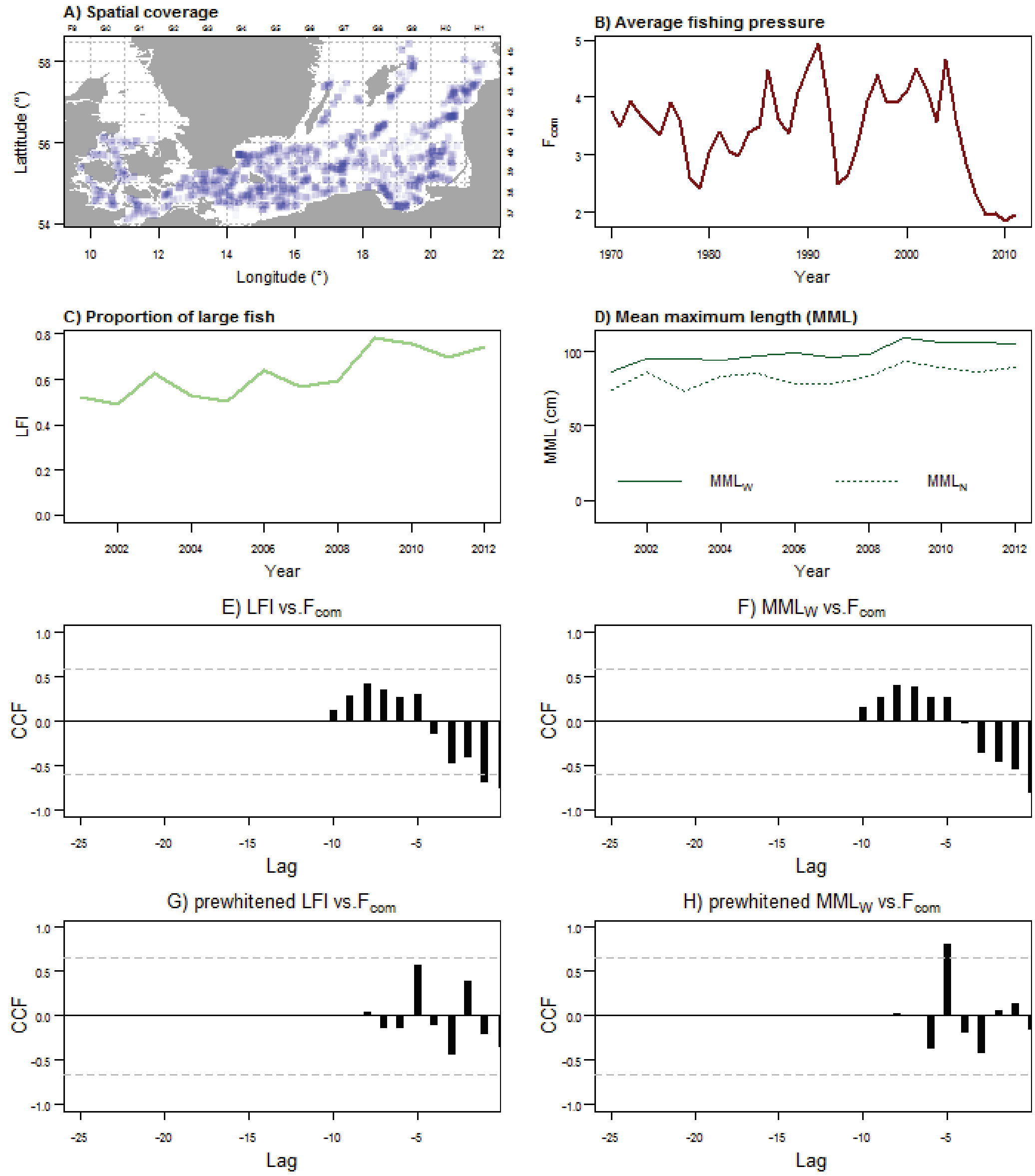
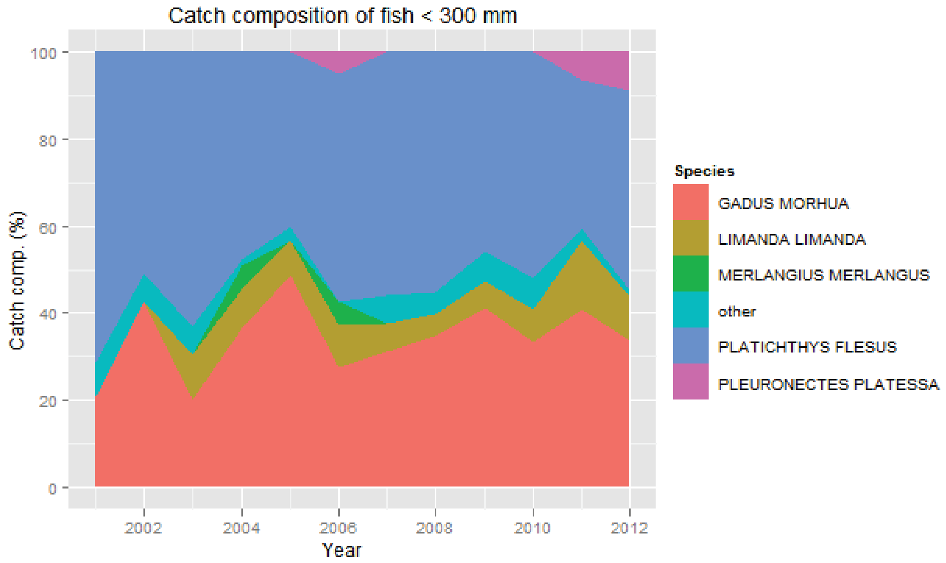


Figure 3.1. Community SBI of the Baltic Sea. A) Overlaid haul stations in the survey area. B) Time series of community fishing pressure (F_{com}) averaged across the relevant commercial stocks. C) Time series of the large fish indicator (LFI). D) Time series of mean maximum length by weight (MML_W) and numbers (MML_N). E) Cross-correlation function (CCF) of F_{com} vs. LFI. F) CCF of F_{com} vs. MML_W. G) Prewhitened CCF of F_{com} vs. LFI. H) Prewhitened CCF F_{com} vs. MML_W.



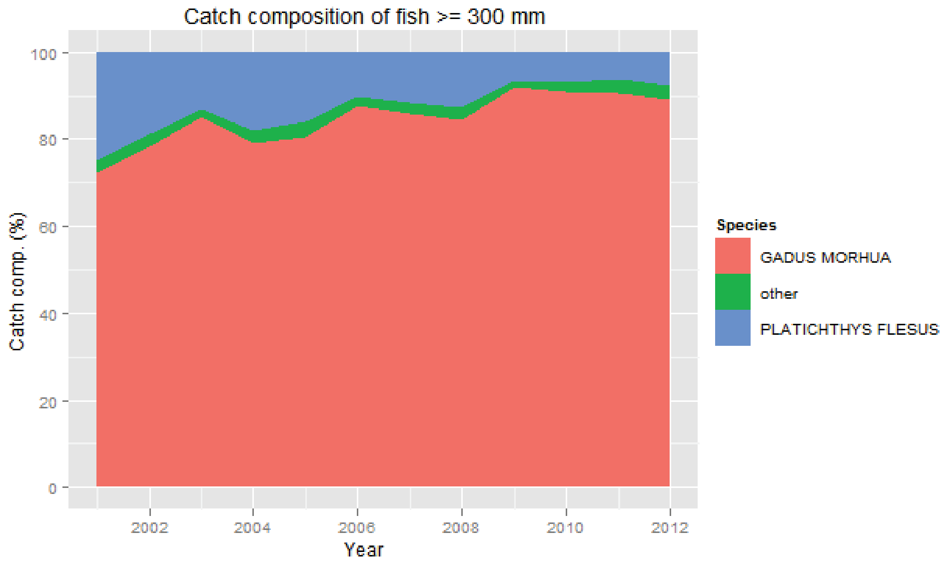


Figure 3.2. Relative species composition by biomass for the small and large proportion of the BITS survey catch.

Spatial coverage

The BITS-survey covers the Baltic Sea including SD22 to SD29 (Figure 3.1A).

Trends in F_{com}

F_{com} showed high fluctuations before 2005, since then it has been declining (Figure 3.1B).

Trends in community SBI

The LFI and MML are constantly increasing since 2001 (Figure X.1C&D), mostly driven by the recovery of the Eastern Baltic cod stock (cod-2532) (Oesterwind *et al*., 2013). Compared to the North Sea LFI, the Baltic Sea LFI is very high (around 0.8) emphasizing the overall importance of the Baltic cod stocks for these indicators.

Pressure-state relationships

There is a short lagged cross-correlation between F_{com} and the community SBI (Figures 3.1E&F), however, the lag at 0 is dubious as the impact of F_{com} on the size structure of a fish community should be lagged by at least one year (Greenstreet *et al*., 2011). The prewhitened time series did not indicate any significant correlations (Figure 3.1G&H).

Species composition

The large proportion of the Baltic Sea fish community is dominated by cod (Figure 3.2). The small proportion of the community is dominated by cod and flounder, plaice and dab provide a smaller proportion.

Methodological considerations

Due to the late standardisation of the sampling gear since 2001 (ICES, 2011) the time series covers 11 years. With such a short time series it is very difficult to identify significances in PSR. Longer time series may be needed to improve the cross-correlation between F_{com} and SBI.

The demersal fish species community in the Baltic Sea is less diverse than in the North Sea. The only species frequently attaining sizes above 40 cm is Baltic cod. Therefore it has been suggested to lower the LFI threshold for the Baltic Sea to 30 cm (Oesterwind *et al*., 2013). It has also has been tested to exclude Baltic cod from the LFI suite of species (Oesterwind *et al*., 2013). However, WKIND felt that cod is a very important part of the demersal fish community in the Baltic Sea and therefore should be included.

3.4 The Bay of Biscay

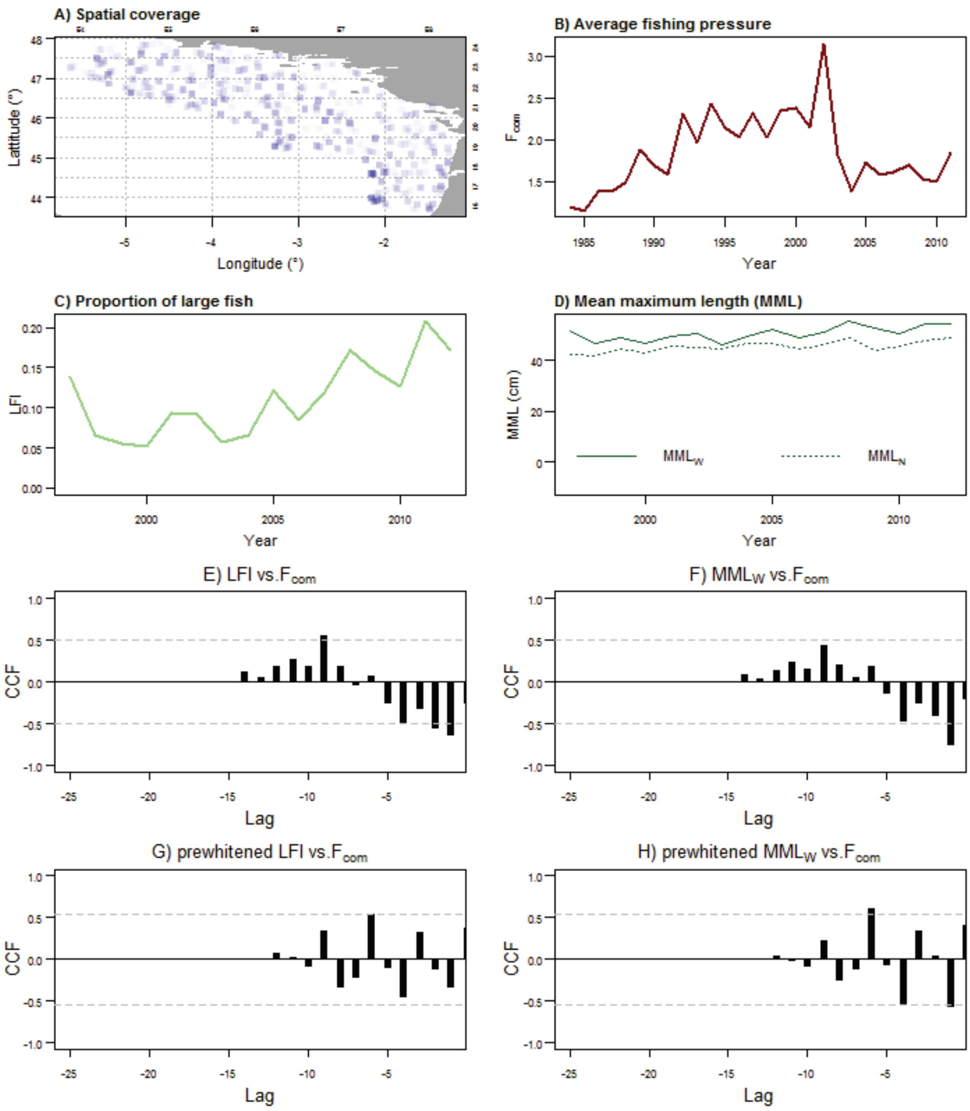


Figure 3.3. Community SBI of the Bay of Biscay. A) Overlaid haul stations in the survey area. B) Time series of community fishing pressure (F_{com}) averaged across the relevant commercial stocks. C) Time series of the large fish indicator (LFI). D) Time series of mean maximum length by weight (MML_W) and numbers (MML_N). E) Cross-correlation function (CCF) of F_{com} vs. LFI. F) CCF of F_{com} vs. MML_W. G) Prewhitened CCF of F_{com} vs. LFI. H) Prewhitened CCF F_{com} vs. MML_W.

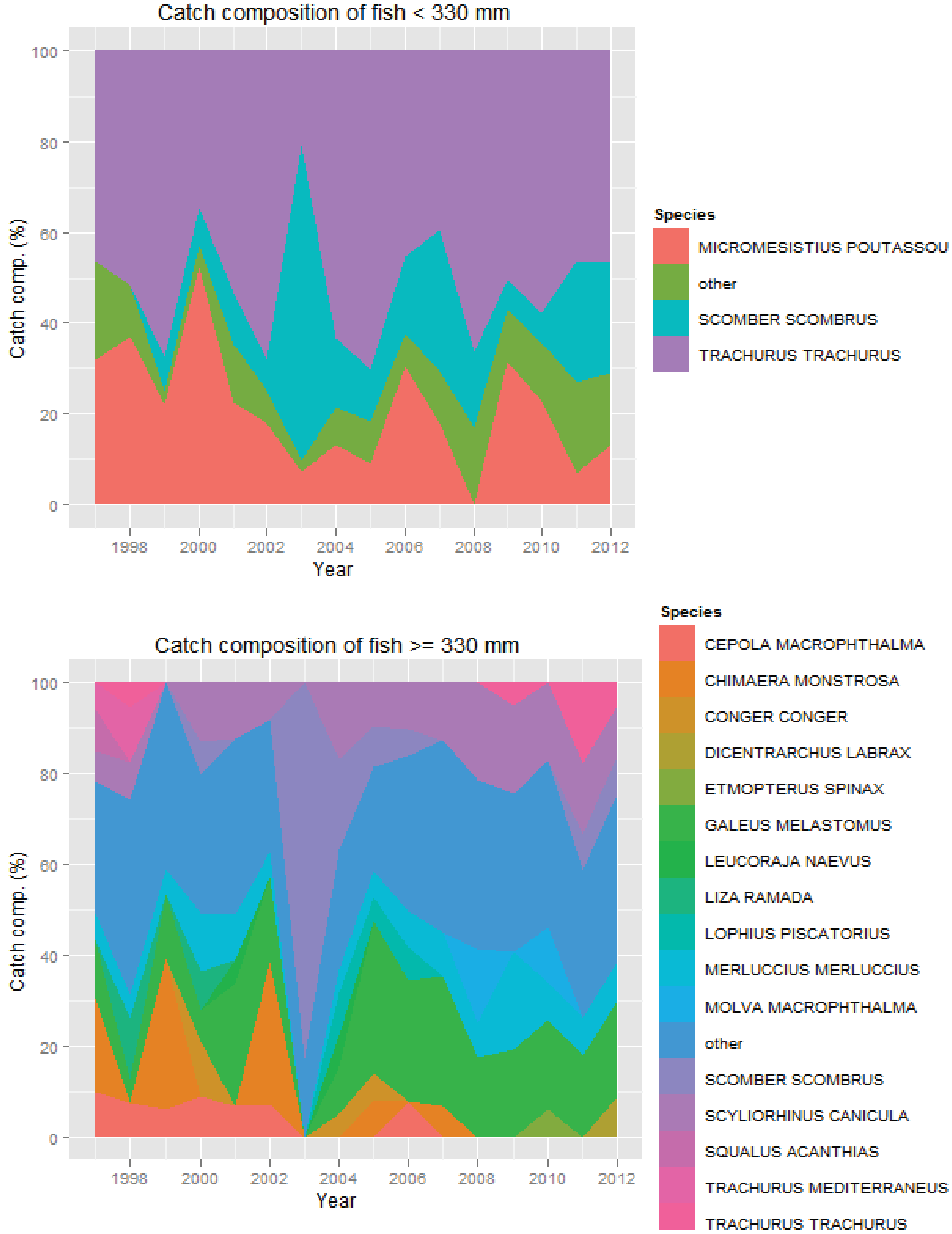


Figure 3.4. Relative species composition by biomass for the small and large proportion of the EVHOE-Bay of Biscay survey catch.

Spatial coverage

The EVHOE in the Bay of Biscay covers ICES subdivisions VIIIa and VIIIb (Figure 3.3A).

Trends in F_{com}

After 2003 F_{com} dropped sharply and remained relatively low since then (Figure 3.3B). However, it has to be noted that the F_{com}-time series includes only data from the sole assessments and therefore may not be representative of fishing pressure in this region. More F-data on other stocks or alternative pressure indicators may be needed to better represent the impacts of fishing on the size-structure and species composition.

Trends in community SBI

The LFI and MML both showed a positive temporal trend (Figure 3.3C&D).

Pressure-state relationships

There were significant PSR-relationships for both the LFI and the MML (Figure 3.3E-H).

Species composition

The small fish community of the Bay of Biscay was dominated by pelagic species, namely mackerel, horse mackerel and blue whiting (Figure 3.4). Contrary, the large fish community was highly diverse.

