Report of the Working Group on the Ecosystem Effects of Fishing Activities (WGECO)

5–12 April 2017

Reykjavik, Iceland
Contents

Executive summary ..................................................................................................................................................1

1 Opening of the meeting .................................................................................................................................4

2 ToRs for the 2017 meeting ............................................................................................................................5

3 Integrate large-scale maps of sensitive benthos and fish and relate this to spatial distribution of effort and landings to identify high-fishing low-sensitivity areas and low-fishing high-sensitivity areas (ToR a) ...............6

   3.1 Introduction ...........................................................................................................................................6

   3.2 Methods ...............................................................................................................................................6

      3.2.1 Data ............................................................................................................................................6

      3.2.2 Analysis .....................................................................................................................................8

   3.3 Results ................................................................................................................................................9

   3.4 Discussion ...........................................................................................................................................16

      3.4.1 Methodological considerations .................................................................................................16

   3.5 Recommendations ................................................................................................................................17

   3.6 References ............................................................................................................................................18

4 Complete the investigation of possible indicators of scavengers, examine their relation to discard amounts and evaluate the spatial effect of a landing obligation on the scavengers (ToR b) ..................................................20

   4.1 Case study 1: Epifaunal scavenger species in the southern North Sea ..................................................21

   4.2 Case study 2: Hagfish in the northern part of the North Sea .................................................................22

   4.3 Case study 3: Hagfish in the Skagerrak and Kattegat .........................................................................22

   4.4 Case study 4: Benthic scavengers in the Grande Vasière .................................................................23

   4.5 Conclusion ..........................................................................................................................................23

   4.6 References ............................................................................................................................................23

5 Use the data available to evaluate the degree to which fisheries in the ICES region are “balanced” (ToR c) ...........................................................................................................................................25

   5.1 Introduction ...........................................................................................................................................25

   5.2 Methods ...............................................................................................................................................25

   5.3 Results ................................................................................................................................................27

   5.4 Ecosystem status ..................................................................................................................................36

      5.4.1 Results .......................................................................................................................................37

   5.5 Conclusions .........................................................................................................................................41

   5.6 References ............................................................................................................................................42

6 Estimate indicators of state of sensitive fish species throughout the ICES region (ToR d) ...........................................44
6.1 Northeast Atlantic ................................................................. 44
  6.1.1 Management Goal: Recovery of Sensitive Species Population Abundance ........................................ 44
  6.1.2 Management Goal: Halt Further Decline in Sensitive Species Population Abundance ........................................ 49
6.2 Examination of Individual Species Trends ................................................................. 53
  6.2.1 Within Region Consistency in Species Trends.................................... 54
  6.2.2 Between Survey Consistency in Species Trends ................................ 55
  6.2.3 Sensitivity and its Effect on Meeting or Missing Recovery Targets ................................................................. 58
6.3 Expanding the method of defining sensitive species to other areas – example of the Baltic Sea ................................................................. 58
6.4 Assessment conclusions ............................................................................. 60
6.5 References .................................................................................... 60

7 In support of providing ecosystem advice, define a list of relevant pressure, driver and state indicators to be estimated by relevant expert groups, including stock assessment groups (ToR e) .......................... 62
  7.1 Commercial fish .................................................................................. 63
    7.1.1 SSB and F-based indicators............................................................... 63
    7.1.2 Indicators addressing age and length structure ................................ 63
    7.1.3 Integration of indicators under the MSFD ......................................... 63
  7.2 Biodiversity and foodweb indicators .................................................. 64
  7.3 Indicators for biodiversity, foodwebs and commercial fish which are candidates for ICES to estimate routinely (automatically?) with present data resources......................................................... 70
  7.4 Benthic habitat .................................................................................... 72
  7.5 Marine litter ....................................................................................... 72
  7.6 Comparison with literature reviews of indicators ............................... 72
  7.7 Important gaps in indicator availability .............................................. 73
  7.8 Selected indicators ............................................................................. 74
  7.9 HELCOM indicators .......................................................................... 75
  7.10 OSPAR indicators ............................................................................ 76
  7.11 References ....................................................................................... 77

8 WGECO is requested to review three ICES workshop reports, WKBENTH (28 February–3 March 2017), WKSTAKE (23 March 2017), and WKTRADE (28–31 March 2017) (ToR f) ......................................................... 79
  8.1 WKBENTH ....................................................................................... 79
    8.1.1 Physical disturbance pressures ...................................................... 79
    8.1.2 Fishing impact indicators .............................................................. 80
    8.1.3 Review of the presented information on impact indicators .............. 82
    8.1.4 Considerations on the suitability of proposed indicators ............. 83
    8.1.5 Set reference levels ................................................................. 84
  8.2 WKSTAKE ....................................................................................... 84
8.3 WKTRADE ........................................................................................................... 85
  8.3.1 Draft advice format (WKTRADE Section 5) ............................................. 85
  8.3.2 Incorporation of WKSTAKE advice ...................................................... 88
8.4 Conclusions and the way forward ................................................................. 89
8.5 References ....................................................................................................... 89

Annex 1: WGECO 2017 Agenda ........................................................................... 90
Annex 2: Participants list ..................................................................................... 92
Annex 3: Vision for WGECO .............................................................................. 94
Annex 4: WGECO ToRs for 2018 ....................................................................... 97
Executive summary

The 2017 meeting of WGECO was held at Marine and Freshwater Research Institute (MFRI) in Reykjavik, Iceland from 5–12 April 2017. The meeting was attended by 14 delegates from ten countries, and was co-chaired by Stefán Ragnarsson (Iceland) and Jeremy Collie (USA). The work conducted was centred on five Terms of Reference, and one advisory request concerning the effects of trawling on benthic fauna, the spatial overlap between scavengers and discards, the degree of balance in fisheries, indicators of sensitive fish species, identification of operational indicators, and a review of three workshops on fishing pressure and sea floor status.

WGECO investigated which life-history traits determine the effect of trawling on benthic fauna. In this ToR, we examined how the relationship between trawling frequency (1/y) and longevity of benthic species varies with sediment position. No relationship between trawling frequency and biomass weighted average longevity was found when data from the whole dataset was used. This study showed that incremental removal of the deepest living infauna (i.e. remove all infauna >10 cm, then all infauna >5 cm) from the analysis yielded significant negative relationships of increasing strength. These findings indicate that living in deeper layers provides a protection from trawling. Surprisingly, the relationship between trawl frequency and longevity among exclusive surface dwelling organisms was slightly positive (and significant). Explaining this counterintuitively finding is difficult. The trait composition of surface and subsurface fauna is largely different and the diversity of traits among the exclusive surface dwellers was greater. There was greater incidence of mobile fauna among the surface dwellers, which may be rapid in recolonising recently fished locations. These findings indicate that life-history traits in addition to longevity are needed for calculating indicators of benthic sensitivity to bottom trawling. This work shows how the ‘longevity approach’ and the ‘population dynamics approach’ developed in WKBENTH (see below) may be reconciled.

The introduction of the Landing Obligation may have consequences in the marine ecosystem. Extracting biomass which is otherwise discarded may have consequences for the scavenger species that feed upon the discards and secondary responses following from them. Banning a substantial part of the discards is expected to decrease populations of large generalist scavenging seabird species. Modelling studies suggest that these large-scale effects will be mirrored in benthic communities, but empirical data at large-scale are missing. WGECO evaluated the potential link between scavengers and discarded biomass at fine-scale spatial resolution while accounting for the main environmental drivers, which may have confounded a possible relationship. The analysis did not lead to a demonstrable relationship between discarded biomass and scavenger abundance at fine-scale resolution in the North Sea. Discard estimates were not available for the Skagerrak and Kattegat, but the presence of hagfish was analysed in relation to swept-area distribution. There was a statistically significant effect of fishing on the spatial distribution of hagfish, but its biological implications were minor. A correlation between discards and benthic scavengers was not found in a reported Bay of Biscay case study. In conclusion, whereas the (partial) elimination of discards resulting from the landing obligation may have both detrimental and beneficial effects on seabird communities, there are no indications from our analysis that similar large-scale effects are to be expected in the epifaunal invertebrate community.
WGECO has developed a promising **empirical approach to measure the degree of balance in fisheries**. An ecological index, niche breadth, was adapted to provide a single measure of balance across species in an ecosystem. We applied this method to multiple time periods in seven different ecosystems. On average, niche breadth was highest in Iceland and the Gulf of Maine and lowest in the Mid Atlantic Bight. In the 1980s the degree of balance increased in three of the four New England regions; in recent years, the degree of balance in all regions remained constant or decreased. A size-based model was used to identify thresholds for community indicators based on the risk of depletion of species in the community. Further work will allow us to demonstrate whether the proposed metrics related to balance between fishery and ecosystem are consistent with exploitation patterns that will maintain species diversity in the ecosystem in the long term.

The **Proportion Failing to Spawn (PFS) sensitivity metric used to derive suites of sensitive species**. The “abundance of a suite of sensitive fish species” indicator and assessment protocol was applied to 19 groundfish survey sensitive species suites to assess their abundance status at survey, individual Region and Northeast Atlantic Area scale. Recovery was apparent among a significant number of sensitive fish species only in the Celtic Seas Region, but further decline in abundance among sensitive fish species has been halted in all four Regions and across the Area. Individual species trends were examined to determine whether: (i) within a region the same species consistently met or missed their individual abundance targets; (ii) whether across different regions, the same species consistently met or missed their individual abundance targets; and (iii) whether a species’ PFS sensitivity metric score had any influence on its likelihood of either meeting or missing its abundance target. Finally, some of the issues that would require consideration if the “abundance of a suite of sensitive fish species” indicator were to be used in the Baltic Sea are introduced and briefly discussed.

WGECO provided a **working list of indicators that could be developed and made operational** by the ICES secretariat or selected expert groups. The descriptors covered were mainly biodiversity and foodweb indicators, but also included brief consideration of indicators of age and length structure in fish, and marine litter. WGECO based this work principally on the common indicators developed by OSPAR, ignoring candidate indicators, which are not usually operational. Evaluations of many, but not all, the indicators chosen have been carried out by WKFOOWI and WGBIODIV. From this selection WGECO used a polling approach to identify the five best candidates for operationalisation based on their effectiveness, defined methods, and data availability:

- FC1, Fish abundance - sensitive species indicator;
- Mean weight-at-age of predatory or planktivorous fish species from data;
- PH2, Plankton biomass and/or abundance;
- Guild level biomass; and
- FW3, Size composition in fish communities (TyL pelagic and demersal).