Methodological considerations

As mentioned before, the LFI indicator is dependent of the catchability of the gear. On this basis, chub mackerel (*Scomber colias*), boarfish (*Capros aper*), snipefish (*Macroramphosus scolopax*), sardine (*sardina pilchardus*), anchovy (*Engraulis encrasicholus*), herring (*Clupea harengus*) and sprat (Sprattus sprattus) were excluded as being intermittent invaders of little sustained importance to the demersal community, and having a predominately pelagic and/or shoaling life style leading to non-representative sampling in the demersal trawls.

The only commercial stock to be included into the F_{com} was "sol-bisc", data from other stock assessments should be made available in the ICES stock summary database. The data available for calculating the time series for community SBI were shorter than 20 years. Therefore the observed PSR may be not representative for the true impact of fishing on the fish community of the Bay of Biscay.

3.5 The Celtic Sea

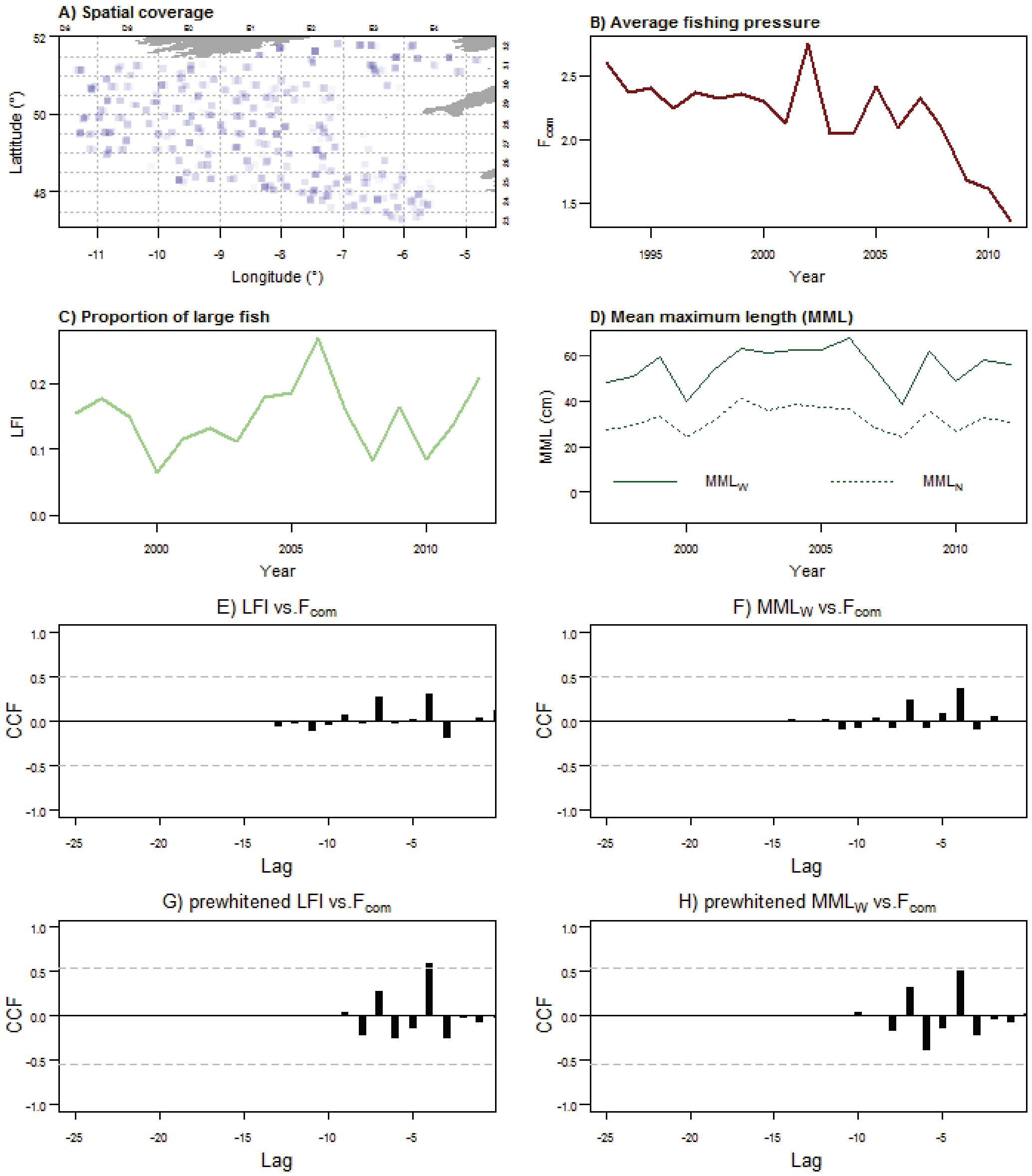


Figure 3.5. Community SBI of the Celtic Sea. A) Overlaid haul stations in the survey area. B) Time series of community fishing pressure (F_{com}) averaged across the relevant commercial stocks. C) Time series of the large fish indicator (LFI). D) Time series of mean maximum length by weight (MML_W) and numbers (MML_N). E) Cross-correlation function (CCF) of F_{com} vs. LFI. F) CCF of F_{com} vs. MML_W. G) Prewhitened CCF of F_{com} vs. LFI. H) Prewhitened CCF F_{com} vs. MML_W.

Figure 3.6. Relative species composition by biomass for the small and large proportion of the EVHOE-Celtic Sea survey catch.

Spatial coverage

The EVHOE in the Celtic Sea covers several subdivisions of ICES divisions VII, but not the Irish Sea (Figure 3.5A).

Trends in F_{com}

F_{com} has declined from 1993 until 1995, stayed stable until 2004 and has declined further since 2005 (Figure 3.5B).

Trends in community SBI

The LFI and MML showed strong interannual fluctuations but no temporal trend (Figure X.5C&D).

Pressure-state relationships

There is no indication for a significant PSR (Figure 3.5E-H).

Species composition

The small fish community of the Celtic Sea was dominated by boarfish (Figure 3.6). The large fish community contained gadoids, monkfish, elasmobranchs and conger.

Methodological considerations

The available time series for F_{com} and the community SBI covers 18 and 16 years, respectively. The length of these time series is most likely too short to detect any statistical significant PSR.

3.6 North Sea

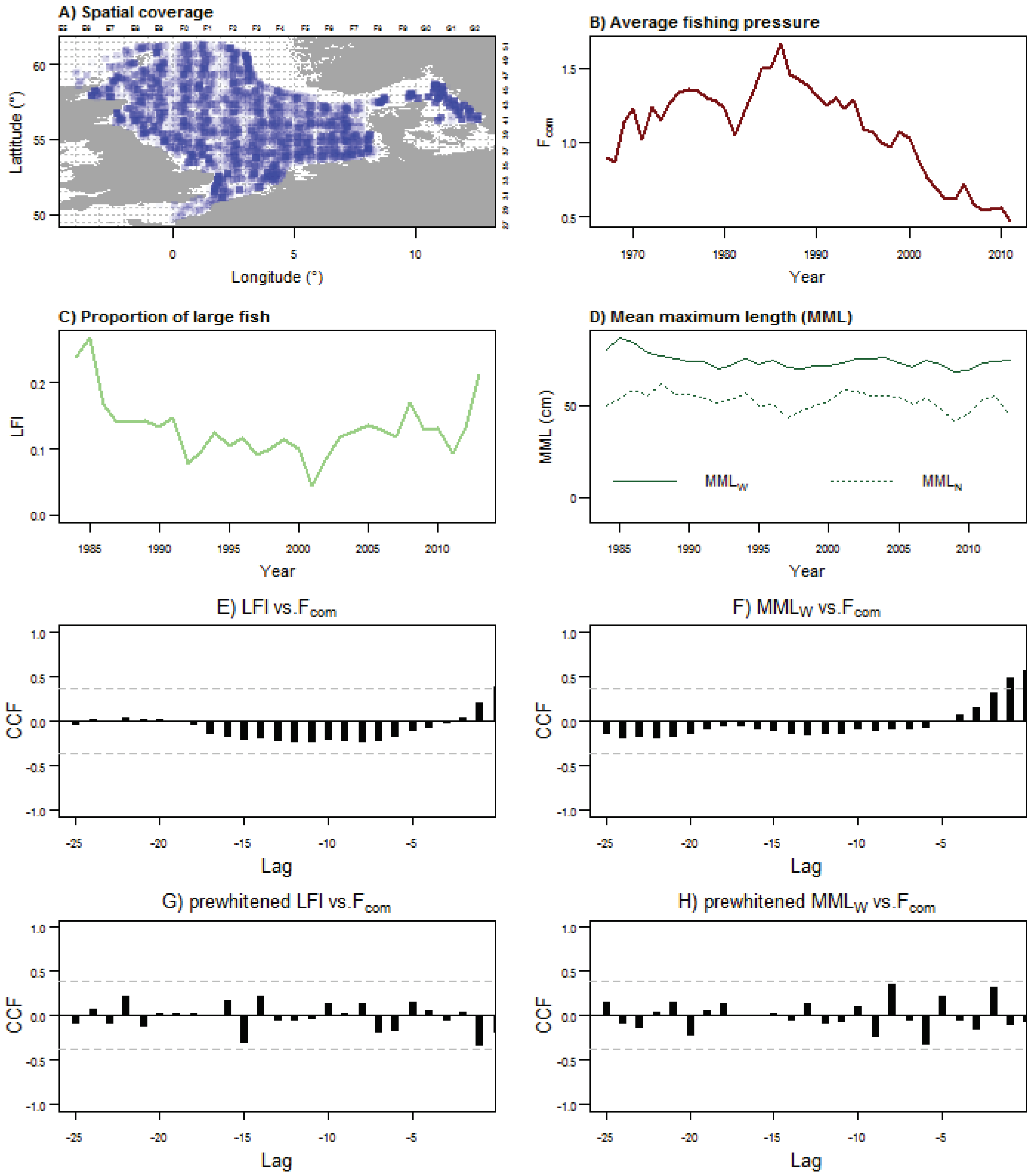


Figure 3.7. Community SBI of the North Sea. A) Overlaid haul stations in the survey area. B) Time series of community fishing pressure (F_{com}) averaged across the relevant commercial stocks. C) Time series of the large fish indicator (LFI). D) Time series of mean maximum length by weight (MML_W) and numbers (MML_N). E) Cross-correlation function (CCF) of F_{com} vs. LFI. F) CCF of F_{com} vs. MML_W. G) Prewhitened CCF of F_{com} vs. LFI. H) Prewhitened CCF F_{com} vs. MML_W.

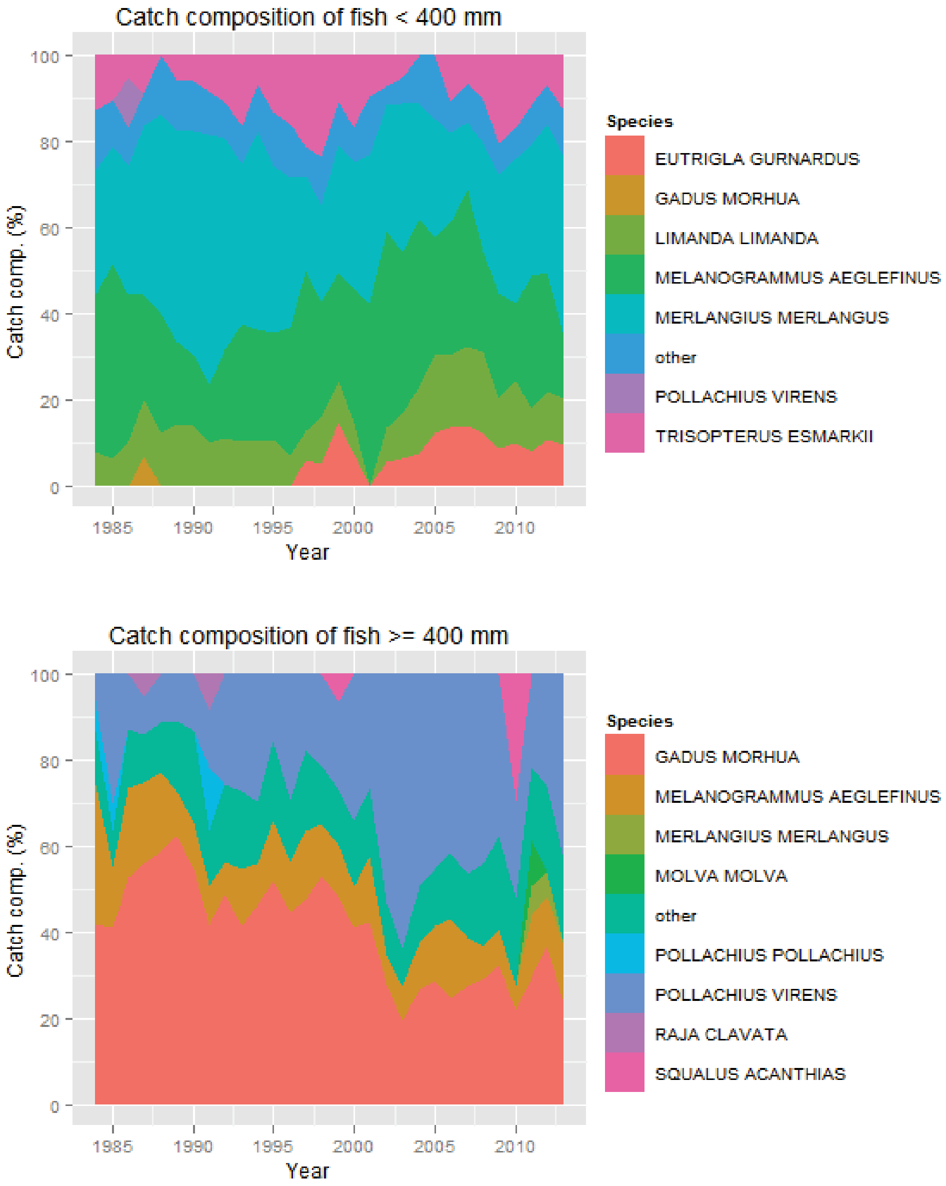


Figure 3.8. Relative species composition by biomass for the small and large proportion of the IBTS-NS survey catch. Species contributing less than 5% to the total catch biomass are grouped as 'others'.

Spatial coverage

The IBTS-survey covers the entire North Sea including the Kattegat and Skagerrak (Figure 3.7A). However, the Norwegian Trench and the Eastern English Channel are not covered by the IBTS time-series considered for the SBI calculations.

Trends in F_{com}

F_{com} has been steadily declining in the North Sea since the 1990s (Figure 3.7B).

Trends in community SBI

The LFI showed a slight trend for recovery in 2012 but was still below its GES target of 0.3 (Figure 3.7 C). The MML_W showed a decline after 1985 but has remained stable since then (Figure 3.7D).

Pressure-state relationships

Contrary to Greenstreet *et al*. (2012a), the cross-correlation between F_{com} and LFI was not significant (Figure 3.7E&G). A significance was also lacking for the cross correlation of F_{com} vs. MML (Figure 3.7F&H). Hence the previously observed pressure-state relationship between the community SBI and fishing pressure could not be confirmed.

Species composition

The small fish community of the North Sea included dab, gadoids and grey gurnard (Figure 3.8). Grey gurnard has not been present with more than 5% of the total catch weight in the small demersal fish before 1996. The large fish community was dominated by gadoids and elasmobranchs.

Methodological considerations

The protocol for the LFI in the North Sea is well established and WKIND was able to reproduce the time series according to previous studies (Greenstreet *et al*., 2011; Fung *et al*., 2012; Greenstreet *et al*., 2012a). Accordingly, the MML_W of WKIND was similar to the time series calculated by WGECO in 2012 (ICES, 2012). Minor differences between MMLW by WGECO and WKIND may be explained by the different L_{max}-values and species list used (which was not specified by WGECO).

F_{com} was similar to the time series by Greenstreet *et al*. (2011), for which, however, data on stock specific F were modelled by MSVPA in cases of missing data. WKIND did not have access to neither data nor the MSVPA model and hence the time-series of F_{com} was only calculated until 1967, including at least data of five out of seven relevant stocks (Table 3.1). Therefore the non-significant PSR may be due to the shorter F_{com}-time series used by WKIND.

3.7 Portuguese waters

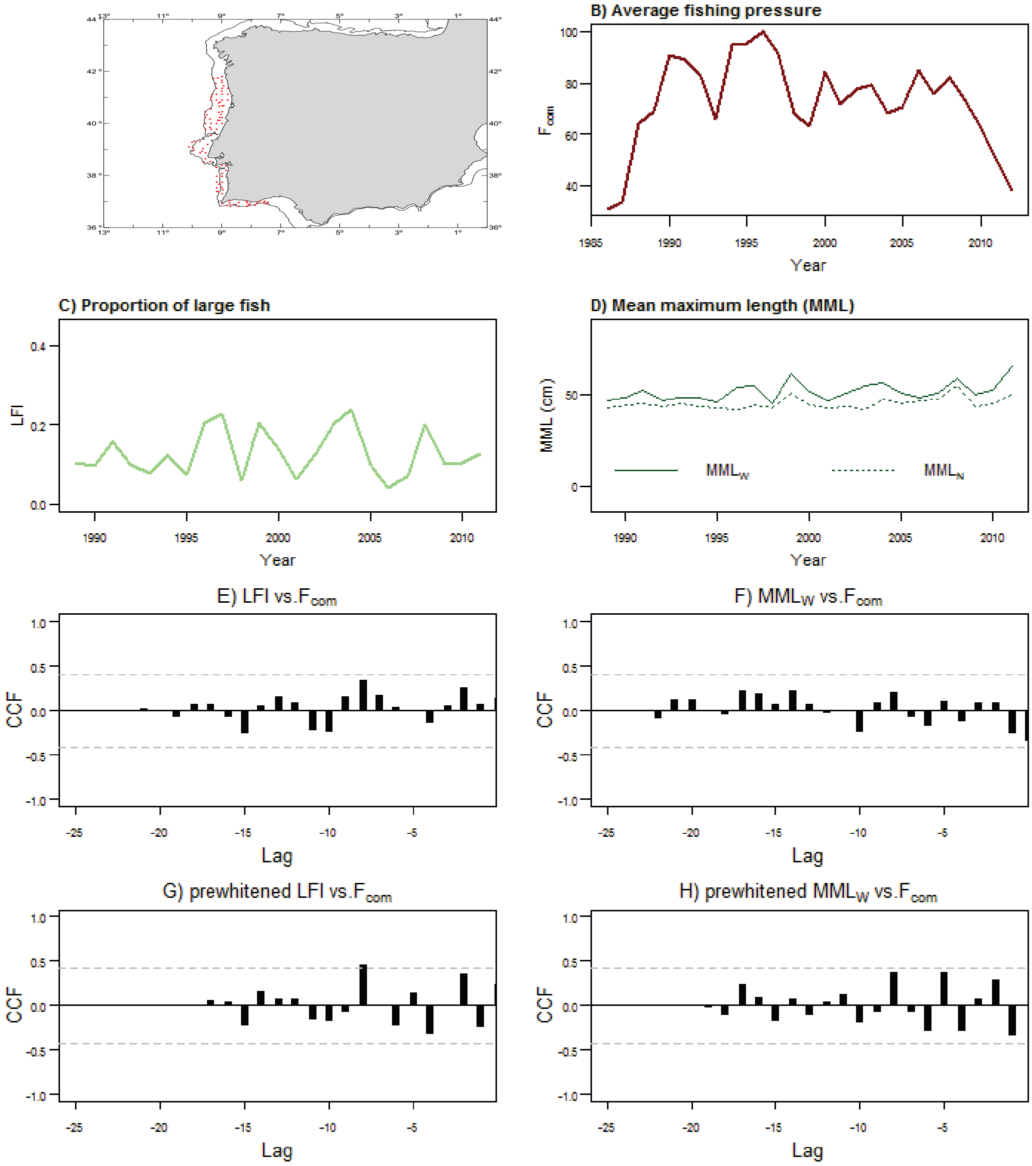
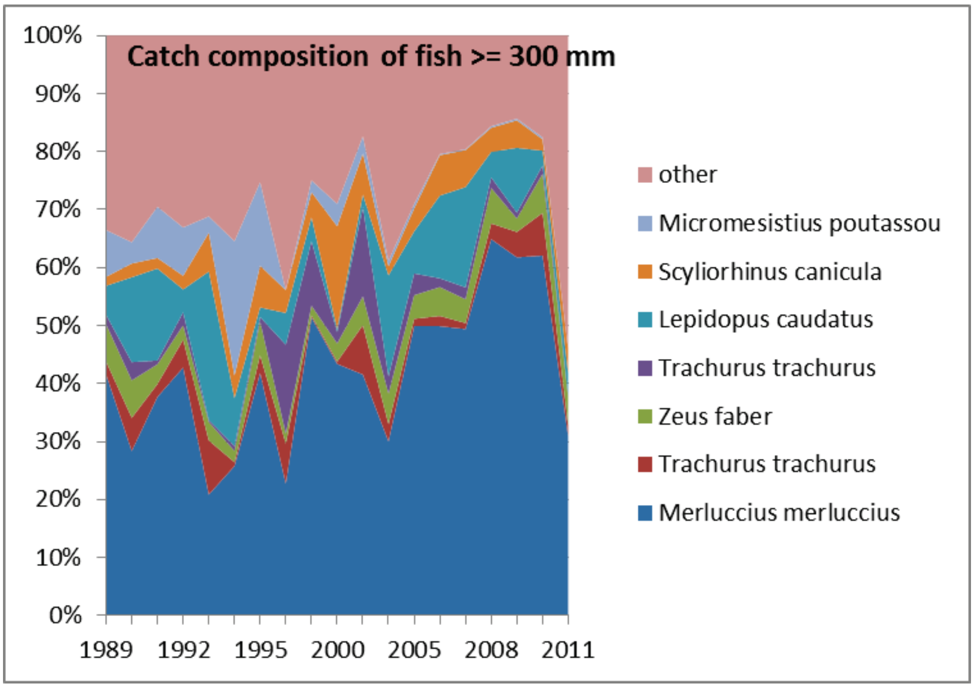


Figure 3.9. Community SBI of the PT-IBTS. A) Overlaid haul stations in the survey area. B) Time series of community fishing pressure (F_{com}) averaged across the relevant commercial stocks. C) Time series of the large fish indicator (LFI). D) Time series of mean maximum length by weight (MML_W) and numbers (MML_N). E) Cross-correlation function (CCF) of F_{com} vs. LFI. F) CCF of F_{com} vs. MML_W. G) Prewhitened CCF of F_{com} vs. LFI. H) Prewhitened CCF F_{com} vs. MML_W.



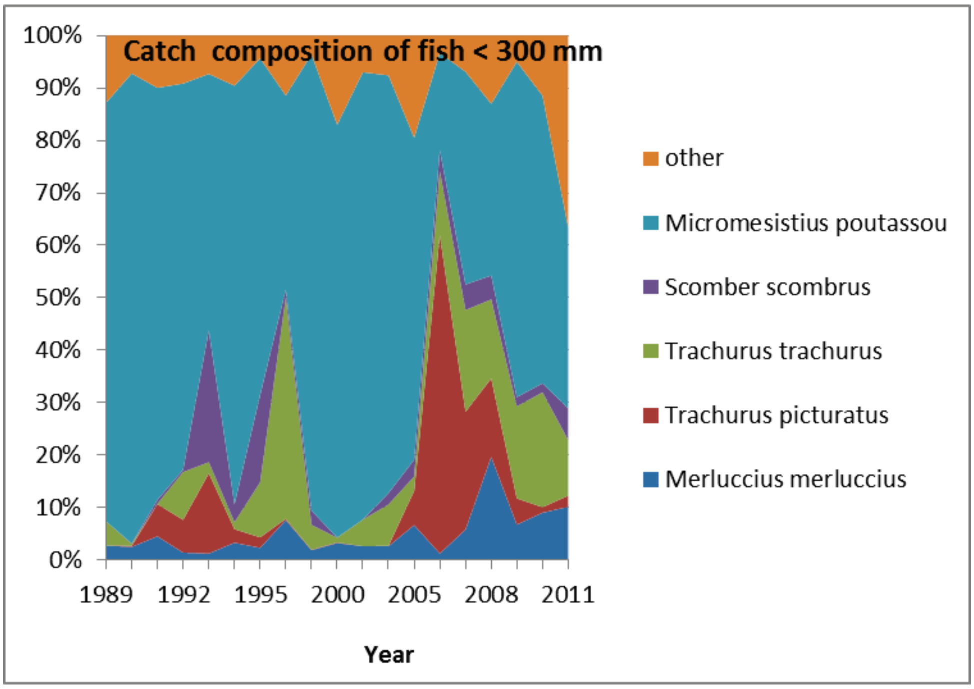


Figure 3.10. Relative species composition by biomass for the small and large proportion of the PT-IBTS survey catch.

Trends in F_{com}

F_{com} increased until 1990, fluctuated on a high plateau dropped around 2008 (Figure 3.9B)

Trends in community SBI

The LFI showed high interannual variations but no significant temporal trend (Figure 3.9C). The MML increased between 1989 and 2011 (Figure 3.9D)

Pressure-state relationships

There were significant PSR-relationships for both the LFI and the MML (Figure 3.9E-H). Seven commercial stocks were included in the F_{com} calculations (Table 3.1). The positive correlation in the estimated cross-correlation function can be a result of the inclusion of widely distributed mackerel and blue whiting F estimations in the regional F_{com} calculations. As these species (mainly blue whiting) have a strong influence in the LFI indicator we recommend that regional species-specific fishing mortalities should be estimated before considering pressure-state relationships.

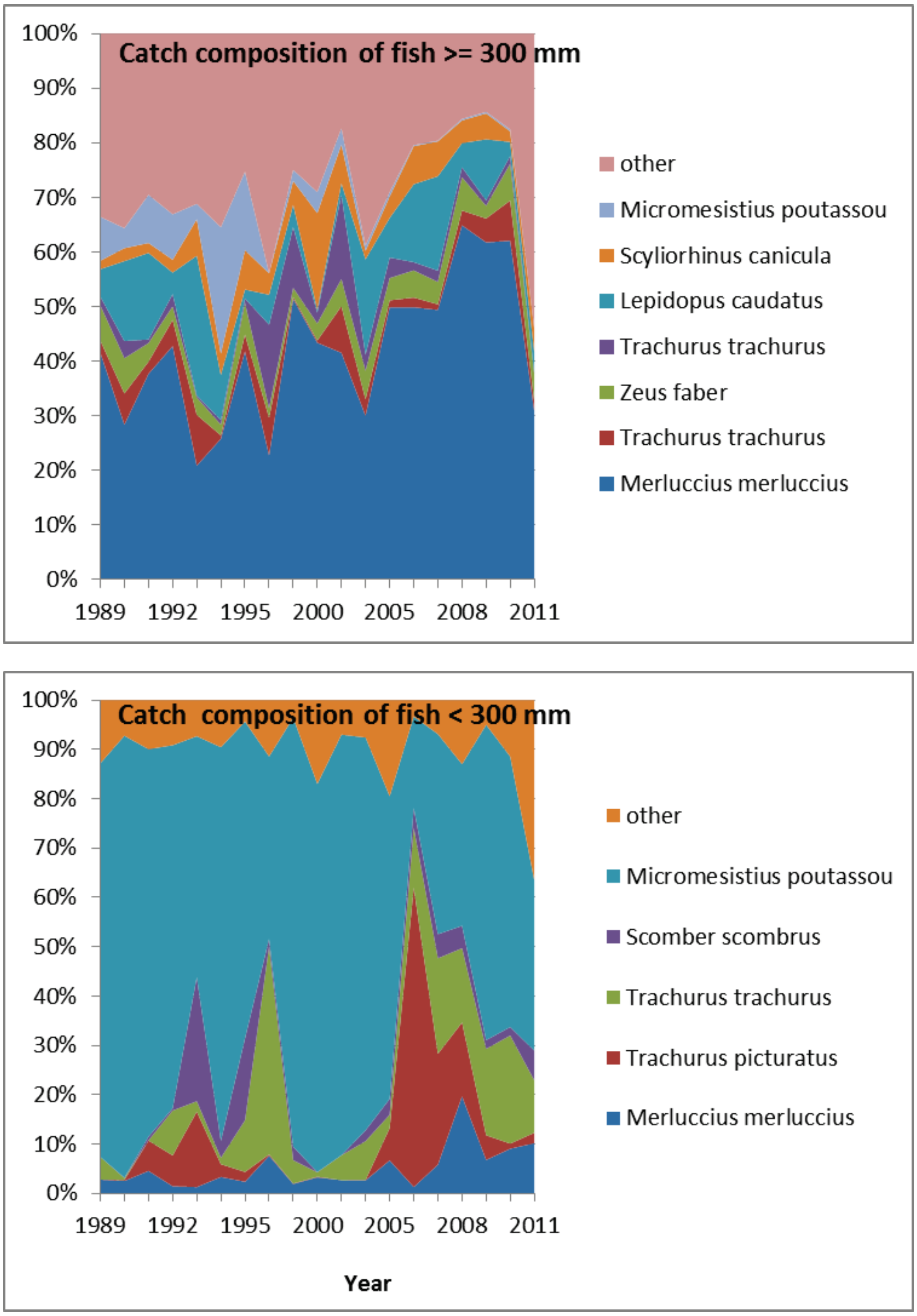
Species composition

The large fish community of the Portuguese waters was mainly dominated by hake (Figure 3.10). The small fish community was dominated by blue whiting, horse mackerel and jack mackerel.

Methodological considerations

Similar to other marine regions the time series of F_{com} and the community SBI was most likely too short to detect any significant cross-correlations. A threshold length of 25cm was selected initially – this defined the largest five-percentile of all fish caught across all survey years (i.e. 5% of all fish caught were larger than 25cm). After preliminary analysis, a final threshold of 30 cm was established to reduce the sensitivity to annual environmental noise, as an optimal LFI should respond more strongly to some underlying signal and least to environment driven recruitment events (ICES, 2012). Moreover, this type of indicators is dependent of the catchability of the gear used in each area. On this basis, boarfish (*Capros aper*), snipefish (*Macroramphosus scolopax*), sardine (*sardina pilchardus*), anchovy (*Engraulis encrasicholus*), chub mackerel (scomber colias) and sprat (Sprattus sprattus) were excluded as being intermittent invaders of little sustained importance to the demersal community, and having a predominately pelagic and/or shoaling life style leading to non-representative sampling in the demersal trawls.

3.7 Portuguese waters



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Trends in F_{com}

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Trends in community SBI

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Pressure-state relationships

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3.8 Western Scottish Waters

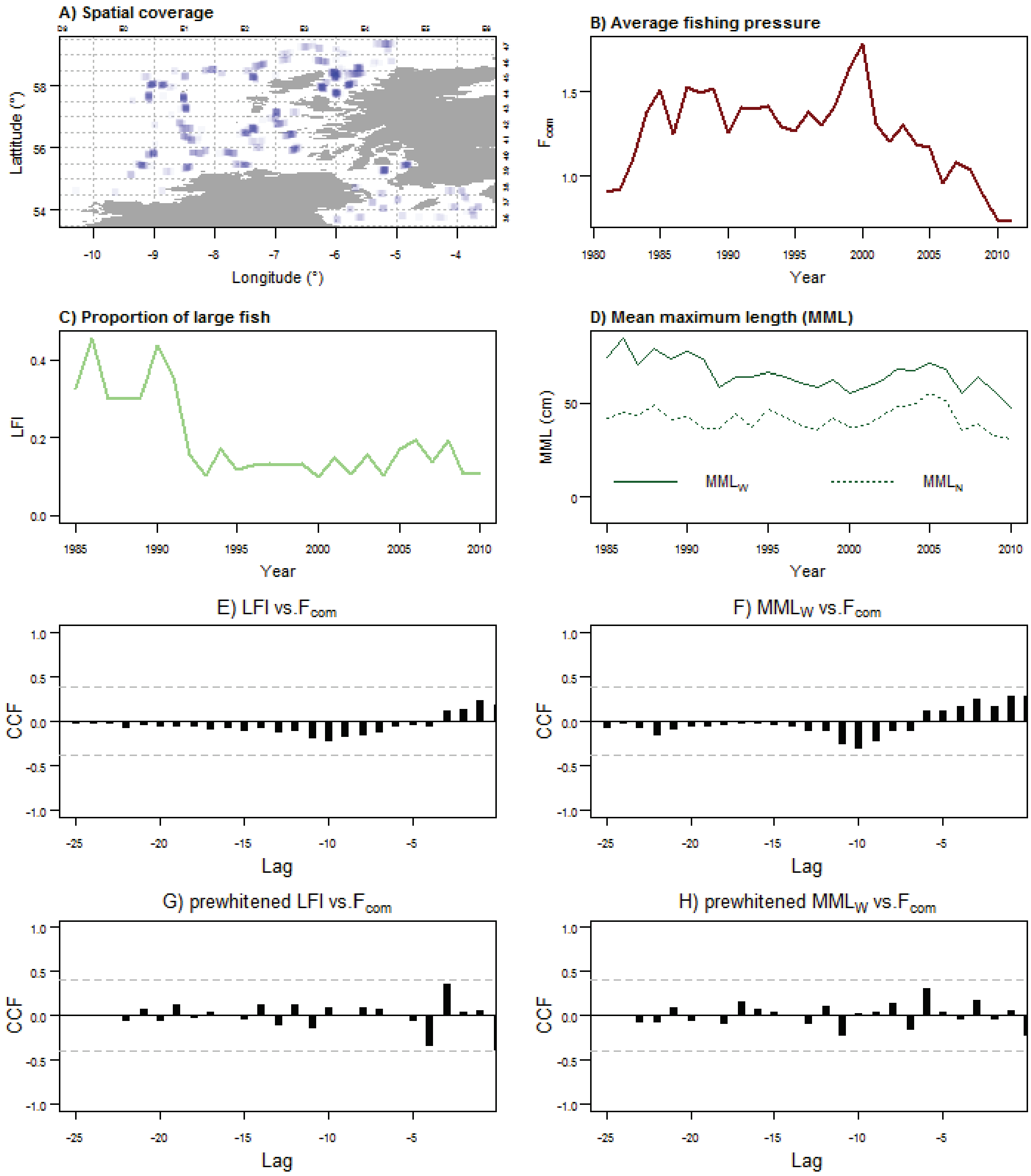
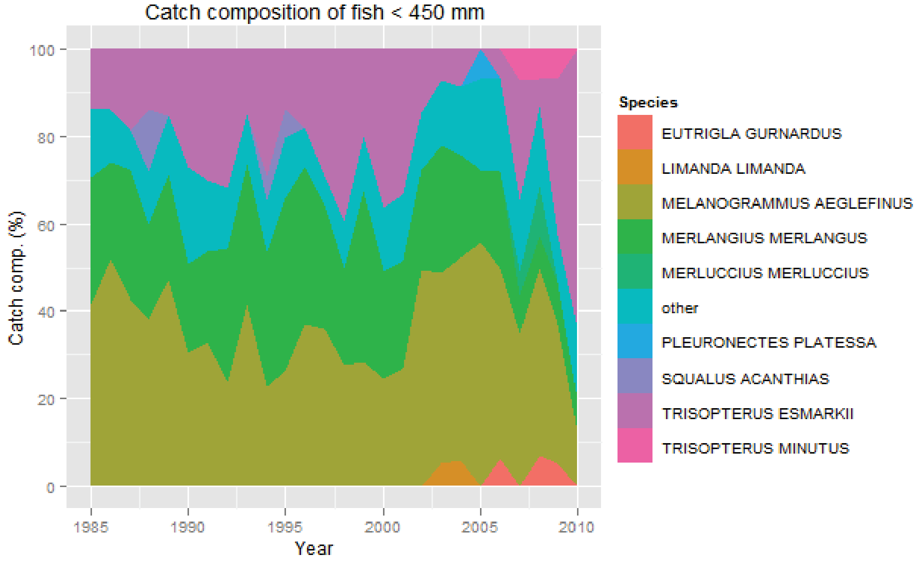


Figure 3.11. Community SBI of the Western Scottish Waters. A) Overlaid haul stations in the survey area. B) Time series of community fishing pressure (F_{com}) averaged across the relevant commercial stocks. C) Time series of the large fish indicator (LFI). D) Time series of mean maximum length by weight (MML_W) and numbers (MML_N). E) Cross-correlation function (CCF) of F_{com} vs. LFI. F) CCF of F_{com} vs. MML_W. G) Prewhitened CCF of F_{com} vs. LFI. H) Prewhitened CCF F_{com} vs. MML_W.