The top five are rather dominated by fish focused indicators, which probably reflects both the general focus of WGECO expertise, but also the maturity of the indicator development and the availability of good data. WGECO also identified six other indicators that could be developed by ICES, which provide a wider ecological range including top predators, and phytoplankton, as well as trophic and distribution based indicators.
As requested WGECO reviewed the reports of three workshops on fishing pressure and seafloor status (WKBENTH, WKSTAKE, and WKTRADE). Several indicators have been put forward for the assessment of fishing pressure and its impact on the seafloor status. Physical disturbance indicators appear to be sufficiently well advanced for assessment purposes. When reporting those indicators the spatial resolution needs to be provided as the indicator value depends on the spatial resolution of the fishing effort data. Higher resolution will give lower pressure values and a smaller fishing footprint. The impact indicators have not matured to the point that they can be used for advice. Several potential indicators are provided which give very different results but there is no scientific basis to select a best indicator. In general, methods that include both Resistance/Depletion and Resilience/Recovery can be considered more specific to the physical disturbance pressure. The population dynamics (PD) approach is specific to physical disturbance and is likely to respond to changes in fishing pressure. A weakness of the PD approach is that it only provides information on the total biomass of the benthic community, which is only one aspect of seafloor integrity. It seems unlikely that one indicator will suffice to address all aspects of benthic status; therefore, a suite of indicators will probably be necessary. As a way forward, WGECO recommends that the further development of these indicators focuses on combining, where possible, the strengths of the different methods. Priority actions identified by WKSTAKE were to identify and communicate the uncertainty associated with maps, accounting for local details, consideration of vessel displacement and gear changes, and coverage of smaller (<12 m) vessels. In its review of WKTRADE, WGECO made specific suggestions for improving the draft advice format.
1 Opening of the meeting

The Working Group on the Ecosystem Effects of Fishing Activities (WGECO) met at Reykjavik, Iceland from 5–12 April 2017. The list of participants and contact details are given in Annex 1. The chairs, Jeremy Collie (USA) and Stefan Ragnarsson (Iceland), welcomed the participants and highlighted the variety of ToRs. The draft agenda was presented (Annex 2) and Terms of Reference for the meeting (see Section 2) were discussed. A plan of action was adopted with individuals providing presentations on particular issues and allocated separate tasks to begin work on all ToRs.
2 ToRs for the 2017 meeting

The Working Group on the Ecosystem Effects of Fishing Activities (WGECO), chaired by Jeremy Collie (US) and Stefan Ragnarsson (Iceland), will meet in Reykjavik, Iceland 5–12 April 2017 to:

a) Integrate large-scale maps of sensitive benthos and fish and relate this to spatial distribution of effort and landings to identify high-fishing-low-sensitivity areas and low-fishing-high-sensitivity areas:
   i) Request VMS effort maps where these are not available;
   ii) Rectangle based catches for the species listed;
   iii) Request map of sensitive habitats where these are available from WKFBI or BEWG.

b) Complete the investigation of possible indicators of scavengers, examine their relation to discard amounts and evaluate the spatial effect of a landing obligation on the scavengers;

c) Use the data available to evaluate the degree to which fisheries in the ICES region are “balanced”:
   i) Establish the distribution of total catch (landing+discards) among size classes (catch size spectrum), species and functional groups;
   ii) Examine how the degree of balance is related to ecosystem status;
   iii) Request catch by species and length group for the species listed;
   iv) Request survey biomass by species and length group, where possible catchability corrected.

d) Estimate indicators of state of sensitive fish species throughout the ICES area;

e) In support of providing ecosystem advice, define a list of relevant pressure, driver and state indicators to be estimated by relevant expert groups, including stock assessment groups;

f) WGECO is requested to review three ICES workshops reports, WKBENTH (28 February–3 March 2017), WKSTAKE (23 March 2017), and WKTRADE (28–31 March 2017).

WGECO will report by 24 April 2017 to the attention of the Advisory Committee.
Integrate large-scale maps of sensitive benthos and fish and relate this to spatial distribution of effort and landings to identify high-fish ing low-sensitivity areas and low-fishing high-sensitivity areas (ToR a)

3.1 Introduction

When this ToR was conceived (ICES, 2016) the first maps of sensitive fish had only just been created and there were no maps of sensitive benthos. Now improved maps of sensitive fish are about to be created and several methods to determine the sensitivity of the benthic community exist. A review of these methods (see ToR f) showed that the resulting benthos sensitivity maps are highly dependent on the choice of methods to estimate benthos sensitivity. Moreover, as the fish sensitivity maps were being revised it was decided to postpone the exercise of collating and combining the various maps until more definitive version of the maps required become available. In order to contribute to this process WGECO explored the possibility to improve the methods to calculate benthos sensitivity. This work was guided by the outcome of the review of the currently available methods (see ToR f). This exploration intends to bring together the strengths of the different methods while avoiding the weaknesses, thereby reconciling some of the methodological differences identified.

The two methods we attempt to reconcile are 1) the population dynamics approach and 2) the longevity-based approach. The population dynamics-based approach has advantages in terms of its applicability as part of integrated assessments and management, but lacks the capability of the trait-based approaches to consider changes in functional composition. As part of this exploration we will consider the application of this approach for habitats other than those for which the two methods were applied, i.e. level-bottom habitats: EUNIS Level 3 A5.1–5.4.

We hypothesize that a number of traits are key determinants of the effect of trawling on benthic fauna, and particularly that there is a degree of interaction among trait modalities in determining sensitivity of individual taxa. A potential example of such trait interdependence, which we test here, is that between sediment position and longevity. Changes in the community distribution of longevity were recently tested as an indicator of bottom-trawling impact on the seabed community (Rijnsdorp et al., 2016). However, trawl gears disturb only the surface and upper layers of the sediment, so deeper-living taxa are expected to suffer less than surface and near-surface inhabitants.

3.2 Methods

3.2.1 Data

The dataset used in this analysis was that of the Dutch annual national benthos survey (boxcorer samples, area 0.1 m²), combined with annual trawling frequency data calculated from VMS records of the Dutch beam trawl fleet (the dominant fleet in the area). The same dataset has been used in previous papers, where further details can be found (Van Denderen et al., 2014; Van Denderen et al., 2016). Because of the small size of the sampled sediment and the considerable variation in the exact location of each sampling station across years (~100s of meters), we considered each annual replicate as an independent sample. Fishing intensity for the sampled stations was only available to us for the period 2002–2007, so for analyses relating traits to
fishing, we used only that period. To compare trait composition of specific groups (surface vs. 0–5 cm infauna), we used the entire time-series available (1991–2010).

Table 1. The ten traits and their 47 modalities, as developed within the BENTHIS project and used in Bolam et al., 2017.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Infaunal categories</th>
<th>Trait definition and functional significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size range</td>
<td>≤10 mm</td>
<td>Maximum recorded size of adult (as individuals or colonies).</td>
</tr>
<tr>
<td></td>
<td>11–20 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21–100 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>101–200 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200–500 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;500 mm</td>
<td></td>
</tr>
<tr>
<td>Morphology</td>
<td>Soft</td>
<td>External characteristics of the taxon.</td>
</tr>
<tr>
<td></td>
<td>Tunic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exoskeleton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crustose</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cushion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stalked</td>
<td></td>
</tr>
<tr>
<td>Longevity</td>
<td>&lt;1 year</td>
<td>Maximum reported lifespan of the adult stage.</td>
</tr>
<tr>
<td></td>
<td>1–3 year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4–10 year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;10 year</td>
<td></td>
</tr>
<tr>
<td>Larval development strategy</td>
<td>Planktotrophic</td>
<td>Indicates the potential for dispersal of the larval stage prior to settlement from direct (no free-living larval stage), lecithotrophic (larvae with yolk sac, pelagic for short periods, often ≤3 days) to planktotrophic (larvae feed and grow in water column, generally pelagic for several weeks).</td>
</tr>
<tr>
<td></td>
<td>Lecithotrophic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct</td>
<td></td>
</tr>
<tr>
<td>Egg development location</td>
<td>Asexual/fragmentation</td>
<td>Indicates dispersal via the egg stage and the potential susceptibility of larger eggs to damage from fishing.</td>
</tr>
<tr>
<td></td>
<td>Eggs – pelagic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eggs – benthic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eggs – brooded</td>
<td></td>
</tr>
<tr>
<td>Living habit</td>
<td>Tube-dwelling</td>
<td>Indicates potential for the adult stage to evade, or to be exposed to, physical disturbance.</td>
</tr>
<tr>
<td></td>
<td>Burrow-dwelling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free living</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crevice/under stone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Epi/endo - zoic/phytic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attached to bed</td>
<td></td>
</tr>
<tr>
<td>Sediment position</td>
<td>Surface</td>
<td>Typical living position in sediment profile.</td>
</tr>
<tr>
<td></td>
<td>0–5 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5–10 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;10 cm</td>
<td></td>
</tr>
<tr>
<td>Feeding mode</td>
<td>Suspension</td>
<td>The method by which the organism collects food.</td>
</tr>
<tr>
<td></td>
<td>Surface deposit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsurface deposit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scavenger</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Predator</td>
<td></td>
</tr>
<tr>
<td>Trait</td>
<td>Infaunal categories</td>
<td>Trait definition and functional significance</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mobility</td>
<td>Sessile</td>
<td>Possibility and method of adults to move.</td>
</tr>
<tr>
<td></td>
<td>Swim</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burrow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crawl/creep/climb</td>
<td></td>
</tr>
<tr>
<td>Bioturbation</td>
<td>Difusive mixer</td>
<td>Describes the ability of the organism to rework and irrigate the sediment.</td>
</tr>
<tr>
<td></td>
<td>Surface deposition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upward conveyor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Downward conveyor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

In order to analyse the sampled data we make use of the Biological Trait classification from Bolam et al. (2014; 2017), which classifies benthic genera in a fuzzy-coded matrix of traits (Table 1). The fuzzy coding used in this classification allows for an inclusion of the degree of uncertainty in the data underlying the classification and the potential occurrence of multiple trait modalities within each classified genus.

We studied the strength of the relationship between mean longevity of the sampled species and bottom-trawling intensity for various subsets of the data with regards to other traits, particularly ‘sediment position’. In order to do so using a linear regression, we assumed the longevity classes represent average longevities of 0.5, 1.5, 6.5 and 15 years respectively. This allowed us to calculate average longevity for each genus present in each sample. The average longevity per sample, weighted by the relative biomass contribution of each genus to that sample, yielded the average sample longevity, which we used in our analysis. Hereafter we refer to this Biomass Weighted Average Longevity as BWAL.

To further explore the variation in trait composition of surface dwellers and infauna, we compared their trait composition using data from the same survey as those described above. The main aim of this comparison is to explore the difference in trait composition between taxa living on the seafloor and those living (at any depth) below the surface. For that reason, we defined two categories, ‘non-surface’, having a value of 0 in the ‘surface’ modality of the sediment position trait and all other taxa, which have non-zero value in that modality. It should be noted that due to the fuzzy coding of the trait classification, the ‘surface’ category does not exclude all subsurface species, but rather includes those that do to some extent occur on the surface, although they may also count as infauna. The two categories are however mutually exclusive, so that the comparison is not clouded by genera occurring in both.