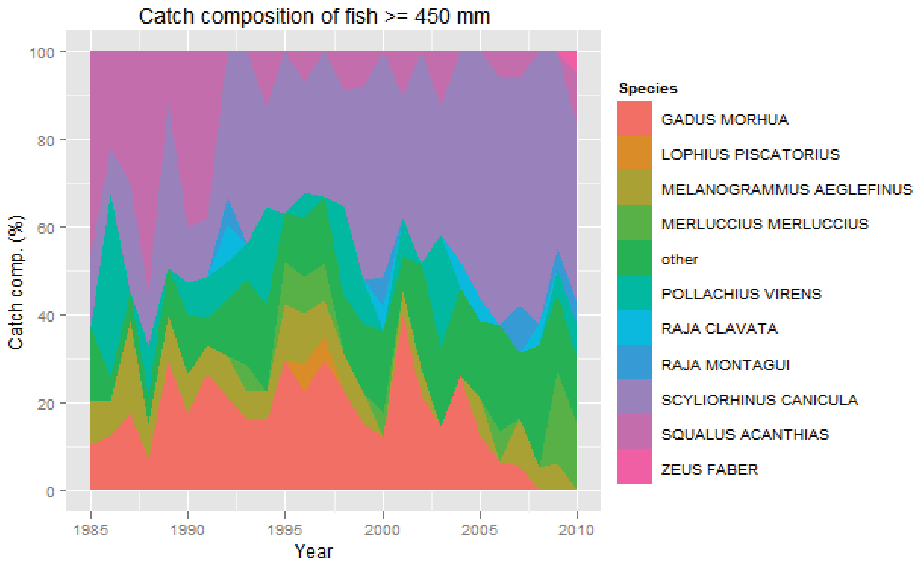


Figure 3.12. Relative species composition by biomass for the small and large proportion of the IBTS-SWC survey catch.

Spatial coverage

The IBTS-SWC covers ICES divisions VIa, VIIa and VIIb (Figure 3.11A).

Trends in F_{com}

F_{com} continuously declined since 2000 (Figure 3.11B).

Trends in community SBI

The LFI and MML have been decreasing after 1990, but whereas the LFI has remained stable at around 0.11 since then, the MML showed a further decline in recent years (Figure 3.11C&D).

Pressure-state relationships

There is no indication for a significant PSR (Figure 3.11E-H).

Species composition

The small fish community of the Western Scottish Waters is dominated by gadoids and flatfish. The large fish community comprises a large fraction of elasmobranchs (Figure 3.12). Since 2005 cod has disappeared from the large fish community.

Methodological considerations

Data from 2011 was missing and there was a change in survey gear in the IBTS-SWC Datras data hence continuous time series for the Western Scottish Waters could only be calculated for the period between 1985 and 2010. There is no official definition of a LFI threshold or a species list. For this report the according information was drawn from a working document by Shephard & Greenstreet (pers. Communication). Data from stock assessments of megrim (meg-4a6a) were not available in the ICES Stock summary database and therefore were not included.

Conclusions

- The F_{com} has declined in all marine ecoregions.
- Time series of community SBI are often too short to establish a valid PSR between F_{com} and community SBI. Improvements in identifying significant PSR may be expected when time series become longer.

Recommendations

- More work is needed to adopt the LFI and MML-concept to the specific marine ecoregions.
- Data availability of survey and stock assessment data should be improved.

4 DCF Indicator 4 Size at maturation of exploited fish species

4.1 Background to indicator

The size at maturation of exploited fish species indicator is included in the DCF list for assessing the performance of the CFP in relation to meeting the objective 'minimizing the impact of fishing activities on the marine ecosystem' (SEC 2008). The indicator has been reviewed by STECF (STECF 2006) and WGECO (WGECO 2012), but some further background on size at maturation and probabilistic maturation reaction norms will be provided.

4.1.1 Theory

Harvesting is not random selection within a population, but highly directed targeting of individuals with certain characteristics, e.g., size, age class, behavior. Age and size at maturation are extremely plastic traits that can evolve due to environmental changes, such as prey availability, oceanographic conditions, or density-dependence. However, genetic changes can occur within a population as a result of concentrated and high selection pressure on individuals if the selected phenotype has a partial genetic basis (Ricker 1981, Rijnsdorp 1993, Law 2000). Teasing apart trait phenotypic plasticity from genetic evolution is problematic in the absence of molecular genetic analysis or common-garden experiments, but often a partial separation can be done using less definitive (correlational) approaches, such as reaction norm methods (Dieckmann and Heino 2007).

Maturation is not a simple process, but consists of a number of potentially heritable changes that control the allocation of resources to growth, maintenance, and reproductive output. Individuals must achieve a minimum size before maturing, but the decision to mature once that size is reached will depend upon many factors, such that individuals with similar growth trajectories may still differ in the size and age at maturation. The probabilistic nature of the reaction norm is emphasized when some individuals of a certain size and age class mature, while others do not. The realized maturation schedule of an individual depends on the environmental conditions to which they are and/or have been experiencing (plasticity) and the selection regimes they have experienced (genetic).

Probabilistic maturation reaction norms (PMRNs) have been suggested as a method to disentangle the effects of phenotypic plasticity from genetic effects on maturation (Heino *et al*. 2002a). PMRNs describe an individual's probability of becoming mature as a function of both its age and size. Stochasticity of the maturation process is accounted for by allowing the probability of maturing to vary continuously from 0 to 1 instead of abruptly changing from 0 to 1 (Heino *et al*. 2002a).

Maturity ogives indirectly describe the maturation process, but they vary with growth and mortality of individuals (Dieckmann and Heino 2007). Because ogives will change when conditions alter growth or mortality, they are reflecting the plasticity in the maturation process as well as potential genetic adaptation. PMRNs are thought to remove the main effects of varying mortality and juvenile growth rates (hence, environmental conditions), but have been criticized for their limitations (see e.g., Dieckmann and Heino 2007, Kraak 2007, Uusi-Heikkilä *et al*. 2011, Harney *et al*. 2012), which include accounting for only growth-related phenotypic plasticity in maturation instead of including e.g., condition or temperature (though the influence of these variables can be included in the PMRN, provided that data are available), and failure to completely disentangle the effects of growth variability in maturation.

However, PMRNs remove the effects of varying average juvenile somatic growth rates from the description of the maturation schedule, which is an improvement over indices that are sensitive to growth variability, e.g. maturity ogives. As with any type of analysis, results from PMRNs must be interpreted critically and a broad blanket approach to their use (indiscriminate application) is typically discouraged.

4.1.2 PMRN estimation

PMRNs can be fit several different ways, but methods typically use data on proportions of immature and mature/maturing individuals at a given age and size. The method used when newly matured and previously matured individuals cannot be differentiated compares proportions of mature individuals at age and size at two consecutive time periods (Barot *et al*. 2004). First, maturity ogives are extended to account for size (*s*) as well as age (*a*), and are denoted by *o*(*a,s*). Then, how the size of an individual change between *a-1* and *a* is taken into consideration. All individuals within an age class are assumed to have identical annual growth increments, denoted by Δ*s*(*a*). Therefore, the probability of maturing for a given age and size is:

$$m(a,s) = \frac{o(a,s) - o(a-1, s-\Delta s(a))}{1 - o(a-1, s-\Delta s(a))} \ .$$

The downside of the method is that it is fairly data intensive. Relatively large sample sizes are required, which restricts its application, especially where the production of time series to determine trends is desired.

PMRNs are typically fit using GLMs (logistic regression) on fisheries independent data and rarely are other factors, such as environmental conditions, fish condition, or fishing pressure, incorporated (but see e.g., Heino *et al*. 2002b, Mollet *et al*. 2007, Pardoe *et al*. 2009, Vainikka *et al*. 2009a, van Walraven *et al*. 2010, Devine and Heino 2011, Wright *et al*. 2011a). Currently, only one study has incorporated knowledge that size, age, and maturation status of fish sampled from the same station (location) in a given year are likely highly correlated and accounted for this by using GLMMs (Devine and Heino 2011).

4.2 PMRN suitability as a DCF indicator to measure effects of fishing on the ecosystem

4.2.1 Introduction

The reaction norm midpoint has been suggested as useful as an indicator. This is commonly referred to as the L_{p50}, or is the size at which the probability of maturing, conditional on being alive for that age, is 50%. The use of PMRN information as an indicator for the effect of fishing is, in theory, a good suggestion, but problems in its estimation limits its broad application across many areas and species. As stated in previous reports (STECF 2006, WGECO 2012), estimation of PMRNs are data intensive.

Relatively moderate time series are needed to estimate meaningful trends in the probabilistic maturation reaction midpoint; the length of which depends on the life-history characteristics of the species. Many of the important commercial demersal stocks in the North Atlantic have been investigated in dedicated studies (see e.g., Mollet *et al*. 2007, Vainikka *et al*. 2009a, Vainikka *et al*. 2009b, van Walraven *et al*. 2010, Wright *et al*. 2011b).

In order to create an indicator, a time series is needed. This implies tracking of cohorts by age over time. To do so:

1. Data must come from a time of year when maturity status can be assessed (e.g., immature fish are readily discernible from mature, resting individuals). For most areas and species, this will be the quarter 1 surveys.
   i. Of the ecoregions, only the North Sea, Baltic Sea, and West of Scotland surveys take place in Q1.
2. Species must have enough data collected each year to break into separate cohorts and ages.
   i. Data needed are maturation status (immature and mature), individual size, and age
   ii. Of the three ecoregions with Q1 surveys, all appear to have enough data to investigate PMRNs for at least a few species.
3. Data must be representative of the population, e.g., mature and immature must be equally represented in the samples, which precludes use of e.g., spawning surveys, unless other data exists that can complement (or weight) the survey information.
4. The estimation procedure itself is broken down into several steps:
   i. Estimate a model for age- and size-specific maturity ogives.
   ii. Estimate a model for age-specific growth.
   iii. Estimate the PMRN using the models in i) and ii).
   iv. Derive a PMRN midpoint from the PMRN model for representative age classes (e.g., those that are fully recruited to the fishery).
   v. Derive the PMRN confidence interval or PMRN width.
5. Resulting midpoint time series must be of sufficient length to track trends in PMRN midpoints. As with e.g. recruitment, trends can be difficult to discern in short time series because of high variability.

4.2.2 Procedure

To use the above criteria on a case by case basis, we can show how estimation can be attempted for the North Sea ,Baltic Sea, and West of Scotland ecoregions.

4.2.3 Case studies

North Sea

Data come from IBTS quarter 1 survey. A large amount of data (age, maturity, and individual weight) was collected for approximately 14 species, all of which had time series of 10 or more years in length.

Saithe: *Pollachius virens*

1. Data on immature and mature fish began were not collected routinely until 1988, which restricts the time series to approximately 20 years.
2. Data on immature fish age 1 and 2 come from 4 countries. Of these, only 2 survey waters where immature saithe should be expected, which is in coastal areas; fish begin to move slightly further offshore beginning at age 2. Ques-

tionable immature fish of ages 1-2 were found in the center of the North Sea, leading to doubts about their accuracy, so they were excluded from the data. Such detailed knowledge about the stock is needed for data cleaning prior to PMRN estimation.

3. Data are then assigned to cohorts. Analysis was restricted to ages 3-9; all fish are mature by age 8. Data on both sexes were combined for PMRN estimation.
4. PMRN midpoints were reliably estimated for ages 3–6 (Figure 4.2.1), cohorts 1988–2007. PMRNs must be focused on those age classes assumed to be fully recruited to the fishery, this precludes the use of age 3 or 4 fish for estimating trends in PMRNs. Age 6 fish were mostly mature and PMRN midpoints could not be estimated for most cohorts.
5. The PMRN envelope (L_{p25}, L_{p75}) was extremely wide for several cohorts and several midpoint estimates were unrealistically low, indicating that sparseness of data was an issue and estimates were not very precise (Figure 4.2.1). The estimate may decrease with size or be negative when data are sparse, noisy, or the probabilities of being mature are very high or very low (Barot *et al*. 2004).
6. No linear trend was present for age 5 North Sea saithe. There is evidence of a slight oscillation (GAM, p=0.05).

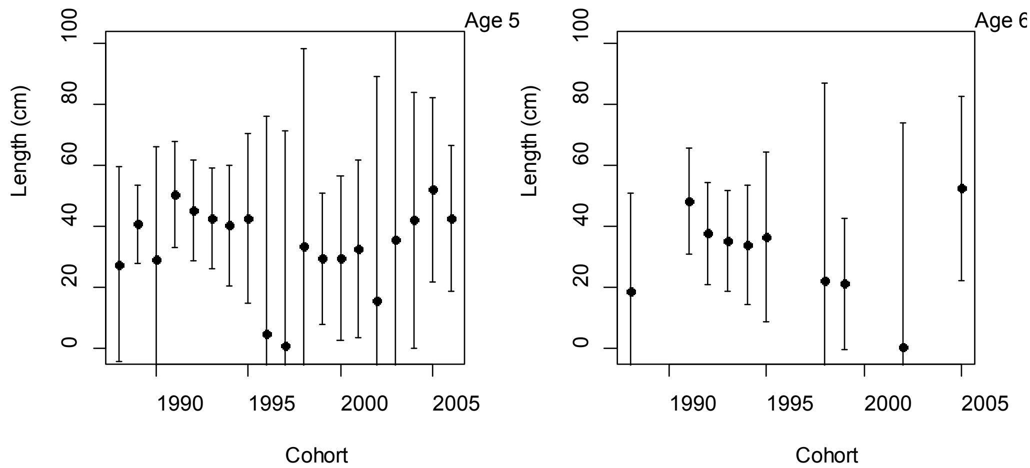


Figure 4.2.1. PMRN midpoint (L_{p50}) for North Sea saithe (*Pollachius virens*), ages 5 and 6, cohorts 1988–2007. Bars are the PMRN quartiles (L_{p25} and L_{p75}). Full range of quartile estimates are not shown where they cross zero or are greater than 100 cm.

Whiting: *Merlangius merlangus*

1. Age 1 fish should not be considered fully recruited to the fishery (ICES-WGNSSK 2013), therefore PMRN midpoints were not estimated for fish of age 1.
2. Most fish were mature by age 3. Because of the low number of immature fish older than age 3, midpoints could not be estimated with reliability for those ages.
3. PMRN estimation was completed for ages 2–3 and cohorts 1964–2009; data were combined for both sexes.

4. PMRN midpoints have been declining in whiting since the 2000 cohort, but there was no distinct linear trend over the entire time series (Figure 4.2.2). Age 3 PMRN midpoint estimates for cohorts 1973–1980 and 2004–2008 appear to be poorly estimated and should be treated with caution; if these estimates are omitted, there is no discernible trend in PMRN midpoints for recent cohorts.

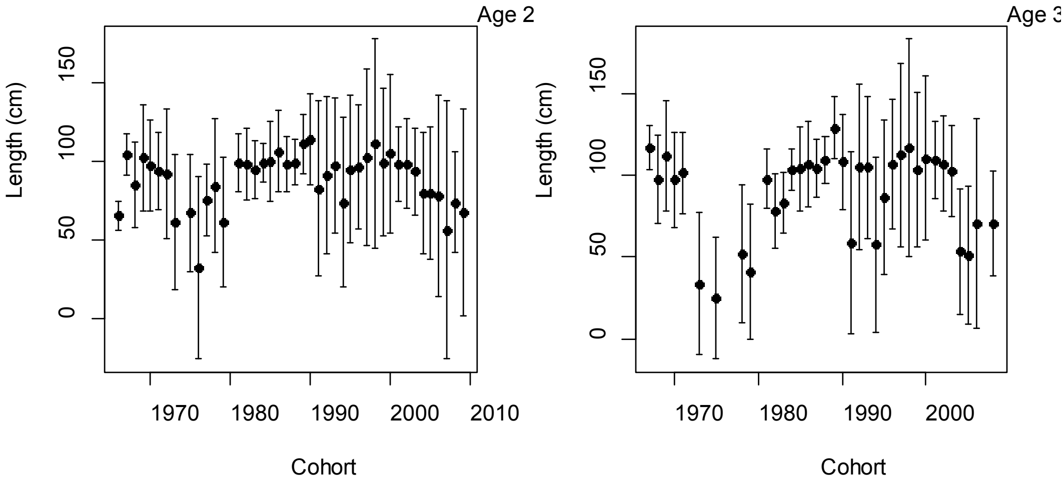


Figure 4.2.2. PMRN midpoint (L_{p50}) for North Sea whiting (*Merlangius merlangus*), ages 2–3 and cohorts 1964–2009. Bars are the PMRN quartiles (L_{p25} and L_{p75}).

Sprat: *Sprattus sprattus*

1. Fish are assumed recruited to the fishery by age 1 (ICES Advice 2013).
2. PMRN midpoints could be estimated for age 2–4 sprat; data on both sexes were combined.
3. The size at maturation appears to have declined for North Sea sprat, age 1 and 2, since the 1970s (linear regression: age 1, $p<0.001$; age 2, $p=0.05$; Figure 4.2.3). For age 1 fish, that decline has halted in the last decade, while age 2 fish are showing an increase in length at maturation.
4. No visible trends existed in size at maturation for sprat of ages 3 and 4 (Figure 4.2.3).
5. As this data comes from a bottom trawl survey, the assumption underlying these estimates are that sprat of all ages are adequately sampled by this survey and gear at this time of year, and that fish of maturity stage 2 will spawn in the current year (i.e., assumed to be mature). If these assumptions are incorrect, then the PMRN midpoints and visible trends may also be incorrect.

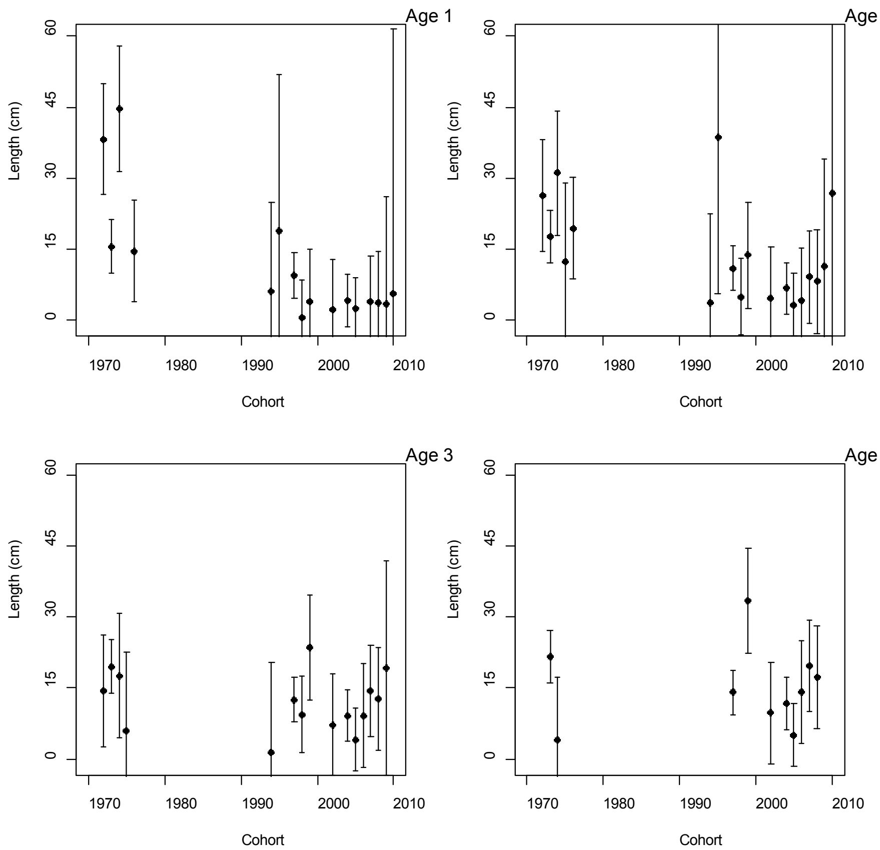


Figure 4.2.3. PMRN midpoint (L_{p50}) for North Sea sprat (*Sprattus sprattus*), ages 2–4 and cohorts 1972–2010. Bars indicate the PMRN quartiles (L_{p25} and L_{p75}). Full range of quartiles (L_{p25}, L_{p75}) were not shown if they overlap zero or were greater than 60 cm.

Other species

The remaining species with enough data to allow PMRN estimation included those for which dedicated PMRN studies had already been completed: cod *Gadus morhua* (Wright *et al*. 2011b), herring *Clupea harengus* (Enberg and Heino 2007), haddock *Melanogrammus aeglefinus* (Wright *et al.* 2011a), plaice *Pleuronectes platessa* (Rijnsdorp 1993, van Walraven *et al*. 2010), sole *Solea solea* (Mollet *et al*. 2007), whiting *Merlangius merlangus*, and Norway pout *Trisopterus esmarkii* (Marty *et al*. 2013). Because these studies have looked at the stocks in greater detail e.g., incorporated subpopulation structure and information from multiple surveys/sources, they would be a better source of information on L_{p50} trends than those estimated from a single survey, e.g., IBTS Q1.

Baltic Sea

Although data from both BITS quarter 1 and 3 surveys exist, BITS Q1 was deemed the best source of maturation data for estimating PMRN midpoints. Six species indicated there might be enough data to estimate size at maturation; these were cod, herring, sprat, dab *Limanda limanda*, plaice and European flounder *Platichthys flesus*.

After data cleaning, few meaningful PMRN midpoint estimates could be made for sprat, dab, plaice, or flounder due to too few data (e.g., midpoints were estimated for European flounder for only 2 cohorts of age 2, 1 for age 3, and 2 for age 4). Cod and herring were investigated in dedicated PMRN studies (see e.g., Vainikka *et al*. 2009a, Vainikka *et al*. 2009b), which were able to integrate more detailed data than that held in the DATRAS database.

West of Scotland

Whiting: *Merlangius merlangus*

1. Age classes that contained both immature and mature fish were limited to ages 1–3. Most fish were mature after age 3.
2. The amount of data was limited to cohorts between 1994–2010, i.e., 6 years.
3. PMRN midpoints could be estimated for only 3 cohorts for ages 1 and 2 (Table 4.2.1). Too few data were available to define trends over time in length at maturation for whiting.

Table 4.2.1. PMRN midpoint (L_{p50}) and quartiles (L_{p25} and L_{p75}) by cohort for age 1 and 2 West of Scotland whiting (*Merlangius merlangus*).

Age	Cohort	L_{p50} (cm)	L_{p25} (cm)	L_{p75} (cm)
1	1995	7.0	1.0	13.0
1	1997	2.0	-5.7	9.8
1	2000	4.2	-3.3	11.7
2	1995	9.4	3.4	15.4
2	1997	8.3	0.5	16.0
2	2000	7.5	0.1	15.0

Herring: *Clupea harengus*

1) Fish are recruited to the fishery by age 2.

2) Enough data existed to estimated length at maturation for 9 cohorts for age 2 and 3 herring (Figure 1.2.4).

3) No trend in length at maturation was present (linear regression over estimated midpoints).

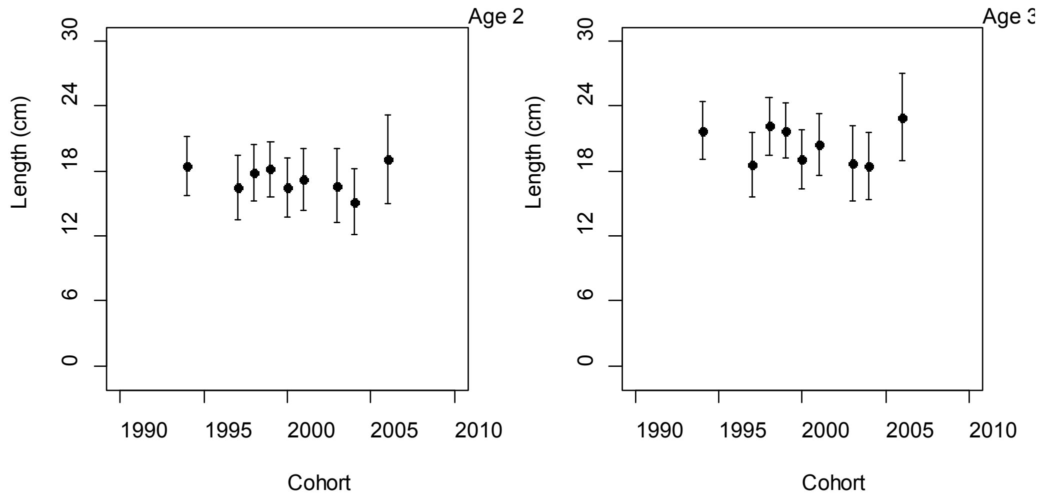


Figure 4.2.4. PMRN midpoint (L_{p50}) for West of Scotland herring (*Clupea harengus*), ages 2–3 and cohorts 1994–2006. Bars indicate the PMRN quartiles (L_{p25} and L_{p75}).

Haddock: Melanogrammus aeglefinus

1. Age classes that contained both immature and mature fish were limited to ages 1–3. Most fish were mature after age 3.
2. The amount of data was limited to cohorts between 1995–2007.
3. PMRN midpoints could be reliably estimated for 7 cohorts (1997–2006) for ages 1 and 2 (Figure 1.2.5). The quartiles were wide and often negative, indicating that sparseness of data was again an issue. As stated previously, when data are sparse, noisy, or the probabilities of being mature are very high or very low, negative estimates may occur (Barot *et al*. 2004).

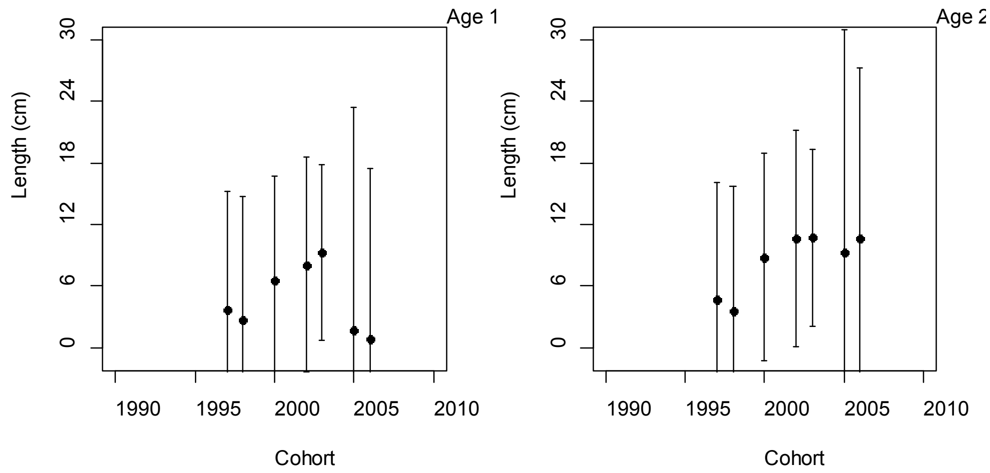


Figure 4.2.5. PMRN midpoint (L_{p50}) for West of Scotland haddock (*Melanogrammus aeglefinus*), ages 1–2 and cohorts 1997–2006. Bars indicate the PMRN quartiles (L_{p25} and L_{p75}), lower quartiles often were negative and the full range was not shown.

4.3 PMRN Conclusions and recommendations

4.3.1 Conclusions

PMRN midpoints are not community indicators, but are species-specific indicators of possible genetic effects of size-selective harvest. The PMRN midpoint is the size at which the probability of maturation for that age, conditional on being alive, is 50%. At young ages, many individuals may be smaller than the PMRN midpoint, which means that only a small proportion of the cohort is expected to mature at that size (Barot *et al*. 2004). PMRNs should not be misinterpreted as the size at which 50% of individuals within a cohort mature (e.g., maturity ogives, not age-specific).

Estimation requires a fair amount of data on maturity and size for a wide range of cohorts and age classes. For most ecoregions, the data available for estimating PMRNs were extremely limited or the fisheries-independent surveys did not occur at the time of year where maturation status was easily determined (e.g., resting and immature individuals were difficult to differentiate).

For those species that had adequate data, most had been previously investigated in dedicated species-specific studies, which were able to investigate changes using a level of detail beyond the scope of quick studies, as attempted here. This again argues that perhaps PMRNs, while useful, are limited in their applications as ecosystem DCF indicators to measure the impact of fishing on the ecosystem.

As suggested by ICES-Advice (2013), targets cannot be set for this indicator nor are trends linked to a clear consequence or benefit, which limits the application of this indicator (PMRN midpoints) to management. However, if rates of the evolution of size at maturation are assessed and then related to growth and total mortality rates on a species-by-species basis, management inferences can begin to be drawn. A metric for quantifying evolutionary rates, the haldane, is used to estimated the change in a population trait in units of standard deviation per generation (Gringerich 1993). Haldanes are easily estimated if generation time (easily estimable) and the PMRN midpoint and width are known. Rates have been estimated for many of the species which have had dedicated PMRN studies (Devine *et al*. 2012), which allowed for comparison with growth and total mortality for some of the species (e.g., Atlantic cod and haddock, Figure 4.3.1). What becomes apparent is that the stocks that are experiencing fast evolutionary rates of trait change, but have slow growth and high mortality (includes both natural and fishing mortality) are those that must be closely monitored. Furthermore, reducing the level of total mortality without compensatory growth changes, can slow the rate of trait evolution. Trait change may not be fast even under high mortality environments if growth can compensate (Figure 4.3.1). Furthermore, as seen for the North Sea sprat, not all trends in PMRNs are negative; some species may be able to compensate to size selective harvest through growth compensation. To summarize, PMRNs in themselves may not be a useful indicator, but rates of evolution, estimated from PMRNs, combined with information on the growth and mortality regime of the species, may have potential.

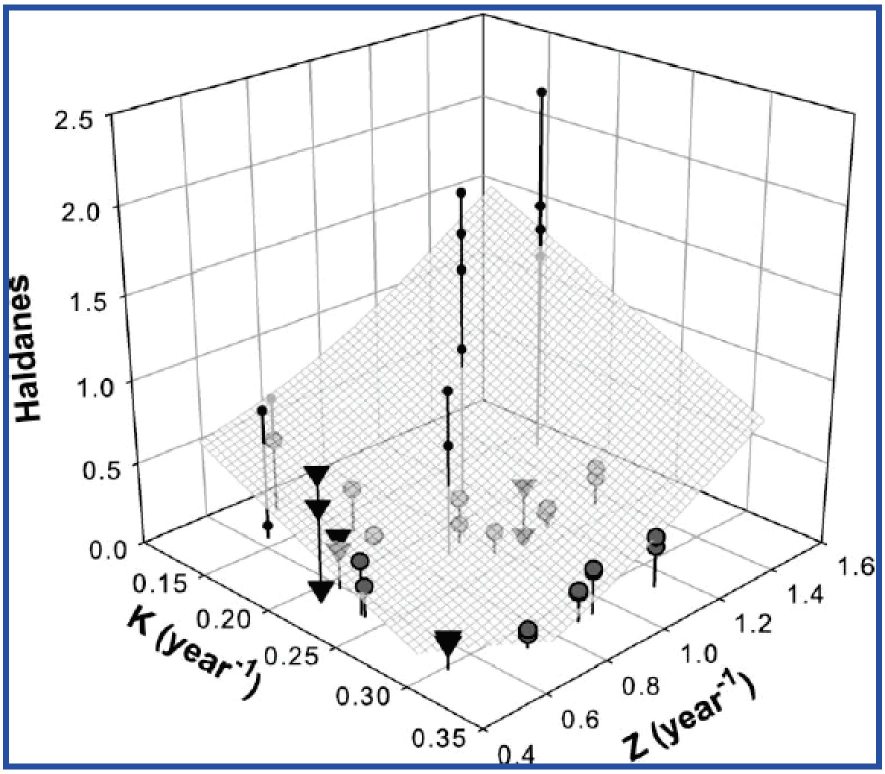


Figure 4.3.1. Response shape of the relationship among rates of evolution in haldanes, total mortality (Z, year^{-1}, geometric mean of time series), and somatic growth (K, year^{-1}, geometric mean of time series) for gadoid stocks (Atlantic cod, haddock) in the North Atlantic. Grey circles are no moratorium stocks, black circles indicate pre-moratorium periods, and black triangles are post-moratorium periods. Redrawn from (Devine *et al*. 2012).

4.3.2 Recommendations

1) PMRNs are not suitable as a regional-wide DCF indicator to measure the effect of fishing on the ecosystem. This is due to timing of surveys, length of time series, and/or data collection. Furthermore, detailed knowledge about the stock is needed for data cleaning prior to PMRN estimation, which limits its indiscriminate application to survey data.

2) The indicator has already been applied to most of the stocks for which adequate data are available. WGEVO is recommended to update these particular studies.

3) There are a number of other stocks for which this indicator might be suitable, but dedicated studies are required to scan suitable data. To be continued on selected studies.

4) WGEVO is recommended to continue the development of operational indicators to measure the effects of fisheries-induced evolution.

5) PMRNs in themselves may not be a useful regional-wide DCF indicator, but rates of evolution, estimated from PMRNs, combined with information on the growth and mortality regime of the species, may have potential as an indicator of the effects of fishing on selected species.

5 DCF Indicators 5 to 7: Spatial indicators on fishing pressures based on VMS data

5.1 Background to indicators

There are three spatial DCF indicators which aim to measure fishing pressure using VMS data. These are:

- DCF 5: Distribution of fishing activities
- DCF 6: Aggregation of fishing activities
- DCF 7: Areas not impacted by mobile bottom gears

The data requirements for the three indicators are VMS vessel position records reported at minimum intervals of 2h for vessels assigned to metiers according to the 6 level metier classification recommended in SGRN 06-03. The recording of VMS location is currently obligatory for fishing vessels of 12m and above (EC 2009).

According to SEC 2008, the indicators are calculated by replacing vessel identifiers with the metier code, applying methods to identify fishing from non fishing and assigning vessel positions, when fishing, to a 3km*3km grid. Total number of vessel position records by metier in each grid cell in each calendar month is calculated.

Indicator 5 "Distribution of fishing activities" is the total area (sum of areas of 3km grid cells) where fishing activity was recorded for each fishing technique in each month and year.

Indicator 6 "Aggregation of fishing activity" is the total area (sum of areas of 3km grid cells) where 90% of fishing activity (90% of the total number of position records) was recorded for each fishing technique in each month and each year.

Indicator 7 "Areas not impacted by mobile bottom gears" is calculated by summing up the total numbers of vessel position records for mobile bottom fishing gears in each 3km*3km cell for each year. This indicator should be reported as the total proportion of the area by depth strata (0- 20m, 20-50m, 50-80m, 80-130m, 130-200m, >200m) in each marine region that has not been fished with bottom gear in the preceding one year period.

5.2 ICES Approach taken in to update indicators for WKIND2013

Within the ICES expert groups, WGSFD, the working group on spatial fisheries data, has developed the expertise to analyse spatial fishing activity based on VMS data. As WGSFD met one month before WKIND 2013 it was agreed that WGSFD will cover the review and update of indicators 5 to 7. The following text has been written in WGSFD2013 and is a direct extract from the corresponding working group report. The review and update were discussed in WKIND with the incoming chair of WGSFD and further recommendations were made based on these discussions.

5.3 Review and update from WGSFD2013

5.3.1 Excerpt from WGECO 2012 report

For references to individual report sections in the text, please refer to the ICES WGSFD 2013 report.

WGECO 2012 explored and calculated the pressure indicators for trawling impact on the different marine habitats based on 2 case studies:

- Distribution of fishing activities (DCF 5);
- Aggregation of fishing activities (DCF 6);
- Areas not impacted by mobile bottom gears (DCF 7).

5.3.1.1 Dutch case study

Dutch data were considered for spatial and temporal scale according to (Piet and Quirijns, 2009) in conjunction with the reconstruction of trawl tracks based on the cubic Hermite spline interpolation technique according to (Hintzen *et al*., 2010). Only vessels fishing with bottom gear were included, which makes it easier to draw assumption on gear properties (see comment in 4.2.2). All aspects of preliminary data preparation and the calculation of the pressure indices were done using the *VMStools* package and *sp* package which are available as add-on packages to the R statistical software.

Applying interpolation (see comment in 4.2.2), grids were constructed at different resolutions to compare and contrast the impact of different grid resolutions on the outcome of the analyses: a 'low' resolution grid (0.6 minutes longitude by 0.3 minutes latitude, approx. cells of 600 x 600 meters), and 'high' resolution grid (0.06 minutes longitude by 0.03 minutes latitude, approximately cells of 60 x 60 meters).

5.3.1.1.1 Distribution of fishing activities (DCF 5)

This indicator was calculated using two specific parameters: total surface area trawled and proportion of surface area trawled.