### 3.2.2 Analysis

We applied a linear regression model to the relationship between BWAL and fishing intensity, for varying subsets of the data. To test our hypothesis that the relationship between longevity and fishery is less relevant to the deeper burrowing infauna, we applied this regression first to the full dataset, then to the data with the deepest infauna (the >10 cm modality of the trait ‘sediment position’) removed, and then with the >5–10 cm class removed as well. Our criterion to test the hypothesis was not solely dependent on the significance of the relationship, but also on the degree to which variation in fishing intensity explained variation in BWAL, which was represented by the coefficient of determination, $r^2$. In addition, the direction of the
relationship is important, as a positive effect would indicate a strong deviation from expectations.

3.3 Results

Using all species to compute BWAL, we found that trawling frequency has virtually zero explanatory power ($r^2<0.01$, Figure 3.3.1) on average longevity. The same analysis but with all deeply burrowing genera removed, considerably strengthened the relationship, and the explanatory power of trawling intensity (Figure 3.3.2). The linear regression was significant ($p<0.01$), negative (a reduction of longevity of ~9 months per unit trawling frequency), and trawling intensity explained nearly 10% of the variation in BWAL across samples ($r^2=0.0847$).

Figure 3.3.1. Relationship between BWAL (years) and frequency of beam trawling (1/years) for all genera in the dataset. The dotted line is a non-significant ($p>0.1$) linear regression. The regression equation and coefficient of determination ($r^2$) are overlaid.
Figure 3.3.2. Relationship between BWAL (years) and frequency of beam trawling (1/year) for all genera with a score of 0 in the modality ‘>10 cm’ in the ‘sediment position’ trait. The drawn line is a significant (p<0.01) linear regression. The regression equation and coefficient of determination (r²) are overlaid.

Excluding the second-deepest (>5 cm) modality of the trait ‘sediment position’ from the analysis (Figure 3.3.3) revealed an even stronger relationship (again, p<0.01), where trawling frequency explained ~16% of the variation (r²=0.158) in longevity and each unit trawling frequency reduced BWAL by ~1.2 years. Hence, the significance of the relationship between longevity and trawling intensity, the magnitude of the effect (steepness) and the fraction of the variation explained were all greater when the deepest-living modalities were excluded from the regression. If we focus on the infauna genera which are categorized exclusively as living in a sediment position between 0–5 cm (having scores of zero in all other modalities of ‘sediment position’), this result was further strengthened (Figure 3.3.4). Significance remained high (p<0.01), the coefficient of determination increased to ~0.23, and the effect increased to a reduction of 1.6 years longevity per unit trawling frequency.

However, calculating the same linear regression but based only on taxa that live exclusively on the seafloor surface (those taxa that have zero values in all modalities of the ‘sediment position’ trait except ‘Surface’), yields a different pattern (Figure 3.3.5). While the regression is still significant (p<0.05), it is now positive, indicating that average longevity increases by ~3 months with each unit increase in trawling frequency. There is also a reversal in the trend of an increasing coefficient of determination (r²=0.0153) with higher-living taxa. The appearance of a ‘threshold’ longevity in the surface dwellers is somewhat artificial. It corresponds to our assumed average longevity of the ‘>3–10 years’ longevity modality which strongly dominates in this group.
Figure 3.3.3. Relationship between BWAL (years) and frequency of beam trawling (1/years) for all genera with a score of 0 in the modalities ‘>10 cm’ and ‘>5–10 cm’ in the ‘sediment position’ trait and thus including ‘surface’ dwellers. The drawn line is a significant (p<0.01) linear regression. The regression equation and coefficient of determination (r²) are overlaid.

Figure 3.3.4. Relationship between BWAL (years) and frequency of beam trawling (1/years) for all genera with a score of 0 in all modalities of the ‘sediment position’ trait, except ‘0–5 cm’. The dotted line is a non-significant (p>0.01) linear regression. The regression equation and coefficient of determination (r²) are overlaid.
Figure 3.3.5. Relationship between BWAL (years) and frequency of beam trawling (1/years) for all genera with a score of 0 in all modalities of the ‘sediment position’ trait, except ‘Surface’. The dotted line is a non-significant (p>0.1) linear regression. The regression equation and coefficient of determination ($r^2$) are overlaid.

We hypothesize that this unexpected result may be due to the possibility that surface dwellers are qualitatively different from infauna in other traits, which may result in them having alternative properties affecting their sensitivity to trawling. To explore this possibility, we compare differences in the composition in all traits, between infauna and surface dwellers (taxa with 0 in ‘surface’ modality vs. those with a positive value, Figure 3.3.6).

The results of this comparison show in general that the surface dwellers have a more diverse trait composition than the infauna. This is most obvious in the egg- and larval types, feeding type, mobility, habitat and size. Surface dwellers have both direct and planktonic larval- and egg dispersion strategies, whereas infauna consist of almost exclusively planktonic strategies. Infauna are furthermore almost by definition sessile (tube- and burrow dwelling) and are dominated by suspension feeding, whereas surface dwellers are often (free-living) mobile predators and/or scavengers. The maximum size of infauna is generally between 2 and 20 cm, whereas surface dwellers span the full range from <1 cm to >50 cm. Virtually all infauna are engaged in some form of bioturbation, while a significant fraction of surface dwellers have no such role.
Figure 3.3.6. Trait composition of non-surface (left hand panels, trait ‘sediment position’ modality ‘Surface’=0) and surface dwellers (right hand panels, trait ‘sediment position’ modality ‘Surface’>0), by year from 1991 to 2010.
Figure 3.3.6. Continued.
Figure 3.3.6. Continued.
3.4 Discussion

We have shown that the relationship between longevity and trawl frequency becomes stronger both in effect size and in the variance explained, as deeper infauna are excluded from the analysis. Our analysis confirms that longevity shows a response to trawling frequency, which is strongest for infauna living at depths which are within reach of the gear (i.e. >0–5 cm) and thus excluding surface dwellers. The beam trawl gears on which our trawling intensity is based have been shown to have a seabed penetration depth in the 0–5 cm range (Depestele et al., 2015). These results support the hypothesis that living in the deeper layers of the sediment in this area is an effective protection against the effects of trawling.

Based on their relative degree of exposure to the trawl gears, we had expected that longevity of sediment surface dwellers would be most strongly related to trawling frequency. Surprisingly, the results show a significant positive relationship between bottom trawling and longevity, but this explains very little of the variation. Further exploration of the trait composition of the surface dwellers and infauna shows that these groups differ substantially. One important distinction is the substantially higher presence of mobile fauna among the surface dwellers. This is a potential alternative mechanism facilitating quick recovery after trawling mortality, at least on a local scale, as it allows for quick recolonization of trawl paths.

One unexpected difference between infauna and surface dwellers is that the latter have a higher fraction of ‘local’ (e.g. non-planktonic) larval stages. This is somewhat counterintuitive as this is a trait which is expected to slow down recovery from trawling mortality (Bolam et al., 2014). However, fishing mortality is only one of many factors determining fitness for these organisms, and ‘local’ larval stages may be a favoured based on other aspects of selection, such as a highly dynamic environment.

3.4.1 Methodological considerations

The WKBENTH report presents a suite of benthos indicators that were developed to assess bottom-trawling impacts of northern boreal habitats (ICES, 2017). Three sets of benthic indicators (i.e. Long-LL 1–2, Long-SBI1–2 and PD1–2), which evaluate chang-
es in benthos relative biomass alone or combined with species longevity were discussed. The indices PDA1–2, Long-SBI1–2 and BH2 included the total fauna assemblages whereas only subcomponents of the fauna were addressed by Long-LL1–2 (long-lived species).

3.4.1.1 Quantitative benthos indices (QBI)

The quantitative benthos indices (i.e. Long-LL1–2, Long-SBI1–2, PD1–2) were all developed based on fauna sieved (mesh size: 1 mm) from sediment collected by a grab or core sampler (i.e. a Day-, Hamon-, or van Veen-grab sampler, or a Reineck boxcorer).

These indices were thus all designed for sediment habitats composed of mud, sand and/or fine gravel only, and were specifically assigned to the three (four) marine level-bottom substrata categorised as the EUNIS Level 3 Habitats: A5.1 ‘Sublittoral coarse sediment’; A5.2 ‘Sublittoral sand’; and A5.3 ‘Sublittoral mud’ (and partly 5.4 ‘Sublittoral mixed sediments’) (ICES, 2017; Rijnsdorp et al., 2016). The quantitative indices can thus not be applied to other habitat types (ICES, 2017), such as pebbles, boulders, bed rock and biogenic habitats (e.g. sponge bottoms, bivalve and coral reefs, limestone deposits, shell gravel and fossilised oak grounds).

The sampling gear used to collect the data used here (and that on which the WKBENTH analysis is based on) collects the upper 15–25 cm sediment of ~0.1 m² seabed. Most sampling stations were represented by 1–6 replicate samples (ICES, 2017), thus a total sampling area of ≤1.0 m². This sample size (and total area of coverage) is generally considered adequate for quantitative sampling of common and evenly distributed macrofauna species of smaller individual body sizes (area cover between 0.05 and 1–2 cm²). Larger megafauna species (with an area coverage ≥1–2 cm²) of sessile (sponges, sea pens) and mobile epifauna (brittlestars, starfish, feather stars, decapods, gastropods and sea pens) or deep-burrowing infauna (such as quahog) or mobile epifauna/deep burrowers (several decapods, such as Norway lobster) are either not caught or greatly underestimated when using the above sampling techniques and design. This also applies to rare or highly patchily distributed species of both macro- and megafauna species (Eleftheriou and Moore, 2013). In order to check the robustness of the approach, the method should also be tested using data collected by other types of sampling gear, such as dredges.

3.5 Recommendations

Based on the results obtained in this preliminary study, we suggest that the development of indicators of seafloor integrity follows a three-pronged approach, where the benthic community is first divided into three groups, separated by burying depth, which we have shown strongly mediates the validity of longevity as a response variable for fishing impact. We suggest the following groups:

1) Surface (=vulnerable)
   1.1) Calculate fishing intensity based on surface swept-area, independent of métier.
   1.2) Estimate depletion (not specific to habitat).
   1.3) Recovery is independent of longevity but determined by recolonization through mobility, whereby swimming and/or crawling taxa are less susceptible than burrowing and sessile taxa.
2) Subsurface vulnerable (sediment position < penetration depth of the gear).
   Gear penetration depth is 0–5 cm for all gears except for the hydraulic dredge (HD), which penetrates all three subsurface categories (Table 3.5.2).
   2.1) Calculate fishing intensity per métier based on subsurface swept-area.
   2.2) Estimate corrected habitat-specific depletion based only on relevant taxa.
   2.3) Recovery is determined by longevity, but new a biomass longevity distribution needs to be calculated based on relevant subset of taxa.
3) Subsurface not-vulnerable (sediment position > penetration depth of the gear). For all gears except HD this is >5 cm (Table 3.5.2).
   3.1) Calculate fishing intensity based on subsurface swept-area.
   3.2) There is no depletion by trawling,
   3.3) Hence no need for recovery estimates.

We recommend this method be tested further, using data from a larger area and variety of benthic habitats, and a variety of benthic sampling gears.

Table 3.5.2. Penetration depth for different trawling gears. (Hiddink et al., in prep).