The total area trawled within each spatial grid cell was calculated based on the width of the gear, a vessel's speed and time spent in that cell. Each VMS registration is allocated to one spatial grid cell. The average time difference between the preceding and succeeding registration is taken as the time spent within the grid cell. Multiplying time spent by gear width and speed provides information on the actual trawl track (km^2) within the spatial grid cell. Aggregating all tracks within a spatial grid cell gives the total surface trawled within the specific grid cell. Aggregating over all grid cells gives the total surface area trawled.

The proportion of the area trawled is calculated by counting each grid cell that is trawled as a trawled grid cell without any consideration of how much of the grid cell is actually trawled. Aggregation over all grid cells in an area gives the total proportion of that area trawled.

5.3.1.1.2 Aggregation of fishing activity (DCF 6)

This indicator was calculated using two specific parameters: proportion of surface area fished by specific proportion of effort and proportion of surface area fished at specific trawling intensity.

Proportion of surface area fished by specific proportion of effort was calculated from the DCF 5 indicator through summation of the grid cells in decreasing order until a specific percentage of the total effort (i.e. 90%) is reached. The indicator equals the total surface area of these grid cells as a proportion of the total surface area.

Proportion of surface area fished at specific trawling intensity was calculated based on the calculations above, can derive the intensity of trawling for each of the spatial grid cells. If the area trawled within a spatial grid cell equals its total surface, trawling intensity equals 1.

5.3.1.1.3 Areas not impacted by mobile bottom gears (DCF 7)

This indicator was calculated using two specific parameters: cumulative proportion of surface area not impacted over a specific period and proportion of surface area not impacted incorporating uncertainty.

Cumulative proportion of surface area not impacted over a specific period was calculated by adding the registrations/tracks for each additional year of fishing to those of the previous year(s). The surface area of each grid cell that has not been fished is thus integrated over successive years. The total surface unfished can then be divided by the total surface area of the EEZ.

Proportion of surface area not impacted incorporating uncertainty in the estimated trawl path based on the VMS registrations and using the available interpolation techniques (Hintzen *et al.*, 2010).

5.3.1.2 Calculation: Italian case study

The Italian experience computing the DCF indicators of fishing pressure 5-Extension of fishing activities and 6-Aggregation of fishing activities.

Specification of the Indicators in Appendix XIII of the DCR identifies a 3 km x 3 km grid size as optimal for representing fleet distributions. For computation of indicator 5 is sufficient to plot fishing set position on the grid and then count the number of cells with at least one point. The value of indicator is then determined by multiplying the number of cells for 9 $km^{2.}$ Thus, the expression of the indicator 5 is:

$$E_{m,a} = n_{m,a} \times 9$$

Where $E_{m,a}$ is the value (in km^2) of the indicator at month *m*, for métier *a*, and nm,a is the number of grid cells "activated" (with at least one point).

The indicator 6 represents the minimal area in which falls the 90% of the total number of fishing points recorded in a given month. This can be computed by sorting, in a decreasing order, cells by fishing points and then cutting the series when the cumulated number of fishing points reaches the 90% of the total value. The expression of the indicator 6 is:

$$Am, a = n90_{m,a} \times 9$$

Where $A_{m,a}$ is the value (in km^2) of the indicator at month *m*, for métier *a*, and n90,a is the number of grid cells summing up the 90% of the total number of fishing points.

5.3.1.3 Synthesis and recommendations from WGECO 2012

From the two case studies presented the following issues were recommended:

- Data cleaning is necessary and should be done consistently following some protocol. This could be drafted from the experiences gained in various studies.
- In contrast to how the indicators were initially defined, i.e. providing some measure of extent expressed in e.g. km2 they should be reported as a proportion to the total regional area or possibly only some relevant part of that region.
- Resolution of the grid cells strongly affects the value of the indicator with higher resolutions providing more realistic values two options emerge: an increase of the VMS frequency or applying the existing method to create

the trawl track through interpolation and with some notion of uncertainty. Usually applies 3x3 km2 grid which appropriate to the two hour intervals.

- The temporal resolution needs to be considered. The indicators can be calculated on a monthly or annual basis. For DCF indicator 7 is relevant to determine a cumulative impact over a number of years. In that case only the annual basis should be applied. The monthly calculation of the three indicators did not reveal any additional information to the annual indicator values other than recurring seasonal fluctuations.
- The proposed calculation of the indicator per level 6 métiers is not considered realistic. They propose to calculate the indicators using level 4 métiers.
- This group proposed addition modifications to the existing indicators or alternative indicators:
    i. For the DCF indicator 5 "Distribution of fishing activity" they propose to use the "Proportion of surface area trawled".
    ii. For the DCF indicator 6 "Aggregation of fishing activity" they propose to use "The Proportion of surface area fished at specific trawling intensity" as the preferred indicator. This has the added benefit that it complements the DCF indicator 7.
    iii. The DCF indicator 7 "Areas not impacted by mobile bottom gears" is an important indicator as it not only can be used to describe fishing pressure but also the state of certain habitats or seabed integrity.
- Despite all the improvements in the methodology to calculate the indicators they only reflect the part of the fishing fleet equipped with VMS transponders which in some regions or for some fisheries excludes a large part of the fleet.

5.3.2 Conventions applied by WGSFD 2013 in light of WGECO recommendations 2012

It was agreed

- to not apply interpolation methods for VMS analysis. Interpolation seems questionable for a number of métiers and therefore was not applied throughout the entire analysis.
- to set the threshold in the analysis of DCF 5 and 7 at 0. This allows including all effort known in the analysis of the distribution of fishing activities.
- to not aim at calculating trawling intensity in terms of frequencies to specify the impact on the ecosystem in terms of times of surface trawled. Although it is evident, that trawling frequency is the ultimate parameter to understand trawling impact (Fock *et al.*, 2011, Piet and Hintzen, 2012)(see also 4.2.1.1.2), it was also recognized that for the majority of métiers gear parameters were not available during WGSFD 2013.
- to work only on data from 2012 onward reflecting the new size limit of 12 m instead of formerly 15 m for vessels to operate VMS.
- It was agreed that ICES areas delimited by the baselines serve as reference areas to calculate percentage coverage as recommended by WGECO 2012 and Piet and Hintzen (2012). However, due to low coverage of available data (see 4.3), this exercise was not undertaken.

As matter of fact, different software solutions could be applied to merge datasets and sum up effort in terms of hours fishing by rectangles at a resolution of 0.05 by 0.05 degrees all applying equivalent speed rules. Métier assignment through *VMStools* was not required since métier definition were provided with the logbooks.

Thus it was not possible to follow WGECO 2012 recommendations in that DCF6 is not interpreted in terms of trawling frequencies and intensity. Percentage values of coverage for DCF 5 and DCF 7 were not calculated taking into account that main fishing countries had not contributed data. Whereas WGECO 2012 applied these percentages to EEZ areas, here ICES areas are recommended. For DCF 7, percentage over time was not calculated due to the restriction to 2012 data.

5.3.2.1 DCF indicator 5: Distribution of fishing activities

DCF 5 is defined as 'indicator of the spatial extent of fishing activity'. The indicator was as understood as the area A_j occupied by n rectangles a_i of size 0.05*0.05 degrees by métier j for which effort E_j was greater than 0.

$$I_{DCF5,j} = A_j = \sum_n a_{i,j|Ei,j>0}$$

The indicator was based on annual values. The indicator is both mapped with binary values (0/1) and calculated as index.

5.3.2.2 DCF indicator 6: Aggregation of fishing activities

WGECO 2012 (p. 47 ff) specifies this indicator as either '2.1- Proportion of surface area fished by specific proportion of effort, or 2.2 - Proportion of surface area fished at specific trawling intensity'. Referring to the above mentioned comments (4.2.1) no intensities were calculated. Further, no proportion was calculated due to limited database.

5.3.2.3 VMStools function indicator

In calculating the surface area fished by a specific proportion of effort, WGSFD investigated the algorithm provided by the *VMStools* software package. The function *indicators* of *VMStools* prescribes that 'DCF 6 calculates the total area of a grid with fishing activity but keeps only the 90 per cent of the points by discarding the outer 10% points (or any other specified percentage). It uses the function tacsatMCP.r adapted from the *aspace* library. This function draws a minimum convex polygon around the central points to keep. Then these points are gridded and the total area of the cells is calculated with the surface.r function with the same optional methods as DCF 5. This total fishing area is processed by month.'

Thus, *vmstools* function *indicator* provides a geographic interpretation of aggregation starting from the midpoint of the métier distribution and moving outward. This leads to spurious aggregations patterns that do not represent main fishing grounds (Figure 2). For métier PTM_SPF_16-31_0_0, for which good coverage was obtained in WGSFD 2013, this means that important fishing ground in the Baltic are completely excluded while in the North Sea even disjointed rectangles with little effort are included in the space that is assumed to represent the main fishing pattern for this métier.

In the case of OTB_CRU_70-99_0_0, i.e. the *Nephrops* fisheries, a major fishing ground in the eastern North Sea would be likewise excluded, although this area is well known for its crustacean fisheries (Fock, 2008).

Maps are displayed at WGSFD 2013 > Data > False DCF 5 and 6 maps.

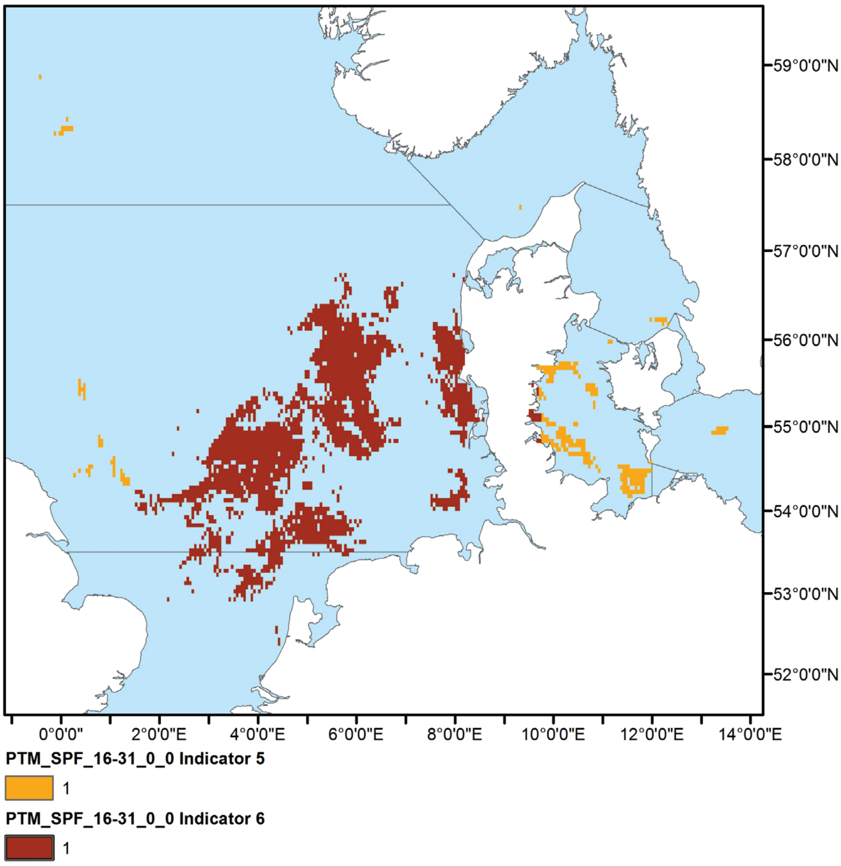


Figure 5.1. Métier distribution according to DCF 5 and aggregation representing DCF 6 calculated by *VMStools* function *indicator* with a threshold of 90%. Almost no areas from the Baltic are included.

5.3.2.3.1 Statistical interpretation of DCF 6

Several indicators, characterizing the extent to which fishing activity is aggregated, have been discussed. Part of the discussion has concerned the use of the Gini index computed for the positive effort values or the spreading area.

Analogous to the spreading area (SA) developed to characterize how a fish population is distributed in space taking into account variations in fish density (Woillez *et al.*, 2007; 2009), distribution of fishing effort in space (in total number of VMS pings or time spent fishing) can be described.

The spreading area is an index related to the Gini index (Gini, 1921), but which has the advantage over the Gini index of having no contribution from zero values. The Gini index (ranging from 0 to 1) equals twice the area between the Lorenz curve (in our case the graphical representation of the cumulative proportion of total effort vs. the cumulative proportion of area) and the 1: 1 line to which it would be reduced if all cell efforts were the same everywhere else. It depends on the proportion of zero values within the domain considered. By contrast, we define the SA as follows. Let T be the cumulated area occupied by the cell effort values, ranked in decreasing order, $Q(T)$ the corresponding cumulated effort, and Q the overall effort. The SA (expressed in area unit) is then simply defined as twice the area below the curve expressing (Q–$Q(T)$)/Q as a function of T:

$$\mathrm{SA} = 2\int \frac{Q - Q(T)}{Q}\mathrm{d}T \; .$$

So, the spreading area depends exclusively on the amount and the histogram of positive effort values. Changes in this index are likely to reveal changes in the way the total effort splits into low and high values. The area of zero values has no contribution to the spreading area (Figure 3). As (Q–$Q(T)$)/Q decreases from 1 to 0, and is convex, the SA is less than the positive area (PA), the total area where fishing occurs. It is equal to the PA when the effort is evenly spread. When normalizing the SA by the PA, we have the simple relation:

$$\frac{\mathrm{SA}}{\mathrm{PA}} + G_0 = 1 ,$$

where G_0 is the Gini index computed from positive values.

Zero values make no contribution to the spreading area, contrary to various indices that characterize aggregation (area coverage: Swain and Sinclair, 1994; Gini index: Myers and Cadigan, 1995; spatial selectivity index: Petitgas, 1998) which all relate to the area coverage of highest values. Therefore in the calculation of the spreading area index the delineation of the domain where data are positive is not necessary. The spreading area depends on the variation in cell effort values (and not on the overall effort) and is much less sensitive to low values of effort than the positive area.

5.3.2.3.2 WGSFD recommendation regarding DCF 6

Hence, following this statistical rationale aggregation of fishing activities can be described in 2 different ways: (1) in terms of mapping, based on the histogram of effort values, those areas are identified that cover a threshold of 90 percent of total effort and plotted based on 0/1 coded values. This is in line with the definition of ‘principal fishing areas’ as defined by Fock (2008), although here a threshold of 75% was applied, and allows to indicate the overlap between significant fishing areas and habitats. This produces straightforward figures of effort distinguishing between core areas and marginal areas less intensely used (Figure 5.3) and disjointed rectangles with little effort are mostly excluded from DCF 6. (2) As a single index value without mapping, the spreading area or the Gini index of the positive effort values could be computed routinely and serve as DCF indicator 6 to help characterize the aggregation of the fishing activity.

Maps are displayed at WGSFD 2013 > Data > DCF56_histograms.

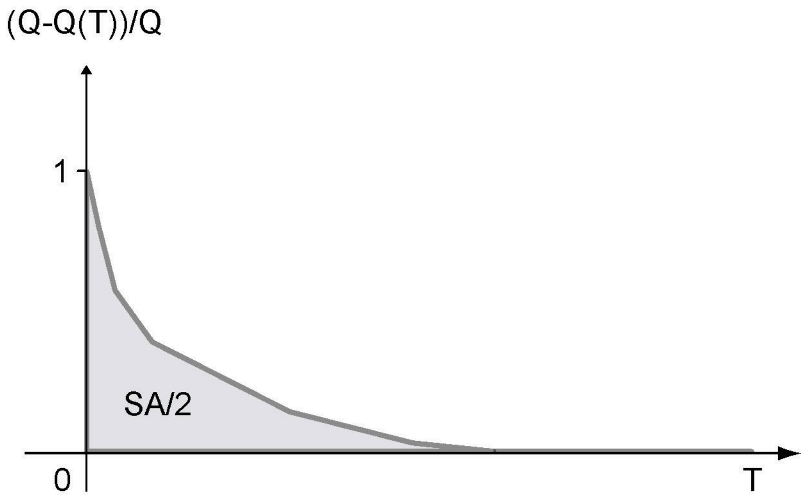


Figure 5.2. The spreading area (SA) is defined as twice the area below the curve expressing ($Q - Q(T))/Q$ as a function of T (after Woillez *et al.*, 2009).

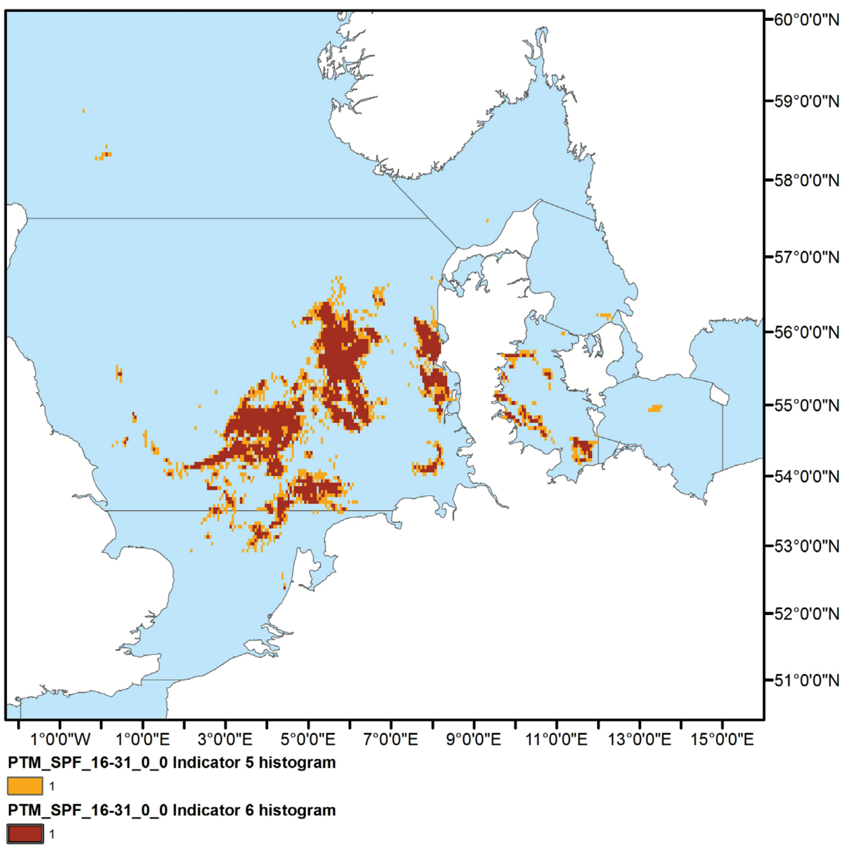


Figure 5.3. Métier distribution according to DCF 5 and aggregation representing DCF 6 calculated as 90%percentile cut-off in cdf histograms. It shows that each fishing ground is represented by a core area and a margin with less effort. Core areas for both the North and Baltic Sea are easily identified.

5.3.2.4 DCF indicator 7: Areas not impacted by mobile bottom gears

All PTB, OTB, TBB and S-métiers were included in the analysis of mobile bottom contacting gears *b*. Midwater gears with potential bottom contact were excluded.

DCF 7 is both mapped and calculated as index value:

$$I_{DCF7} = A_{SA} - A_b = A_{SA} - \sum_m a_{i,b|E_{i,b}>0},$$

where E_b is the effort by all bottom contacting gears in area unit a_i, m is the number of rectangles where $E_b>0$ and A_{SA} is the space of the respective ICES area.

Instead of relating the figure for DCF 7 to ICES areas it appears more reasonable to relate DCF 7 to habitat areas (Fock *et al.*, 2011). This would require habitat maps digitized and resolved to 0.05*0.05° c-squares, which were not available. It is recommendable to prepare such maps for all ICES areas. Habitats smaller than 0.05*0.05° can still be assigned to c-squares and be weighted by a multiplier indicating the portion of c-square inhabited by this habitat type (method applied in Fock *et al.*, 2011).

5.4 Conclusions and outlook for DCF indicators 5-7

The update and summary from WGSFD2013 was reviewed in WKIND and the following issues were raised and recommendations made by the workshop.

- WKIND supports the recommendations by WGECO and WGSFD of how the indicator metrics can be improved. These include the following:
  - increasing the resolution of the grid cells to 0.05 degrees,
  - applying the statistical techniques as recommended by WGSFD to calculate DCF indicator 6
  - expressing all three indicators as a proportion of total seabed area rather than absolute area.
- WKIND also reiterate the recommendation from WGSFD that the utility of indicators to measure the impact of fishing would improve if they are expressed in relation to habitat types. This is not only applicable to indicator 7 as proposed by WGSFD, but also to indicators 5 and 6. The interaction between gear type and habitat type can be directly evaluated and highlight where potential negative impacts are occurring. Static bottom fishing gear, for example, has a smaller spatial footprint than bottom mobile gear, but can be associated with vulnerable habitats such as biogenic reefs (ICES 2013b).
- The inclusion of intensity in the indicators was raised by WGECO 2012 and further discussed in WKIND. It is recommended that the concept of intensity is further developed by WGSFD with a view of developing gear specific measures of intensity. « Hours fished » does not have the same utility across gears. A more meaningful measure should be considered in relation to each gear and their anticipated impact. For mobile bottom gear this would be "number of times area trawled" in conjunction with "swept area", while for static gear which impact the bottom, a more meaningful measure might be the numbers of fishing operation which impact the bottom.
- Access to VMS data is still the main hindrance to a European wide computation of DCF indicators 5 to 7. The indicators have limited utility if not all national data sets and in particular the main fishing nations are contributing their data to the analysis. WGSFD has developed a data flow protocol which

includes data preparation in national laboratories including anonomysing national data. This should overcome some of the hurdles that prevent data access. Currently, data is provided by national experts who participate in WGSFD. It is strongly recommended that countries that cannot send national experts to WGSFD, follow the data routines and provide anonomysed VMS data for inclusion in future work by WGSFD. Details on workflow and data preparation are given in WGSFD 2013.

6 DCF Indicators 8 – Discard rates of commercially exploited stocks

6.1 Background to indicator

DCF indicator 8 is the rate of discarding of commercially exploited species in relation to landings. According to SEC2008 the indicator requires discard rates by species measured in weight, landings rates by species measured in kg and metier according to the 6 level metier classification recommended in SGRN 06-03. The indicator is the discard weight as a proportion of landed weight by species, fishing technique, quarter and year and can be calculated either with discards and landings data collected on the same trips or with raised data.

A composite indicator of discarding rates is derived by expressing the discard rates in any given year and for any given fishing technique as the proportion of the discard rates in the first 3 years of the time series. In any given year, a composite indicator would be calculated as the geometric mean of relative annual discard rates. SEC2008 states that the indicator should also be evaluated on a species by species level to identify the species responsible for reported trends in the composite indicator.

SEC2008 further notes that the current DCF does not specify the collection of discard data for many of the species that are most vulnerable to fishing. It is recommended that bycatch and discard monitoring should be extended to at least all the species that are used to compile the indicator 'Biodiversity of vulnerable fish species' in each marine region (see section 2).

6.2 Work and review by WKEID2010 and WGECO2012

In 2010, the Workshop on Ecosystem Indicators of Discarding (WKEID) attempted to construct time series of discard rates of commercially exploited fish species for a number of case studies (ICES, 2010). Due to limited data supplied to the workshop, only one indicator for one case study was calculated (trawl fisheries for cod in the Eastern Baltic (subdivision 25-35) (OTB_DEF_>=105_1_110). A GAM model was used to model the relative changes in discard rates. Estimated absolute rates compared closely to raised data. As this was only based on one case study, it was not possible to determine whether this approach was appropriate to generate absolute discard rates that can be compared across metiers.

The Working Group on the Ecosystem Effects of Fishing Activities (ICES 2012) did not have access to any discard data at the time of their meeting in April 2012. Therefore the group did not attempt the calculation of any discard indicators. Instead it listed several issues concerning the discard rate indicator:

- obtaining precise and accurate estimates of discard amounts is difficult owing to the inherently high variability of catch and discards, limited sampling effort, representativeness of trips for sampling and limited quality of data used to raise discard samples, such as effort or landings data.
- there is no standardisation of sampling programmes across countries, introducing potential differences in the data collected and the way they can be used to estimate discarding rates.
- There is no estimation of bias.

6.3 Discard data available to WKIND

Both groups, WKEID and WGECO, were not able to calculate DCF indicator 8 due to limited availability of discard data.

There are two databases housed in ICES which contain discard information on commercially exploited stocks. Intercatch contains catch data for ICES stocks, stratified by fleets and areas. Data is submitted by national data submitters and stock coordinators and the output is used in the ICES stock assessment process. Discard data is submitted by some countries for some stocks. A query on discard information in Intercatch revealed that discard information is only available from 2004 onwards for a restricted number of stocks. The number of stocks which have discard information in this database has increased steadily and there are now 54 stocks which contain discard estimates (Table 6.1).

Year	Count of Stocks per year which have discard information in INTERCATCH
2004	2
2005	1
2006	6
2007	5
2008	13
2009	19
2010	26
2011	34
2012	54

Table 6.1.) Number of stocks per year which have discard information in Intercatch.

The DCF indicator on discarding focuses on relative changes over time and requires the computation of a composite indicator by fishing method. WKIND considered that the data currently available in Intercatch is not suitable to compute the indicator as the available time series are too short and the data is reported by stock without consistent approaches across stocks and metiers.

The second data source within ICES is the regional data base which contains the disaggregated DCF sampling data. The database includes sampled discard data but these data are not raised to landings data and can therefore not be used for the calculation of discard to landings' ratios.

The availability and quality of European discard data has received much focus in recent months due to the upcoming obligation to land all catch. This is one of the measures introduced in the newly reformed common fisheries policy to reduce the effect of fishing on the marine ecosystem (Article 15 of the new CFP Basic Regulation (BR)). In September this year, a STECF meeting was held to review the issues for implementation, catch forecasting, stock assessment and control and monitoring associated with the newly introduced landings obligation (STCF EWG 13-16). Part of this meeting was to evaluate the differences between ICES and STECF discard estimates through a historic comparison of catch estimates, disaggregated into landings and discards, from the STECF and ICES data sources. This required the provision of catch data from both sources in time for the September STECF EWG meeting. The dataset provided by STECF in preparation of EWG 13-16 consisted of nationally submitted disaggregated catch data for the years 2003 to 2012 for 85 stock units covering all ICES ecoregions. WKIND considered this the most suitable dataset for the calculation of DCF indicator 8.

WKIND requested and received the prepared discard data from STECF and the use of these data by WKIND was agreed upon by all member states. Some member states did, however, raise concern about the use of the data to construct the discard indicator. The MS and EC concerns about the data are summarized below:

- The relevance of trends in discard rates as an indicator to measure the effects of fisheries on the marine ecosystem should be considered carefully in the light of the forthcoming discard ban (Ireland, Germany)
- There is inherent variability in the data due to low sample sizes (relative to overall fleet effort) and natural recruitment fluctuations (Ireland, Germany, Belgium, France)
- The STECF dataset is partly based on interpolations (i.e. 'borrowing' data from neighbouring cells where data are missing for certain métiers/areas/years/…) (Germany, France).

In addition, it is acknowledged that the data tables are not official yet and may be subject to changes during the STECF review process (including at the next plenary meeting from 4 to 8 November). The data was prepared for EWG -13-16 on landings obligation and the STECF report for this meeting will be officially released in week 47 (18-22 November).

6.4 Discard data: issues on consistency, data quality and raising procedures

When comparing discard data between STECF and ICES Intercatch for the mixed fishery in the North Sea, pronounced differences between the two different data sets have been noted (ICES 2013a), with ICES estimates of discards consistently higher than the estimates of discards provided in the STECF data base. The pronounced differences (of the order of 50% difference) in discard estimates are mainly due to different raising procedures applied.

Discard data quality and inconsistencies between discard estimates by ICES INTERCATCH and the STECF database have been examined by ICES, 2013b. The discrepancies in data can be related to differences in end user needs and required aggregation of the supplied data (see table X.2 for summary) as well as differences in the supplied data itself.

	ICES AWGs	STECF EGs
End user needs	AWGs need discard estimates by stock to estimate fishing mortality and population numbers at size or age. For some statistical models the catch data are disaggregated into broad fleet groupings to allow separate modeling of selectivity patterns.	STECF EWGs ask for data aggregated at very fine scales (e.g. métiers defined by target species, gear type, mesh size and in some cases vessel length class) in order to consider how management measures applied to vessels using different regulated and unregulated gears would affect overall fishing mortality at age.
Required aggregation and raising procedures	Prior to 2012, MS were free to supply data to the AWGs using raising and aggregation procedures appropriate to their sampling schemes. The national strata may have included fleet or gear groupings corresponding to a variable extent to those required by STECF. The data were then further aggregated to the stock levels as required for stock assessment models. In 2012, ICES called for North Sea fishery data to be entered on InterCatch at the métier level following a request by ICES WGMIXFISH. In 2013, the combined data call for the AWGs and WGMIXFISH was extended to the Celtic Seas ecoregion. For Intercatch to raise data by métier, raising factors are needed by métier. As national sampling schemes are frequently adequate only for the main métiers, procedures are needed to impute missing national estimates for any national métiers with no sampling. Currently there are few guidelines for dealing with this.	STECF EWG requirements are met by national scientists working with the same discards data supplied to ICES. Data are raised to the métier level by the national scientists. This may require complex manipulations of data and imputations where métier data are missing for areas or quarters. The raised data are supplied to the STECF database, and the Commission's scientists at JRC in Ispra apply algorithms that have been developed to make any imputations needed to fill gaps in data. Some countries and JRC, post submission, impute métier estimates for missing strata by "borrowing" data for sampled trips in surrounding strata, whilst other countries raise the data for sampled trips in accordance with their sampling scheme, then distribute data to the different métier cells proportionally to the raising factor.

Table 6.2: Differences in discard estimates due to differences in end user needs and required aggregation (based on review by ICES PGCCDBS 2013).

Differences related to discrepancies in the supplied data include the use of different units, differences in stock/report boundaries between ICES and STECF and different gear categories, metier definitions. There are concerns about the quality of data submitted by member states to STECF, in particular in the early years of the time series. Comparison of discard data from ICES and STECF, for stocks with available time series, indicates that discard estimates are converging in later years, giving more confidence in the overall quality of recent data (N. Graham, pers. com).

6.5 Review and update of indicator

6.5.1 Introduction

DCF indicator 8 "discarding rates of commercially exploited species" was analysed with data supplied from STECF, extracted and prepared for the purpose of EWG-13-16. The SEC2008 procedure to compute the indicator requires the following step by step procedure:

- As data input use discard rates by species measured in weight, landings rates by species measured in kg and metier according to the 6 level metier classification recommended in SGRN 06-03.
- Calculate total discard weight as a proportion of landed weight by species, fishing technique, quarter and year. As the indicator is a ratio it may be calculated with discards and landings data collected on the same trips or with raised data.
- To minimise the amount of information reported when summarising patterns of discarding, discard rates in any given year and for any given fishing technique could be expressed as a proportion of the discard rates in the first 3 years of the time series. In any given year, a composite indicator would be calculated as the geometric mean of relative annual discard rates.
- The indicator summarises trends in discard rates for a number of species and it is likely that users would also request species by species information on discard rates to identify the species responsible for reported trends in the composite indicator.

6.5.2 Procedure applied:

Grouping into ICES ecoregion:

To analyse the STECF catch data, the ICES divisions were matched to ICES ecoregion, as grouped in the table below.

ICES Ecoregion	ICES divisions	Ecoregion split in this study
Baltic sea	ICES IIIb, 22-32	Baltic sea
North sea	ICES IVa-c, IIIa, VIId	North sea
Celtic Seas	ICES VIa-b, VIIa-k	Celtic Seas
Bay of Biscay and Iberian Seas	ICES VIIIabd	Bay of Biscay
Bay of Biscay and Iberian Seas	ICES VIIIc, IXa	Iberian coast

From SEC 2008, it is not clear if the indicator refers to European waters only, or also requires the inclusion of discarding by European vessels in Non EU waters. Here, ICES divisions included EU and international waters.

Grouping into fishing technique:

The indicator requires the calculation of relative discard rates by species, fishing technique, quarter and year. Data was available with gear codes based on STECF classifications. In order to group these into fishing techniques the following classes were created:

Fishing technique	Code	Gear code in STECF data
Bottom trawl	BT	3a,3b,BEAM,BOTTOM TRAWLS,BT1,BT2,DEM_SEINE, GT1 None, OTTER, r-BEAM, r-DEM_SEINE, r-OTTER, TR1, TR2 ,TR3
Dredge	DR	DREDGE
Gillnet	GILL	3b, GILL, GN1 r-GILL,
Longline	LL	3c, LL1, LONGLINE, r-LONGLINE
Pots	POT	POTS
Pelagic Seine	PS	PEL_SEINE
Pelagic Trawl	PT	PEL_TRAWL PELAGIC TRAWLS r-PEL_TRAWL
Trammel net	TRA	3t ,r-TRAMMEL , TRAMMEL

The merging of data into gear classes is a trade off between ensuring adequate data availability per class while at the same time separating fishing techniques with different discard behaviours. It is acknowledged that within the class of bottom trawls, fisheries can exhibit very different discard patterns e.g. in beam trawls and otter trawls but also within otter trawls e.g. targeting *nephrops* or gadoids. These broad gear classes were used as an initial step for the analysis. More detailed analysis are required to define meaningful gear groupings with regards to discard behaviour and estimating the minimum sampling levels required to estimate discards with adequate precision for each gear grouping.

Elimination of low quality data:
In the supplied catch data, STECF has included an Index of Discard Coverage (DQI). The DQI is expressed by stock, fishery and Member State as the proportion of national landings covered by discard estimates in relation to the total national landings; DQI = ΣLd / ΣL where L denotes landings (t) and Ld landings with a discard estimate. STECF considers this an exploratory tool that allows the identification of the proportion of overall landings fishery that was sampled. In the data, the DQI is classified in three separate groups:

- A = 67 % or more of the provided landings are with an accompanying discard estimate,
- B = 34-66 % of the provided landings are with an accompanying discard estimate, and
- C = less the 33 % of the provided landings are with an accompanying discard estimate.

STECF considers **category A** estimates to be sufficiently reliable to be used for assessment purposes, as the majority of the landings by species and fishery are accompanied with a discard estimate. However STECF notes that this DQI cannot inform on the quality of the discard rate estimates supplied by nations, as affected for example by the proportion of fishing trips sampled for discards. It does not reflect the level of discarding each fishery carries out and it does not distinguish between a fishery with a high discard rate and a fishery with a low discard rate, or the level of sampling allocated to each fishery.

Category B discard estimates are considered to be less reliable than category A and require careful scrutiny before they are used for assessment purposes. **Category C** discard estimates are the least reliable and STECF considers that they should not be used for assessment purposes.

For the analysis of discard data in WKIND, only discards estimates and their associated landings with an A flags were selected. This corresponded to 18% of the records and 15% of the total landings.

6.5.3 Demonstration of indicator calculation using a case study

To demonstrate the calculation of the indicator and its outcome, a case study for a fishing technique in one ICES ecoregion was selected: this was the bottom trawl fishery in the Celtic Seas. Landings consist primarily of haddock, whiting, anglerfish and cod, while the dominant discarded species between 2003 and 2012 were haddock (43%) whiting (31%) and cod (6%). Blue whiting, plaice, saithe and skates and rays contributed a further 2-3% per species to the overall discard weight.

Single species discard ratios

As a first step, discard ratios were calculated for each species in relation to associated landings as stated in SEC2008. This however poses mathematical problems for species which are 100% discarded and have no recorded landings. The discard to landings ratio is also highly variable resulting in inflated values for species which have larger discards in relation to landing's weight, such as pelagic species in demersal gear. In the Celtic Sea case study, ratios ranged from 0 for *Nephrops* to >700 for pelagic species such as argentine. Results between species can only be effectively visualised on a log scale, but this precludes information on species with zero discarding such as *Nephrops* (figure 6.1).

The ratio of discards in relation to total catch, on the other hands, allows including 100% discard species and reduces overall noise. All ratios range between 0 and 1 (figure 6.2) and species can easily be compared with each other. WKIND recommends the indicator calculation to be based on discard to catch ratios and subsequent calculations by WKIND were carried out with this proposed adjustment.

Relative change over time

As the next step, the relative changes in discard ratios over time were calculated by expressing the discard to catch ratios in year 2006+ as a proportion of the mean in the first three years of the time series, ie 2003 to 2005 (fig.6.3). Relative discard ratios remained below 10 for most species but values above 20 were detected for monkfish, while values for sole ranged between 23 and 37 in years 2008 to 2010. The relative discard rate over time is based on an already calculated relative ratio, i.e. the ratio of discards to catches. While it highlights when drastic changes occur for some stocks in some years, it can mask general trends over time when comparing between species. It also results in the loss of three years in an already limited time series. All data is fixed to the first three years, making this the reference period. As there are concerns about the quality of the STECF data in the first years of the time series, the use of an early reference period is not advised.