<table>
<thead>
<tr>
<th>Gear</th>
<th>Penetration depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otter Trawl</td>
<td>3.2 ± 2.0</td>
</tr>
<tr>
<td>Beam Trawl</td>
<td>4.0 ± 1.2</td>
</tr>
<tr>
<td>Towed Dredge</td>
<td>5.1 ± 3.8</td>
</tr>
<tr>
<td>Hydraulic Dredge</td>
<td>19.9 ± 12.1</td>
</tr>
</tbody>
</table>

3.6 References


**4 Complete the investigation of possible indicators of scavengers, examine their relation to discard amounts and evaluate the spatial effect of a landing obligation on the scavengers (ToR b)**

The introduction of the Landing Obligation may have consequences in the marine ecosystem. Extracting biomass, which is otherwise discarded, may have consequences for the scavenger species that feed on the discards and secondary responses following from them. Banning a substantial part of the discards is expected to decrease populations of large generalist scavenging seabird species (Bicknell *et al*., 2013). Modelling studies suggest that these large-scale effects will be mirrored in benthic communities, but empirical data at large-scale are missing. This ToR addresses that gap, and is following-up upon previous work by WGECO in 2015 and 2016.

In 2015, WGECO identified the primary scavenging species in the benthic communities of the North Sea. In 2016, data were made available to evaluate the link between discard biomass and scavengers as a proportion of the benthic community or individual scavenger species abundance. It was concluded that no demonstrable link could be established between the discard biomass and the scavengers at the level of the ICES rectangle.

This ToR has addressed the suggestions of 2016 and has evaluated the potential link between scavengers and discarded biomass at fine-scale resolution. WGECO has evaluated this relationship, in conjunction with a limited selection of environmental variables, in order to partition the variation of species abundance data due to environmental variation vs. discarding (see Annex 8 in ICES, 2017).

WGECO focused on four case studies: (1) southern part of the North Sea, (2) northern part of the North Sea, (3) the Skagerrak/Kattegat, and (4) the Grande Vasière (Bay of Biscay). The fourth case study is based on Launay (2017), while the following datasets were used to investigate the potential links between discards and scavengers in the case studies 1 to 3:

- Epibenthic scavenger abundance distribution data from the database for epibenthic species abundance provided by Cefas (case study 1).
- Hagfish abundance distribution data from the ICES DATRAS database based on the Dutch BTS survey (case study 2) and the IBTS (case study 3).
- Discard biomass data at ICES-rectangle scale for the North Sea derived from the STECF database and developed for the DiscardLess project atlas 2014 (case study 1 and 2).
- Swept-area estimates by gear type for the North Sea developed by the BENTHIS project (Eigaard *et al*., 2017) were used to proportionally distribute the rectangle-based discard estimate to 1-by-1 minute grid cells (case study 1 and 2) or as a proxy for discarding activities (case study 3).
- Environmental data were limited to the main hydrodynamic drivers for epifauna (Callaway *et al*., 2002; Reiss *et al*., 2009) and hagfish (Martinez *et al*., 2011) (depth, substrate and energy level) and were extracted from data portals of EMODnet (www.emodnet-seabedhabitats.eu) and from NOAA (Amante and Eakins, 2009).
4.1 **Case study 1: Epifaunal scavenger species in the southern North Sea**

The analysis focused on the five most abundant scavenging epifaunal genera in the southern North Sea: starfish (*Asterias*), swimming crabs (*Liocarcinus*), ophiurids (*Ophiura*), hermit crabs (*Pagurus*) (ICES, 2016) and Norway lobster (*Nephrops*), the latter because of its commercial importance and potential scavenging feeding habits. None of the selected epifaunal species showed a significant relationship between their abundance and the fine-scale discard estimates. The distribution of *Asterias* and *Pagurus* individuals was not correlated with depth or % mud as defined in Stephens and Diesing (2015) (Table 4.1), confirming their ubiquitous nature in the southern North Sea (Callaway *et al*., 2002). The abundance of *Liocarcinus* was significantly correlated with depth as was the case for *Ophiura*. The abundance of both *Ophiura* and *Nephrops* was correlated with % mud (Table 4.1).

Table 4.1. Statistical significance and adjusted $R^2$ of the redundancy analysis (RDA) using the R package ‘vegan’ for five scavenger genera in the southern North Sea case study. Adjusted $R^2$ is only reported when >0 and explains the variance in log-transformed scavenger abundance of a single variable (e.g. discarded biomass) after removing the effect of the remaining two variables (e.g. % mud and depth). % mud was taken from Stephens and Diesing (2015).

<table>
<thead>
<tr>
<th>Scavenger genera</th>
<th>Statistical significance (p-value)</th>
<th>Biological significance (Adjusted $R^2$ in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>discards</td>
<td>% mud</td>
</tr>
<tr>
<td>Asterias</td>
<td>0.176</td>
<td>0.808</td>
</tr>
<tr>
<td>Liocarcinus</td>
<td>0.434</td>
<td>0.275</td>
</tr>
<tr>
<td>Nephrops</td>
<td>0.934</td>
<td>0.049</td>
</tr>
<tr>
<td>Ophiura</td>
<td>0.162</td>
<td>0.009</td>
</tr>
<tr>
<td>Pagurus</td>
<td>0.719</td>
<td>0.599</td>
</tr>
</tbody>
</table>
4.2 Case study 2: Hagfish in the northern part of the North Sea

The catch per hour of effort of hagfish from the Dutch BTS survey was related to discarded biomass in the northern part North Sea between 54°N and 60°N (where contrasts between low and high abundance hauls were deemed sufficient). Depth was accounted for as a proxy encompassing large hydrographical features and energy as categorized in low, medium and high energy forces at the seabed due to currents in the EUNIS habitat classification (www.emodnet-seabedhabitats.eu, accessed on 9/4/2017) and identified as a significant driver of hagfish abundance (Martinez et al., 2011).

The WGECO analysis confirms the statistical significance of energy (p<0.01) although the Adjusted R² was reported by our RDA analysis was below zero and thus does not explain much of the variation in hagfish abundance. The depth, in contrast, explained 12% of the hagfish abundance (p<0.01). There was no statistically significant relationship between hagfish abundance and discarded biomass (p=0.66).

4.3 Case study 3: Hagfish in the Skagerrak and Kattegat

The abundance of hagfish in the Skagerrak and Kattegat was extracted from the IBTS survey and converted to presence and absence data, given that a GOV trawl is not effective for sampling hagfish. The distribution was linked to depth and energy level as for case study 2. Discard estimates for the Skagerrak and Kattegat case study were not available. Instead, the effect of fishing was evaluated by swept-area estimates as a possible proxy for discard volume. As for the Skagerrak and Kattegat area, both depth and energy level were statistically significantly linked to hagfish abundance (p<0.01, p<0.01) and explained a substantial part of the variability of hagfish presence.
The swept-area estimates were also statistically significantly linked to hagfish presence (p<0.01), but explained only 1% of its presence (Adj R²).

### 4.4 Case study 4: Benthic scavengers in the Grande Vasière

Launay (2017) analysed the spatial match between discards and benthic invertebrate scavengers in the Grande Vasière (Bay of Biscay). Benthic invertebrates were categorized into groups using three biological traits: feeding mode, mobility and size. Discards were categorized as roundfish, flatfish, elasmobranchs and benthic invertebrates according to a bird’s ability to consume discards with different morphologies (Depestele et al., 2016). Spatial coincidence of discards and benthic scavengers were mapped at the finest scale possible (approx. ~1.9 km² at 56° N, Eigaard et al., 2017). Then, statistical correlation tests were performed. The results highlighted the spatial heterogeneity of discards whereas the spatial distribution of scavengers is more homogeneous. No significant correlations between the spatial distributions were found. Nonetheless, the least weak correlation coefficients corresponded to the expected categories.

### 4.5 Conclusion

The analysis did not lead to a demonstrable relationship between discarded biomass and scavenger abundance at fine-scale spatial resolution in the southern or in the northern North Sea. Discard estimates were not available for the Skagerrak and Kattegat, but the presence of hagfish was analysed in relation to swept-area distribution. There was a statistically significant effect of fishing (swept-area trawled in the Skagerrak/Kattegat case study) on the spatial distribution (presence/absence) of hagfish, but its biological implications were minor.

Despite the limitations of the data available, their associated uncertainties (e.g. estimating discards at fine-scale resolution) and potential collinearity with other covariates than the variable of interest (discards), a large effect size of discards on the abundance distribution of benthic scavengers would be detected if it were present. Discards do not appear to provide an important energy subsidy for benthic invertebrate communities (Collie et al., 2016). These results confirm several modelling results (e.g. Kaiser and Hiddink, 2007 and see further discussion in Depestele et al., 2016) but contrast the anticipated influential effect of discards on benthic scavengers in other models (Catchpole et al., 2006; Heath et al., 2014).

In conclusion, whereas the (partial) elimination of discards resulting from the landing obligation may have both detrimental and beneficial effects on seabird communities, there are no indications from our analysis of the available data that similar large-scale effects are to be expected in the epifaunal invertebrate community.

### 4.6 References


5 Use the data available to evaluate the degree to which fisheries in the ICES region are “balanced” (ToR c)

“We are telling the oceans only what we are willing to eat, rather than asking them what they are willing to provide.” Barton Seaver, Chef.

5.1 Introduction

This ToR continues work started by WGE CO in 2014 and continued in 2016 under ToR c. The objective is to empirically examine the extent to which fisheries are balanced with respect to the relative abundance of species in the ecosystem.

The steps proposed to address this ToR included:

i ) establish the distribution of total catch (landing+discards) among size classes (catch size spectrum), species and functional groups;

ii ) Examine how the degree of balance is related to ecosystem status;

iii ) Request catch by species and length group for the species listed;

iv ) Request survey biomass by species and length group, where possible catchability corrected.

During this meeting, the group again concentrated on the distribution of catch among species because length data from commercial catches were not readily available. However, obtaining length-frequency distributions from the commercial landings remains a priority to complete this ToR. Length-based models were introduced to help examine how the degree of balance is related to ecosystem status.

5.2 Methods

Landings data were extracted from national and ICES databases (Table 5.2.1). Unusual species (e.g. mussels, algae) that would not be typically caught with survey gear were removed. Other invertebrates (e.g. shrimps, crabs) were retained if they are also recorded in the corresponding survey. For the New England data, it was necessary to match different species codes from the landings and survey databases. Some species were removed if they did not occur in both databases.

Discard estimates were available for the New England areas starting in 1989. For these areas and years only, discards were added to landings to obtain total catch. The time frame explored varied between regions. Within the New England regions, the time-series spanned from 1970 to 2015 while data were available starting in 2003 and 2004 for the other areas. Analyses were conducted on blocks of years. In New England, five-year blocks were used, given the length of the time-series. In the other areas, with shorter time-series, three-year blocks were used (Table 5.2.1).

Landings (catch) were expressed as proportions of their sum. The subset of species accounting for 95% of landings was identified. Evenness of the species distribution in the landings was calculated according to Simpson’s reciprocal index, corrected for the number of species $n$:

$$\frac{1}{\sum \frac{1}{i^2}}$$
where \( l_i \) is the proportion of species \( i \) in the landings.

### Table 5.2.1. Sources of data used to calculate the distribution of species in landings and surveys.

<table>
<thead>
<tr>
<th>Area</th>
<th>Dicards (years)</th>
<th>Landings (years)</th>
<th>Survey (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iceland</td>
<td>Directorate of Fisheries</td>
<td>MRI (2003–2007)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Northeast Fisheries Science Center. Sean Lucey (personal communication).

\(^2\) Northeast Fisheries Science Center. Michael Fogarty (personal communication).

Survey biomass data were extracted from national and ICES databases (Table 5.2.1). The survey data for New England only were adjusted for the catchability of species in the survey trawl, based on a set of coefficients derived by the NEFSC. Although it would be appropriate to adjust for catchability in the other areas as well, catchability coefficients could not be made available at the appropriate scale during the meeting. After initial screening for well-represented species, survey biomass was converted to proportions of the total survey biomass. The subset of species accounting for 95% of survey biomass was identified.

Analyses were conducted on the set of species comprising 95% of landings or 95% of survey biomass. This set includes commercially and ecologically important species. The distributions of species both in the landings and surveys were expressed as proportions of their respective totals:

\[
\begin{align*}
  l_i &= \frac{L_i}{\sum_j L_j} \quad \text{and} \quad b_i = \frac{B_i}{\sum_j B_j}
\end{align*}
\]

and plotted with pie charts and bar plots.

Landings were compared with survey biomass on a per-species basis. By considering fisheries as predators, we can use existing ecological indices to measure preference of the fishery for each species. Manly’s preference index is:

\[
\alpha_i = \frac{i_i/b_i}{\sum_j (i_j/b_j)}
\]

where index \( j \) is used for summation over all species (Krebs, 1989). If a species is fished in proportion to its biomass, \( \alpha = 1/n \), where \( n \) is the number of species in the community. If \( \alpha > 1/n \) the species is selected for by fishermen; conversely, \( \alpha < 1/n \) means that a species is selected against. The \( \alpha \) are normalized to sum to 1, such that preference for a given species is expressed relative to preference for other species in the community. This preference index \( (\alpha) \) was plotted (on a log scale) as bar plot with species names and \( 1/n \) as reference level. The same analysis was repeated for catch (instead of landings) for the New England data.

An ecosystem-wide metric of the breadth of the fishery was calculated with Levins measure of niche breadth:
**Niche breadth** is maximal when all species are fished in proportion to their biomass and decreases when species are increasingly selected for or against (Krebs, 1989). This metric provides a single measure of fishing balance that can be compared among time stanzas. Normalizing niche breadth by the number of species allows it to be compared among ecosystems.

### 5.3 Results

Examples of the proportions in the survey and catches are shown for the New England stocks for the period 1970–1974 (Figure 5.3.1). There was a much closer correspondence between survey and catch proportions on the Scotian Shelf, meaning that this area was more in balance. By contrast, the other three areas had species with either larger proportions in the catch (e.g. mackerel and herring) or larger proportions in the survey (e.g. cod and spiny dogfish).

**Scotian Shelf 19**

**Gulf of Maine 197**

**George’s Bank 15**

**Mid-Atlantic Bigl**

![Figure 5.3.1](image-url)  
*Figure 5.3.1. Proportions of biomass in the trawl survey and in commercial catches from four regions in New England for the five-year time period 1970–1974.*
The Georges Bank survey was initially dominated by cod (*Gadus morhua*) and dogfish (*Squalus acanthias*) (Figure 5.3.2). Since 1980 it has increasingly been dominated by dogfish and skates (*Leucoraja* sp.), and since 2000 by haddock (*Melanogrammus aeglefinus*). In the 1970s catches were dominated by herring (*Clupea harengus*), mackerel (*Scomber scombrus*), and silver hake (*Merluccius bilinearis*). Cod and sea scallops (*Placopecten magellanicus*) became more important in the 1980s. Starting in 1995 catches of skates increased in response to their increased abundance in the ecosystem.
In the Gulf of Maine survey catches were dominated by pollock (*Pollachius virens*), cod, silver hake, and Acadian redfish (*Sebastes marinus*) in the 1970s. Herring and spiny dogfish became the dominant species, starting in the 1980s. Herring accounted for about 50% of the catch in the 1970s. Lobster (*Homarus americanus*) became more important in the catches in the 1980s and spiny dogfish (*Squalus acantbias*) in the 1990s, in response to the increased abundance of dogfish in the ecosystem. During 2010–2014, lobster constituted over 40% of the catch.
In Iceland the proportion of capelin (*Mallotus villosus*) in the survey and catch has decreased substantially such that the proportions of each species were more equal in 2008 compared to 2002 (Figure 5.3.4). The balance of the fisheries has become less in time, where in 2008 a larger number of species had smaller proportion in the landings than in the biomass compared to 2002 (Figure 5.3.5). In the first stanza, there was positive selection for cod, shrimp (*Pandalus borealis*), saithe (*Pollachius virens*), capelin, and Greenland halibut (*Reinhardtius hippoglossoides*). By the third stanza there was positive selection only for cod and saithe.

Figure 5.3.4. Iceland proportions of biomass in the survey (outer circle) and in the catch (inner circle). Dates refer to the starting year of each three-year stanza.
Figure 5.3.5. Selectivity indices for Iceland. Dates refer to the starting year of each three-year stanza.

In the Celtic Sea the proportions of poor cod (*Trisopterus minutus*) and herring were high in the survey, except in 2009 when the proportion of herring was low (Figure 5.3.6). The proportion of poor cod in landings was, however, very low. Three species, cod (*Gadus morhua*), angler (*Lophius piscatorius*), and European hake (*Merluccius merclussius*) were preferred in the fisheries in the Celtic Sea during all time periods (Figure 5.3.7). In 2006, common sole (*Solea solea*) was preferred, but has over time become
underutilized while the opposite occurred for blue whiting (*Micromesistius poutassou*), which is now preferred in the fisheries.

![Selectivity indices for Iceland](image)

**Figure 5.3.7.** Selectivity indices for Iceland. Dates refer to the starting year of each three-year stanza.

![North Sea proportions of biomass](image)

**Figure 5.3.8.** North Sea proportions of biomass in the survey (outer circle) and in the catch (inner circle). Dates refer to the starting year of each three-year stanza.

In the North Sea, the proportion of herring (*Clupea harengus*) has increased in the landings, while it has decreased in the survey (Figure 5.3.8). Only two species, Atlantic horse mackerel (*Trachurus trachurus*) and common sole (*Solea solea*) were preferred
in the North Sea at all times, while the remaining species were underutilized (Figure 5.3.9).

Figure 5.3.9. Selectivity indices for the North Sea. Dates refer to the starting year of each three-year stanza.

Figure 5.3.10. Catch evenness in temporal stanzas.
On average, catch evenness was highest in the Mid-Atlantic Bight and lowest in the Gulf of Maine (Table 5.3.1, Figure 5.3.10). Over the time stanzas, evenness increased then decreased in the Mid-Atlantic Bight, decreased on the Scotian Shelf, increased on Georges Bank, and varied with little trend in the Gulf of Maine. Catch evenness has increased in Iceland from 2003 to 2009 while it has decreased in the Celtic Sea from 2006 to 2012. In all regions except Iceland, catch evenness decreased in the most recent stanza with data available.

![Figure 5.3.11. Niche breadth in temporal stanzas.](image)

Changes in catch evenness are at least partly a response to changes in the abundance of fish species in the environment. The selectivity and niche breadth indices attempt to standardize the catches in relation to available biomass in the environment. For the New England regions, the overall standardized niche breadth was highest in Gulf of Maine and lowest in the Mid-Atlantic Bight (Table 5.3.1, Figure 5.3.11). Within the New England regions, niche breadth increased from 1970 towards 1985/1990. At that time, niche breadth reached a maximum and has decreased since then in the Gulf of Maine and Scotian Shelf. The trend differed at Georges Bank where the niche breadth has increased during the whole time period and little changes were observed during this time in the Mid-Atlantic Bight. For the other regions, the overall standardized niche breadth was highest in Iceland and lowest in the Mid-Atlantic Bight. Niche breadth decreased in both these regions during these years. However, in the Celtic Sea little changes were observed during these years.
Table 5.3.1. Niche breadth, standardized niche breadth, catch evenness, and relative exploitation rate in each region by temporal stanza.