WKIND recommends that discard ratios should not be expressed as a relative change over time, unless the specific intention is to evaluate the change in discarding behaviour against a particular event in time, e.g. as the response to the introduction of a management regime or change in data reporting requirements.

Calculation of composite indicator

SEC 2008 specifies a composite discard indicator to minimise the amount of information reported. In any given year, a composite indicator would be calculated as the geometric mean of relative annual discard rates. The geometric mean is proposed as it allows a better expression of the central tendency than the arithmetic mean when data is skewed or has extreme values. One of the problems associated with geometric means is that it cannot deal with zeros, because values are multiplied with each other, before taking the n^{th} root. In order to calculate the geometric mean, zeros need to be converted and choices have to be made which can influence the outcome of the indicator (see also section 2 on the conservation status of fish). WKIND calculated the arithmetic and geometric means and the geometric mean of the relative discard rate to demonstrate the different outcome of the indicator (figure 6.4)

If the recommendations by WKIND are followed to calculate the discard ratio on catches rather than landings and not to express the relative changes over time, values for all species, in all years, will range between 0 and 1. This will eliminate the necessity to use the geometric mean, and the arithmetic mean can be applied to calculate changes in discard ratios over time. When applying the average to create a composite discard indicator, it has to be noted that all species included in the catch receive equal weight. Some weighting criteria e.g. contribution of each species to total catch or a selection criteria, i.e. to only include species which contribute above a certain % to total catch should be considered.

Interpretation of the indicator and considerations for its use

The discarding rate of commercially exploited stocks is a pressure indicator that aims to measure the performance of the CFP in relation to the objectives of 'minimising the impact of fishing activities on the marine eco-system. To interpret this indicator correctly, it has to be considered that changes in discard ratios can be strongly influenced by recruitment variability. This can be demonstrated on e.g. Celtic Sea cod, which exhibited strong recruitment fluctuations in the last 10 years, some of which were mirrored in the change in discard rates (Figure. 6.5).

SEC2008 recommends that bycatch and discard monitoring should be extended to at least all the species that are used to compile the indicator 'Biodiversity of vulnerable fish species' in each marine region (see section 2). Due to low sampling levels, it is unlikely that the indicator will pick up any significant trends of discarding of vulnerable fish species. In order to improve sampling resolution, high risk fisheries (in relation to vulnerable fish species) should be identified and sampling restratified to enable reliable estimates of their discard levels.

The newly reformed CFP includes an obligation to land all catch, which refers to commercial species. Sampling programmes and the interpretation of trends in discard rates need to be considered in light of the discard ban.

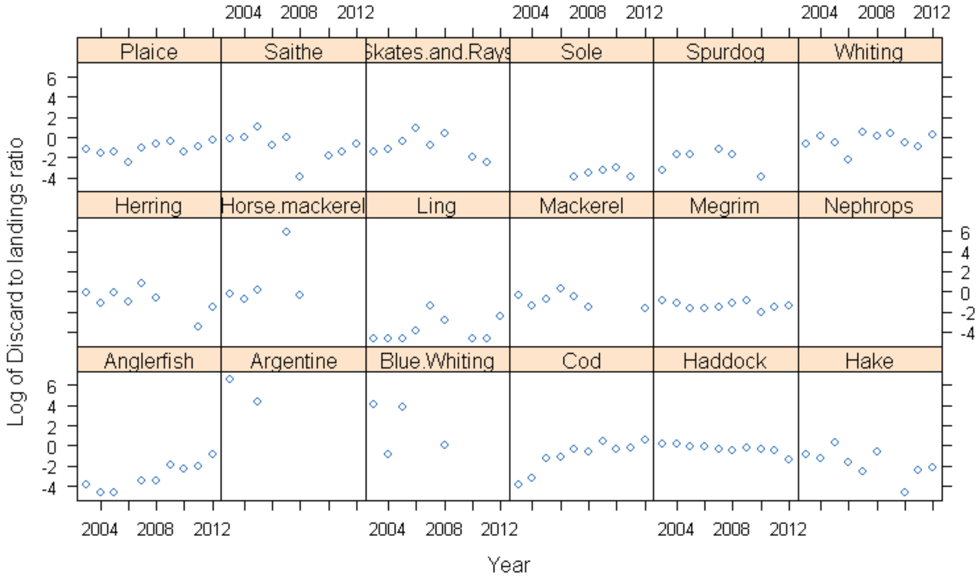


Figure 6.1 Discard to landings ratios: Bottom trawl in the Celtic Sea – data is presented on a log scale due to large data ranges, this results in loss of data for zero discard species eg nephrops.

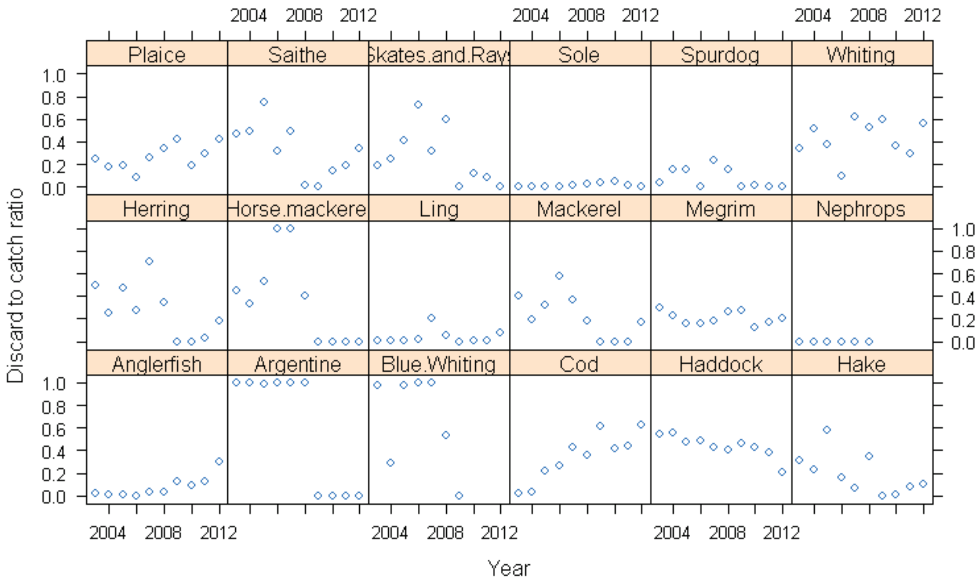


Figure 6.2 Discard to catch ratios: Bottom trawl in the Celtic Sea.

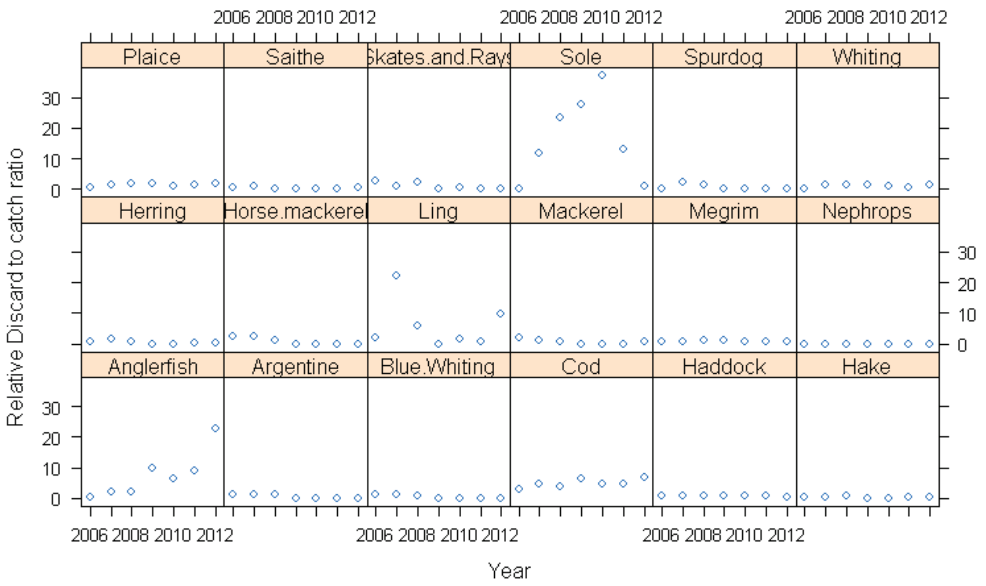


Figure 6.3 Relative discard to catch ratios (annual value as a ratio of the mean from 2003 to 2005) : Bottom trawl in the Celtic Sea.

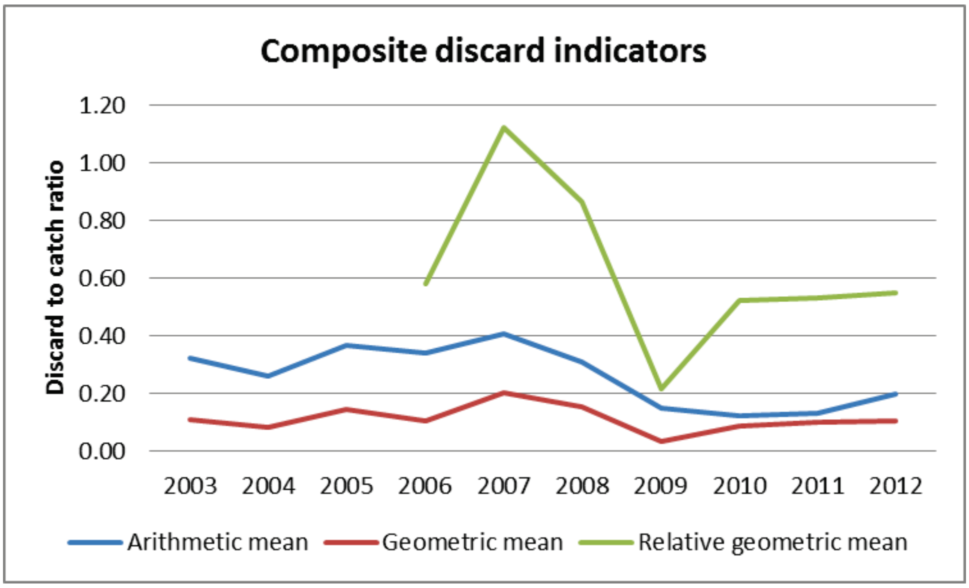


Figure 6. 4 Comparison of different calculations of the discard composite indicator for bottom trawling in the Celtic Sea: Arithmetic mean, geometric mean and the geometric mean of the relative change in discards over time (proportion of discard ratio in 2006+ to mean discard ratio 2003-2005).

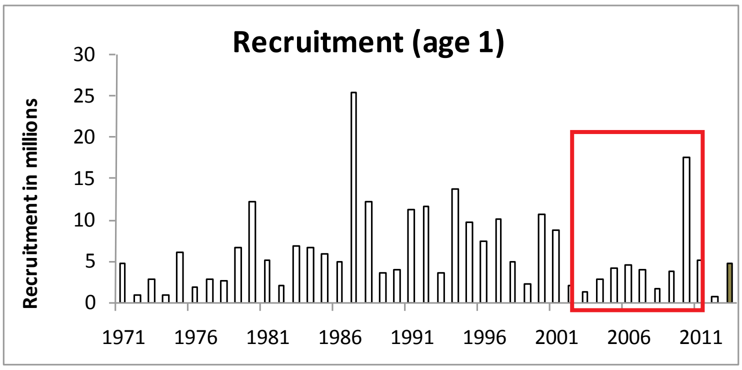


Figure 6.5 Recruitment of Celtic Sea cod as presented in 2013 assessment. Red box indicates period for which discard rates are reported in the STECF data.

6.5.4 Recommendations

By reviewing and testing the indicator calculation of DCF indictor 8 –"Discard rate of commercially exploited species", the following recommendations were developed:

- Discards should be expressed as the ratio to total catches rather than to landings.
- Time series of discard to catch ratios should be presented without fixing them to the average of the first three years.
- The arithmetic mean can be used to combine discard ratios of different stocks/species, however weighting factors or inclusion/exclusion criteria could be considered.
- The interpretation of trends in discard ratios needs to consider data quality issues and natural fluctuations in recruitment.
- The utility of the discard indicator needs to be reviewed in light of the newly introduced obligation to land all catch.
- Categories of "fishing techniques" per ecoregion should be defined based on availability of data and relevance to discarding behaviour. These might be at higher aggregation than metier level six to ensure sufficient data input, but lower than categories used in this study.

7 Conclusions and Recommendations

Table 7.1 summarises the main conclusions and recommendations on each of the eight DCF indicators:

	Indicator	Recommendation
1	**Conservation status of fish species**	There are concerns regarding the reproducibility and interpretation of this indicator. Direction and scale of the indicator is sensitive to decisions made when applying the protocol, including choice of reference period and species selection. Indicator can mask strong signals of single species abundance. Alternative single species metrics indicators to track the abundance of vulnerable species to be considered instead. Species selection could be based on approaches such LeQuesne *et al.*, 2012. Suitable approaches to track single species metrics are Greenstreet *et al.*, 2012; Probst *et al*. 2012.
2	**Proportion of large fish**	To be continued as a fish community indicator. Reference levels for existing time series to be carefully considered in relation to historic exploitation patterns. Otherwise directional trends can be used. Pressure state relationship should be further validated in different regions. Technical details including species list and length threshold need to be adjusted on a regional basis. Regional adaptations need to continue for most regions.
3	**Mean maximum length of fishes**	To be continued as a fish community indicator. So far there is no example of suitable reference levels. Approaches of reference level setting used in the LFI should be explored for the MML. Pressure state relationship should be further validated. Technical details including species list and length threshold need to be adjusted on a regional basis Regional adaptations need to continue for most regions. Weight based calculations improve the signal (larger fish) and reduces the noise (caused by fluctuations in small fish).
4	**Size at maturation of exploited fish species**	Due to data requirements, not suitable as a regionally wide DCF indicator to measure the effect of fishing on the ecosystem. This is due to timing of surveys, length of time series and or data collection. The indicator has already been applied to most of the stocks, for which adequate data is available. WGEVO to update these particular studies. There are a number of other stocks for which this indicator might be suitable, but dedicated studies are required to scan suitable data. To be continued on selected studies. For WGEVO to continue the development on operational indicators to measure the effects of fisheries induced evolution. PMRNs in themselves may not be a useful regional-wide DCF indicator, but rates of evolution, estimated from

		PMRNs, combined with information on the growth and mortality regime of the species, may have potential as an indicator of the effects of fishing on selected species.
5	**Distribution of fishing activities**	To be continued as pressures indicators with recommendations on adjustments including: DCF 5, DCF 6 and DCF7 should be expressed as a relative proportion of the seabed rather than the total area. Measure of intensity should be included in this indicator, however this should be considered on a gear by gear basis The indicator should be related to the type of habitat impacted
6	**Aggregation of fishing activities**	
7	**Areas not impacted by mobile bottom gears**	
8	**Discarding rates of commercially exploited species**	Suitable with technical adjustments, to measure effects of fishing on the marine ecosystem, but application needs to be reviewed in light of landings obligation. Interpretation needs to consider data quality, aggregation and strong signals of recruitment. Technical adjustments include: Expressing discard ratios as a proportion of catch, not landings Not expressing trends relative to the first three years of the time series Using the arithmetic mean
9	**Fuel efficiency of fish capture**	Not evaluated.

Table. 7.1 Conclusions and recommendations for the 8 DCF indicators.

General recommendation:

- Improve availability of survey data in DATRAS for all regions.
- It is recommended for ICES to develop data products that facilitate the calculation of the DCF indicators. These data products should include "Individuals per unit of swept area" in DATRAS.
- MS to follow WGSFD procedures to prepare VMS data and to submit to ICES prior to WGSFD independent of participation at the working group.
- For the EU via ICES to consider how the update and assessment of these indicators should be organised and how they can be integrated into ecosystem advice. A possible route is through WKECOVER and regional integrated ecosystem assessment WGs.

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Annex 1 – List of participants

Workshop on DCF indicators (WKIND)

21 - 25 October 2013

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Annex 2 WKIND ToR – Workshop on DCF indicators

2012/2/ACOM38 The **Workshop on update and calculation of the DCF indicators** (WKIND), chaired by Leonie Dransfeld (Country), will be established and will meet in ICES HQ, Denmark 21–25 October 2013 to:

c) Based on the outcome of WGECO 2012 and the WKEID 2010 examine and report on the DCF indicators of fishing pressures/impacts and possible developments/ improvements in these

d) Update the indicators in terms of technical details of how to do it if required and then make the actual analysis/calculation thereby establishing timelines for each indicator.

WKIND will report by 15 November 2013 for the attention of the Advisory Committee (ACOM)

Supporting information

Priority	ICES has a standing request from the European Commission to report on the DCF indicators
Scientific justification	The EU Data Collection Framework (DCF; Council Regulation (EC) No 199/2008 and EC Decision 2008/949/EC) requires the collection of data to construct indicator on fisheries impact on the environment i.e. fish stocks, fishing activities, impact on habitats and discard. The indicator on discarding rates of commercially exploited species is defined in the DCF as an indicator of the rate of discarding of commercially exploited species in relation to landings. The specified data required are: species, length and abundance of catches and discards based on respectively logbooks and observer trips processed separately. Data are to be linked to the level 6 for the metier classification (Appendix IV (1-5) of 2008/949/EC), meaning that data are required at the level of fishing ground, gear type, mesh band, target species. The DCF specifies collection of data on an annual basis with the exception of those which are specified to be collected at more disaggregated levels. The data specified for indicators in Appendix XIII of 2008/949/EC are to be collected at a national level in order to allow end-users to calculate the indicators at the relevant geographical scale, as given in Appendix II (sub-region/fishing ground, region or supra-region). Regulation 199/2008 requires Member States to collect discards data for metiers where discards are estimated to exceed 10 % of the total volume of catches.
Resource requirements	Sufficient data available based on a data call in spring 2013
Participants	The WK is expected to attract 15 experts.
Secretariat facilities	Meeting room and participation of the ICES data centre (DATRAS)
Financial	No costs identified
Linkages to advisory committees	ACOM
Linkages to other committees or groups	PGCCDBS, WGECO, SSGESST, WKDRP
Linkages to other organizations	European Commission