<table>
<thead>
<tr>
<th>Region</th>
<th>Time period</th>
<th>Niche breadth</th>
<th>Standardized niche breadth</th>
<th>Catch evenness</th>
<th>Relative Exploitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Maine</td>
<td>1970</td>
<td>2.53</td>
<td>0.181</td>
<td>0.280</td>
<td>1.06e-04</td>
</tr>
<tr>
<td></td>
<td>1975</td>
<td>3.67</td>
<td>0.211</td>
<td>0.272</td>
<td>9.17e-05</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>4.39</td>
<td>0.224</td>
<td>0.349</td>
<td>1.34e-04</td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>8.38</td>
<td>0.441</td>
<td>0.292</td>
<td>7.30e-05</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>7.11</td>
<td>0.474</td>
<td>0.274</td>
<td>8.17e-05</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>5.53</td>
<td>0.346</td>
<td>0.208</td>
<td>6.96e-05</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>6.18</td>
<td>0.384</td>
<td>0.266</td>
<td>3.84e-05</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>4.71</td>
<td>0.336</td>
<td>0.255</td>
<td>2.83e-05</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>5.02</td>
<td>0.295</td>
<td>0.223</td>
<td>4.18e-05</td>
</tr>
<tr>
<td>Georges Bank</td>
<td>1970</td>
<td>2.27</td>
<td>0.118</td>
<td>0.288</td>
<td>6.56e-04</td>
</tr>
<tr>
<td></td>
<td>1975</td>
<td>3.16</td>
<td>0.156</td>
<td>0.349</td>
<td>3.88e-04</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>4.13</td>
<td>0.208</td>
<td>0.310</td>
<td>9.52e-05</td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>5.04</td>
<td>0.215</td>
<td>0.219</td>
<td>8.56e-05</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>5.52</td>
<td>0.213</td>
<td>0.335</td>
<td>9.68e-05</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>4.35</td>
<td>0.230</td>
<td>0.510</td>
<td>6.39e-05</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>3.20</td>
<td>0.151</td>
<td>0.425</td>
<td>9.82e-05</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>4.98</td>
<td>0.274</td>
<td>0.550</td>
<td>6.74e-05</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>4.42</td>
<td>0.260</td>
<td>0.419</td>
<td>5.32e-05</td>
</tr>
<tr>
<td>Scotian Shelf</td>
<td>1970</td>
<td>2.05</td>
<td>0.128</td>
<td>0.618</td>
<td>3.03e-04</td>
</tr>
<tr>
<td></td>
<td>1975</td>
<td>2.54</td>
<td>0.133</td>
<td>0.485</td>
<td>2.04e-04</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>1.32</td>
<td>0.083</td>
<td>0.504</td>
<td>2.73e-04</td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>3.53</td>
<td>0.252</td>
<td>0.569</td>
<td>2.27e-04</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>3.69</td>
<td>0.246</td>
<td>0.567</td>
<td>1.83e-04</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>4.00</td>
<td>0.235</td>
<td>0.499</td>
<td>1.63e-04</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>3.11</td>
<td>0.194</td>
<td>0.390</td>
<td>1.44e-04</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>1.32</td>
<td>0.094</td>
<td>0.360</td>
<td>1.32e-04</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>1.07</td>
<td>0.082</td>
<td>0.247</td>
<td>5.34e-05</td>
</tr>
<tr>
<td>Mid-Atlantic Bight</td>
<td>1970</td>
<td>1.01</td>
<td>0.056</td>
<td>0.178</td>
<td>2.30e-04</td>
</tr>
<tr>
<td></td>
<td>1975</td>
<td>1.35</td>
<td>0.062</td>
<td>0.240</td>
<td>8.41e-05</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>4.09</td>
<td>0.186</td>
<td>1.135</td>
<td>5.90e-05</td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>2.05</td>
<td>0.085</td>
<td>0.480</td>
<td>9.92e-05</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>1.96</td>
<td>0.076</td>
<td>0.766</td>
<td>1.69e-04</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>1.35</td>
<td>0.059</td>
<td>0.868</td>
<td>1.23e-04</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>1.46</td>
<td>0.059</td>
<td>0.875</td>
<td>7.27e-05</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>2.02</td>
<td>0.081</td>
<td>0.744</td>
<td>8.38e-05</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>1.06</td>
<td>0.031</td>
<td>0.521</td>
<td>1.21e-04</td>
</tr>
<tr>
<td>North Sea</td>
<td>2006</td>
<td>3.33</td>
<td>0.221</td>
<td>0.312</td>
<td>2.12</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>2.07</td>
<td>0.129</td>
<td>0.534</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>2.28</td>
<td>0.143</td>
<td>0.218</td>
<td>2.24</td>
</tr>
<tr>
<td>Region</td>
<td>Time period</td>
<td>Niche breadth</td>
<td>Standardized niche breadth</td>
<td>Catch evenness</td>
<td>Relative Exploitation</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>---------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Celtic Sea</td>
<td>2006</td>
<td>4.22</td>
<td>0.264</td>
<td>0.476</td>
<td>4.22e-05</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>4.50</td>
<td>0.282</td>
<td>0.444</td>
<td>5.26e-05</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>4.41</td>
<td>0.276</td>
<td>0.180</td>
<td>5.69e-05</td>
</tr>
<tr>
<td>Iceland</td>
<td>2002</td>
<td>5.95</td>
<td>0.661</td>
<td>0.263</td>
<td>469.56</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>4.31</td>
<td>0.479</td>
<td>0.437</td>
<td>314.77</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>2.91</td>
<td>0.323</td>
<td>0.650</td>
<td>259.86</td>
</tr>
</tbody>
</table>

### 5.4 Ecosystem status

Marine ecosystems are impacted by human activities directly and indirectly, which presents a risk that exploited communities may suffer a loss of biodiversity. Ecosystem-based management aims to ensure that activities are sustainable such that species diversity and ecosystem functioning are maintained. Management measures must balance conservation objectives against the economic benefits that the exploitation of marine resources delivers. To support the ecosystem approach, ecological indicators have been developed that measure properties of the ecosystem (relating to structure and/or function) and quantitative targets are required to assess the status of these properties. When assessment level targets are available, management strategies can be considered and evaluated against the likelihood of achieving a good status.

We use a recently developed model (Thorpe et al., 2016) of the North Sea fish community to investigate the trade-offs that management must consider between fisheries yield and maintaining a low risk of biodiversity loss. The model utilises size theory of foodwebs along with diet information to parameterise predator–prey interaction strength. Fishing fleets (otter, beam, industrial and pelagic trawls) target species with size-selectivity functions (ICES, 2017). Equilibrium projections are considered here for a range of multipliers on fishing effort by fleet (from 0 to 2 times observed levels between 1990 and 2010). From the 10,000 scenarios, model data (biomass and catch by length category per species) are used to evaluate the risk of stock depletion due to the fishery, where depletion of a species is considered to occur when the modelled biomass falls to less than 10% of its unfished biomass. The overall risk of species diversity loss within a scenario is given by the count of species with depleted biomass in the projection. To complement this information, we model the economic value of the catch as defined by the total weight (t) of the fish caught and the total value of the catch (million £GBP). The contrast between the risk of species diversity loss and economic value obtained represents the balance required between maintaining ecological resilience and long-term economic prosperity.

Using the complete set of scenarios, we evaluate the relationship between community level indicators (size spectrum slope, Figure 5.4.1, and Shannon Entropy) and the risk of species diversity loss. Given a chosen tolerance on the level of risk accepted, we demonstrate the level of effort management of the fishery (assuming no other measures) that would be required to meet the EBM aim and the trade-off made in terms of loss of yield. The indicators reported here are:

**Size spectrum slope (SSS, Figure 5.4.1)**

\[\log B = [\text{SSS} \cdot \log L] + c\]
\[\text{SSS} = \frac{\log B - c}{\log L}\]
Shannon Entropy (SEN)

\[ SEN = - \sum P[i] \log P[i] \]

\( P[i] \) = proportion of total population which is species i. Note, Hill’s diversity metric \( N_i = \exp[SEN] \) (Hill 1973).

Figure 5.4.1. Size spectra describe the relationship between organism size and abundance and can be predicted from the expected joint change in abundance and organismal mass that occurs across one trophic link (Reproduced from Petchey and Belgrano, 2010).

5.4.1 Results

The simulations confirm that increasing fishing effort by the fleets targeting demersal species (i.e. otter and beam trawl) beyond recent (1990–2010) levels will lead to an increase in the number of demersal stocks at risk of depletion (Figure 5.4.2). Although increasing the pelagic trawl effort (targeting herring, horse mackerel and mackerel) beyond recent levels will increase the number of pelagic stocks at risk of depletion, this can be offset by simultaneous reductions in the effort by industrial trawlers (targeting Norway pout, sandeel and sprat).
Figure 5.4.2. Modelled risk of species diversity loss in the North Sea (colour) given impact on the foodweb by specific fleet combinations: risk to demersal species by otter and beam trawl fleets (left) and risk to pelagic species by pelagic and industrial trawl fleets (right). Note the axis range from 0 to 9 which correspond to fleet effort multipliers from 0 to twice the recent fishing effort (1990–2010).

The size spectrum slope indicator for the entire community does not relate strongly to the total risk of species diversity loss (35% of the variability of the risk measure is explained by the model derived indicator, Figure 5.4.3, left panels). However, once the SSS metric is calculated separately for the demersal and pelagic communities, strong non-linear relationships emerge between the risk of species diversity loss in each community and the size-spectrum slope (73% and 94% of variability of risk explained respectively). Each SSS indicator responds strongly to the increase in fishing effort by either the otter trawl or pelagic trawl fleet (Figure 5.4.3, right panels). In contrast, the Shannon Entropy measure does not relate strongly to risk of species diversity loss at the entire community level (SEN vs. total risk) or for the demersal species community (SEND vs. risk to demersal species) and neither measure relates strongly to fishing effort by any fleet (Figure 5.4.4). However, the Shannon Entropy of the pelagic community (SENp) does relate strongly to risk of species diversity loss within that community (>96% of variability of risk explained) and the indicator also responds strongly to the pelagic trawl effort only (Figure 5.4.4).
Figure 5.4.3. Modelled size spectrum slope (SSSA for all species, SSSP for the pelagic community and SSSD for the demersal community) vs. risk of species diversity loss (where total risk includes all species, and pelagic/demersal risk relates only to those species deemed pelagic/demersal respectively) given fishing effort scenarios for the North Sea.
Figure 5.4.4. Modelled Shannon Entropy (SENA for all species, SENP for the pelagic community and SEND for the demersal community) vs. risk of species diversity loss (where total risk includes all species, and pelagic/demersal risk relates only to those species deemed pelagic/demersal respectively) given fishing effort scenarios for the North Sea.

Where relationships between indicator and modelled risk of species diversity loss are strong (SSSD vs. demersal risk, SSSP and/or SENP vs. pelagic risk), the relationships can be used to identify indicator values below which species diversity is at risk (e.g. red and blue dashed lines in Figures 5.4.3 and 5.4.4 set at 1 and 2 stocks at risk respectively). If the acceptable risk-tolerance is set at 2 vs. 1 stock at risk, the indicator value required to reach this state is reduced but the allowable effort by the fishing fleets is increased. If we set an objective of no more than one species in total at risk of loss then the best choice from the currently investigated indicators within the EBM approach would be to use both the demersal and pelagic specific metrics (SSSD and SSSP) rather than one for the total community. Managing towards targets for both communities would impose restrictions on both otter and pelagic trawl effort, suggesting a decrease in otter trawl effort and a limit to any increase in pelagic trawl effort relative to 2010 levels (where effort = 1) (Figure 5.4.5) and lead to a loss of total value of the catch. In reality other management tools may be considered more appropriate (technical measures, area closures, etc.).
5.5 Conclusions

WGECO has developed a promising empirical approach to measure the degree of balance in fisheries in relation to the available biomass. An ecological index, niche breadth, was adapted to provide a single measure of balance across species in an ecosystem. We have now applied this method to seven different ecosystems and to different time periods within ecosystems. On average, niche breadth was highest in Iceland and the Gulf of Maine and lowest in the Mid-Atlantic Bight. Niche breadth can increase when fisheries diversify across a wider range of available species. Such diversification occurs with a lag, as time is needed for gear modifications and to develop markets for new species. Niche breadth can decrease when fisheries specialize on high-value species, such as lobster in the Gulf of Maine. In the 1980s the degree of balance increased in three of the four New England regions. In recent years, the degree of balance remained constant or decreased.

A number of improvements are needed to complete this ToR. For regions other than New England it would be desirable to add discards to the landings data. The survey data should be catchability corrected where such coefficients exist. Some of the imbalance between catch and survey could be caused by species that are not well sam-
pled in the survey. Differences in catchability introduce variability of the selection indices but do not drive the main patterns that were observed. In several areas, the filter for 95% of the biomass included too many species to distinguish in plots. Future work could retain a lower percentile (e.g. 90%) or combine less abundance species in an “other” category. Alternatively, species could be aggregated into functional groups and the degree of balance measured among functional groups.

WGECO was unable to investigate the degree of balance with respect to size distributions. The aggregation of length–frequency data for all commercially important species requires requests to the national laboratories that maintain these databases. Compilation of such data in ICES databases would support a number of ecosystem-based analyses and modelling efforts. In the shorter term, WGECO decides to compile length data from one or more regions (e.g. West Coast of Ireland, Iceland, or New England) to develop and demonstrate the methodology. WGECO did not examine how the degree of balance is related to ecosystem status, though a number of indices were suggested (e.g. relative harvest rate, mean L_max). Size-based models could be used to investigate how the degree of fisheries balance responds to fishing pressure and selectivity (see below).

The size-based model has been used to identify thresholds for community indicators based on the risk of depletion of species in the community. Further work will consider both the North Sea (Thorpe et al., 2016) and Celtic Sea (using a recently developed model, ICES, 2017) and evaluate a greater suite of indicators of relevance to biodiversity, commercial fish and foodwebs (for demersal, pelagic and all stocks we will consider Typical length, Mean Maximum Length, size spectrum slope, Shannon entropy, mean of the species 95th percentile of length, mean of proportion mature by species and for demersal fish only the Large Fish Indicator with thresholds of 40 and 50 cm). The suite of indicators will be investigated to identify if there is a parsimonious combination of indicators that will reduce the risk to loss of species diversity overall with limited loss of yield (value).

Once a set of targets are identified for the suite of indicators, we will contrast for a range of fishing scenarios (effort by fleet):

- the proportion of species in the modelled ecosystem against the proportion of catch of those species;
- the size spectrum slope of species in the modelled ecosystem against the catch spectra;
- the niche breadth, catch evenness and the level of pressure.

The output from these simulations will be comparable to the empirical work described in Sections 4.2 and 4.3 and allow us to demonstrate whether the proposed metrics related to balance between fishery and ecosystem (e.g. niche breadth and evenness of the catch) are consistent with exploitation patterns that will maintain species diversity in the ecosystem in the long term.

5.6 References


6 Estimate indicators of state of sensitive fish species throughout the ICES region (ToR d)

In 2015 and 2016, WGECO examined the “abundance of a suite of sensitive fish species indicator that had been developed to support implementation of the Marine Strategy Framework Directive (MSFD) in respect of Descriptor 1 “biological diversity is maintained”. This indicator was originally introduced by Greenstreet et al. (2012) specifically to meet MSFD needs. Assessment of each species’ sensitivity relies on their life-history traits and originally an “average life-history trait” (ALHT) metric was used. In 2015, WGECO raised concerns over the ALHT sensitivity metric (ICES, 2015) and in 2016 these were addressed and a new metric, the “proportion failing to spawn” (PFS), was devised (ICES, 2016). More recent developments in the PFS sensitivity metric are described in the supporting working document (Greenstreet et al., 2017a). In this section the PFS is used as the primary metric to support assessments of the status of suites of sensitive species in four regions of the Northeast Atlantic area.

6.1 Northeast Atlantic

Both the ALHT and PFS sensitivity metrics depend on availability of a number of life-history trait parameters for each species (e.g. maximum recorded length $L_{\text{max}}$, von Bertalanffy Length infinity $L_{\text{inf}}$, von Bertalanffy Growth term $K$, Length-at-maturity $L_{\text{mat}}$, and Age-at-maturity $A_{\text{mat}}$). Compilation of these parameters for 479 species encountered in 19 groundfish surveys carried out in the Northeast Atlantic, and where missing, the methods used to estimate them, are described in a supporting document (Greenstreet et al., 2017b). The assessments presented address two different principal management goals:

1) Achieving recovery in the population size of sensitive species, such that increasing abundance trends should be apparent among a significant number of species;

2) Halting further decline in the population size of sensitive species, such that either no abundance trend, or an increasing abundance trend, should be apparent among a significant number of species.

6.1.1 Management Goal: Recovery of Sensitive Species Population Abundance

The PFS metric was used to identify sensitive species among the full inventory of species sampled by each of the 19 groundfish surveys (Table 6.1.1.1). These 19 surveys are organised into four groups associated with four OSPAR regions: Region IV the Bay of Biscay and Iberian Coast, Region III the Celtic Seas, Region II the Greater North Sea and Region V the Wider Atlantic Ocean. They thus cover a large marine area covering the continental shelf waters and some outlying banks from Norway to southern Spain. This area covers parts or all of ICES Areas 3.a, 4, 5, 6, 7, 8 and 9.
Table 6.1.1.1. The number of sensitive species actually sampled in 19 groundfish surveys operating in the Northeast Atlantic, together with the number of these species meeting the “adequately sampled” criterion of having been sampled in at least 50% of years that the survey operated, the number of species whose species-specific abundance metric met their “Recovery Goal” related species-specific abundance metric-level target of lying in the upper 25% of all abundance values observed throughout the time-series (the sensitive species abundance indicator), the sensitive species abundance indicator-level target value representing a significant (at P < 0.05) departure from the binomial distribution, and the assessment outcome assuming the last year in each time-series to be the “assessment” year. Row colour coding highlights the different OSPAR Regions. The survey naming protocol also indicates the OSPAR region in which the survey operates (WA Wider Atlantic, BBIC Bay of Biscay and Iberian Coast, BBCS Bay of Biscay and Celtic Sea [operates in two OSPAR regions], CS Celtic Seas, GNS Greater North Sea), the country operating the survey (Spa Spain, POR Portugal, Fra France, Eng England, Ire Ireland, NIr Northern Ireland, Sco Scotland, Ger Germany, Int International, Net The Netherlands), the type of gear used (OT otter trawl, BT beam trawl) and the quarter of the year when the survey is undertaken (1 first, 2 second, 4 fourth). Integrated assessment outcomes at the scale of the individual Regions and at the scale of the whole Northeast Atlantic are also shown. The common-scale indicator scores are given for each survey (column 5 / column 6) and the average common-scale indicator scores for each Region and for all 19 surveys are given. Column colour coding illustrates the assessment outcomes.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Survey</th>
<th>Number of Sensitive Species Sampled</th>
<th>Number of Sensitive Species Meeting 50% of Years Criterion</th>
<th>Number of Sensitive Species Meeting Metric-level Targets in Last Year of Survey</th>
<th>Indicator-level Target</th>
<th>Target Met</th>
<th>Common-scale Indicator Score</th>
<th>Subregional Average Integrated Assessment Outcome</th>
<th>Regional Average Integrated Assessment Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BBIC(n)SpaOT4</td>
<td>39</td>
<td>17</td>
<td>10</td>
<td>10</td>
<td>YES</td>
<td>1.000</td>
<td>0.754</td>
<td>1.003</td>
</tr>
<tr>
<td></td>
<td>BBIC(s)SpaOT1</td>
<td>80</td>
<td>25</td>
<td>9</td>
<td>13</td>
<td>NO</td>
<td>0.692</td>
<td>0.667</td>
<td>1.067</td>
</tr>
<tr>
<td></td>
<td>BBIC(s)SpaOT4</td>
<td>83</td>
<td>28</td>
<td>11</td>
<td>14</td>
<td>NO</td>
<td>0.786</td>
<td>1.000</td>
<td>0.861</td>
</tr>
<tr>
<td></td>
<td>BBICPorOT4</td>
<td>51</td>
<td>25</td>
<td>7</td>
<td>13</td>
<td>NO</td>
<td>0.538</td>
<td>NO</td>
<td>0.667</td>
</tr>
<tr>
<td></td>
<td>CSBBFraOT4</td>
<td>73</td>
<td>44</td>
<td>14</td>
<td>21</td>
<td>NO</td>
<td>0.667</td>
<td>0.667</td>
<td>0.667</td>
</tr>
<tr>
<td></td>
<td>CSireOT4</td>
<td>69</td>
<td>37</td>
<td>19</td>
<td>18</td>
<td>YES</td>
<td>1.056</td>
<td>1.056</td>
<td>1.056</td>
</tr>
<tr>
<td></td>
<td>CSNirOT1</td>
<td>32</td>
<td>22</td>
<td>15</td>
<td>12</td>
<td>YES</td>
<td>1.250</td>
<td>1.250</td>
<td>1.250</td>
</tr>
<tr>
<td></td>
<td>CSNirOT4</td>
<td>31</td>
<td>22</td>
<td>12</td>
<td>12</td>
<td>YES</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>CSScoOT1</td>
<td>49</td>
<td>28</td>
<td>16</td>
<td>14</td>
<td>YES</td>
<td>1.143</td>
<td>1.143</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>CSScoOT4</td>
<td>49</td>
<td>28</td>
<td>15</td>
<td>14</td>
<td>YES</td>
<td>1.071</td>
<td>1.071</td>
<td>1.071</td>
</tr>
<tr>
<td></td>
<td>GNSEngBT3</td>
<td>33</td>
<td>16</td>
<td>6</td>
<td>9</td>
<td>NO</td>
<td>0.667</td>
<td>0.667</td>
<td>0.667</td>
</tr>
<tr>
<td></td>
<td>GNSFraOT4</td>
<td>35</td>
<td>25</td>
<td>13</td>
<td>13</td>
<td>YES</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>GNSGerBT3</td>
<td>19</td>
<td>9</td>
<td>4</td>
<td>6</td>
<td>NO</td>
<td>0.667</td>
<td>0.667</td>
<td>0.667</td>
</tr>
<tr>
<td></td>
<td>GNSIntOT1</td>
<td>58</td>
<td>36</td>
<td>17</td>
<td>18</td>
<td>NO</td>
<td>0.944</td>
<td>0.944</td>
<td>0.944</td>
</tr>
<tr>
<td></td>
<td>GNSIntOT3</td>
<td>58</td>
<td>36</td>
<td>17</td>
<td>18</td>
<td>NO</td>
<td>0.944</td>
<td>0.944</td>
<td>0.944</td>
</tr>
<tr>
<td></td>
<td>GNSNetBT3</td>
<td>33</td>
<td>21</td>
<td>11</td>
<td>12</td>
<td>NO</td>
<td>0.917</td>
<td>0.917</td>
<td>0.917</td>
</tr>
<tr>
<td></td>
<td>WASooOT3</td>
<td>32</td>
<td>16</td>
<td>6</td>
<td>9</td>
<td>NO</td>
<td>0.667</td>
<td>0.667</td>
<td>0.667</td>
</tr>
<tr>
<td></td>
<td>WASpaOT3</td>
<td>63</td>
<td>42</td>
<td>19</td>
<td>20</td>
<td>NO</td>
<td>0.950</td>
<td>0.950</td>
<td>0.950</td>
</tr>
</tbody>
</table>

Almost by definition, the species deemed sensitive to fishing mortality are among the rarest in each surveyed community. For many of these species therefore, the data available are too sparse to support meaningful assessment. Greenstreet et al. (2012) used the criterion “only species encountered in ≥50% of occasions that each survey was carried out are sufficiently well sampled as to support formal assessment”. This same criterion was applied to each survey dataset to identify the suites of sensitive species whose abundance trends could be assessed (Table 6.1.1.1). In the majority of cases, those species deemed sufficiently well sampled as to support formal assessment were representative, in terms of their sensitivity metric scores (and hence life-history trait composition), of the full suite of sensitive species encountered by each survey (Figure 6.1.1.1).
Figure 6.1.1.1. Box-plots (showing median [horizontal bar], 50%ile of data range [box] and full data range [whisker]) comparing sensitivity scores of species meeting the “adequate” sampling criterion of having been encountered in 50% of years, and species that do not meet this criterion. Generally the plots show that the species sampled sufficiently well as to support formal assessment are representative of the full suite of “sensitive” species encountered in each species. Significant differences are indicated (Mann–Whitney U Test), and in these cases there might be some concern.

None of the surveys extend sufficiently far back in time as to provide an adequate reference period to establish species abundance levels commensurate with “Acceptable Status”. A trends-based assessment approach, relying on the use of trends-based targets, has therefore been adopted. By virtue of their being sensitive to fishing-related mortality, the population abundance of each of the sensitive species sampled by each survey is assumed to have declined as a result of fishing activities in the past. There is ample evidence that fishing mortality has indeed caused declines in the populations of many sensitive species (Walker and Hislop, 1998; Philippart, 1998; Jennings et al., 1999; Greenstreet and Rogers, 2000; 2006; Le Quesne and Jennings, 2012). Thus trends-based targets related to population recovery have been set; sensitive species should be increasing in abundance. Abundance trends for most species are not monotonic, so simple parametric trends-based approaches (e.g. linear regression) are not appropriate; instead a non-parametric approach has been used. Essentially, the
entirety of each survey time-series acts as the reference period, and the target is set as “abundance in the assessment year must lie in the upper 25% of all abundance values observed throughout the time-series”. Thus the surveys provide abundance estimates for each sensitive species in each year: the species-specific abundance metric. These data can be ranked and the ranking representing the lower boundary of the upper 25%ile of all the data established. This is the species-specific abundance metric-level target. In any stipulated assessment year, each species-specific abundance metric rank should be greater than the ranking representing the species-specific abundance metric-level target. (Greenstreet et al., 2012).

For any given survey, the actual sensitive species abundance indicator is then defined as the number of species in any assessment year whose species-specific abundance metric meets or exceeds its species-specific abundance metric-level target of being within the upper 25%ile of all their own abundance data over the whole survey time-series, up to and including the year defined as the assessment year (Table 6.1.1.1). A random walk simulation suggests that the probability of the last abundance datum in a time-series falling into the upper 25%ile of all data is 0.332 (the probability distribution is platykurtic). Knowing the number of assessed sensitive species in each survey, and the probability of any one species-specific abundance metric meeting its upper 25%ile species-specific abundance metric-level target, the sensitive species abundance indicator-level target can be defined as the sensitive species abundance indicator value that represents a significant (at P <0.05) departure from the binomial distribution (Table 6.1.1.1).

The assessment year is generally the last year in the time-series for which data are available, but trends in the sensitive species abundance indicator can be evaluated by defining each preceding year in the time-series as the assessment year. These trends are shown for the 19 Northeast Atlantic surveys assuming all years back to 2010 represent the assessment year (Figure 6.1.1.2). For some of the more shorter-lived surveys, it would not be feasible to look further back in time as the length of the time-series preceding earlier assessment years would be too short to determine adequate species-specific abundance metric-level targets.
Figure 6.1.1.2. Plots showing trends in the sensitive species abundance indicator, the number of species-specific abundance metrics meeting or exceeding their individual species-specific abundance metric-level targets of being within the upper 25%ile of all their own abundance data over the whole survey time-series, up to and including the year defined as the assessment year. Grey dashed lines indicate the sensitive species abundance indicator-level target for each survey, defined as the sensitive species abundance indicator value that represents a significant (at P <0.05) departure from the binomial distribution. Plots are colour coded to distinguish between surveys carried out in different OSPAR regions.

An averaging integration procedure (Borja et al., 2014) was used to combine the individual survey assessments and derive overall integrated assessment outcomes for each OSPAR Region and for the Northeast Atlantic Area as a whole. All sensitive species abundance indicator values were first converted to a common scale by expressing each value as a fraction of its relevant sensitive species abundance indicator-level target value (each datapoint shown in Figure 6.1.1.2 divided by the grey dashed target value for the plot in question) (Table 6.1.1.1). These common-scale indicator values were then averaged across all surveys carried out over the entire Northeast Atlantic Area, or across just the surveys carried out in each Region to derive an integrated assessment indicator values at each of these two spatial scales (Table 6.1.1.1; Figure 6.1.1.3). Where common-scale indicator values are ≥1, targets for recovery among a significant number of “sensitive” fish species have been achieved. The averaging integration procedure conferred equal weighting to each survey carried out within an individual region, and across the entire area. A case could be made that some sort of weighted-averaging procedure should be used instead, but at present the rationale for setting appropriate weighting factors to each survey has not been established. Indeed, alternative integration methods, such as a probabilistic or a one-out-all-out approach, could be preferred over either averaging method (Borja, 2014). The current integrated assessments at the Area scale weight all 19 surveys equally, but alternatively the in-
individual averaged Region-scale integrated assessments could be averaged, thus weighting each Region equally in arriving at the Area-scale assessment.

Figure 6.1.1.3. Results of integrated assessments for the whole Northeast Atlantic area and for each of four Regions, the Wider Atlantic (WA), the Bay of Biscay and Iberian Coast (BBIC), Celtic Seas (CS) and the Greater North Sea (GNS), based on an “averaging” integration procedure applied to the individual survey assessments shown in Figure 6.1.1.2.

An improving situation is apparent across the whole Northeast Atlantic, but as yet the target for the number of sensitive species populations showing significant recovery in abundance has not quite been met. This improving trend at the whole area scale is largely driven by strong recovery trends in both the Celtic Seas and Greater North Sea Regions. In the Celtic Seas region, the integrated assessment suggests that the target has been achieved; a significant number of sensitive species are recovering. The situation in the Wider Atlantic and Bay of Biscay and Iberian Coast Regions is less clear-cut.

6.1.2 Management Goal: Halt Further Decline in Sensitive Species Population Abundance

Recovery in population abundance among a significant number of sensitive fish species was apparent only in the Celtic Seas Region. The situation appeared to be improving in the Greater North Sea, but targets had yet to be met. Furthermore, in the
Wider Atlantic and Bay of Biscay and Iberian Coast Regions there was little evidence of recovery. In these circumstances, it is pertinent to ascertain whether a less ambitious management goal might have been achieved. Where evidence of declining population size among sensitive fish species is unambiguous, and can be linked to human activity, it is relevant to assess whether these declines are still ongoing, or whether they have been halted. The first step towards recovering these populations is at least to halt further decline.

The logic underlying this second assessment is identical with that described above, but the individual species-specific abundance metric-level targets need to be adjusted to match the revised management objective. Instead of stipulating that “abundance in the assessment year must lie in the upper 25% of all abundance values observed throughout the time-series” (a “recovery” goal target), the species-specific abundance metric-level target should stipulate that “abundance in the assessment year must lie outside the lower 25% of all abundance values observed throughout the time-series” to reflect the “halt further decline” goal, or alternatively “abundance in the assessment year must lie in the upper 75% of all abundance values observed throughout the time-series”. The random walk simulation suggests that the probability of the last abundance datum in a time-series falling into the upper 75%ile of all data is 0.668. Thus the same binomial method can be used to determine sensitive species abundance indicator-level targets and assess whether or not observed sensitive species abundance indicator values represent a significant departure from the binomial distribution.

The assessment process described above is now repeated for this alternative management goal. Table 6.1.2.1 summarises the data for the 19 individual surveys. Figure 6.1.2.1 shows recent trends in the sensitive species abundance indicator values for each survey. Figure 6.1.2.2 shows the integrated assessment outcomes for each Region and for the whole Northeast Atlantic Area. The final integrated assessment outcomes for the most recent assessment year in each survey are also summarised in Table 6.1.2.1. At both the Regional and whole Area spatial scales, current management regimes have halted further decline in abundance in populations of sensitive fish species.
Table 6.1.2.1. The number of sensitive species actually sampled in 19 groundfish surveys operating in the Northeast Atlantic, together with the number of these species meeting the “adequately sampled” criterion of having been sampled in at least 50% of years that the survey operated, the number of species whose species-specific abundance metric met their “Halt Further Decline” related species-specific abundance metric-level target of lying in the upper 75% of all abundance values observed throughout the time-series (the sensitive species abundance indicator), the sensitive species abundance indicator-level target value representing a significant (at P < 0.05) departure from the binomial distribution, and the assessment outcome assuming the last year in each time-series to be the “assessment” year. See legend for Table 6.1.1.1 for further details.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Survey</th>
<th>Number of &quot;Sensitive&quot; Species Sampled</th>
<th>Number of &quot;Sensitive&quot; Species Meeting 50% of Years Criterion</th>
<th>Number of &quot;Sensitive&quot; Species Meeting Metric-level Targets in Last Year of Survey</th>
<th>Indicator-level Target</th>
<th>Target Met</th>
<th>Common-scale Indicator Score</th>
<th>Subregional Average Integrated Assessment Outcome</th>
<th>Regional Average Integrated Assessment Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BBIC(n)SpaOT4</td>
<td>39</td>
<td>17</td>
<td>16</td>
<td>15</td>
<td>YES</td>
<td>1.067</td>
<td>1.073</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>BBIC(s)SpaOT4</td>
<td>80</td>
<td>25</td>
<td>23</td>
<td>21</td>
<td>YES</td>
<td>1.067</td>
<td>1.095</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>BBIC(s)SpaOT4</td>
<td>83</td>
<td>28</td>
<td>26</td>
<td>24</td>
<td>YES</td>
<td>1.083</td>
<td>1.073</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>BBICPorOT4</td>
<td>51</td>
<td>25</td>
<td>22</td>
<td>21</td>
<td>YES</td>
<td>1.083</td>
<td>1.048</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>73</td>
<td>44</td>
<td>40</td>
<td>35</td>
<td>YES</td>
<td>1.143</td>
<td>1.143</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>33</td>
<td>22</td>
<td>17</td>
<td>19</td>
<td>NO</td>
<td>0.895</td>
<td>1.095</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>69</td>
<td>37</td>
<td>32</td>
<td>30</td>
<td>YES</td>
<td>1.067</td>
<td>1.067</td>
<td>1.006</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>31</td>
<td>22</td>
<td>19</td>
<td>19</td>
<td>NO</td>
<td>0.947</td>
<td>1.038</td>
<td>1.038</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>49</td>
<td>28</td>
<td>26</td>
<td>24</td>
<td>YES</td>
<td>1.083</td>
<td>1.042</td>
<td>0.927</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>33</td>
<td>16</td>
<td>16</td>
<td>14</td>
<td>YES</td>
<td>1.143</td>
<td>1.143</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>35</td>
<td>25</td>
<td>20</td>
<td>21</td>
<td>NO</td>
<td>0.952</td>
<td>0.952</td>
<td>0.889</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>19</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>NO</td>
<td>0.889</td>
<td>0.952</td>
<td>0.889</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>58</td>
<td>36</td>
<td>31</td>
<td>30</td>
<td>YES</td>
<td>1.033</td>
<td>1.033</td>
<td>1.033</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>57</td>
<td>42</td>
<td>40</td>
<td>34</td>
<td>YES</td>
<td>1.176</td>
<td>1.176</td>
<td>1.176</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>33</td>
<td>21</td>
<td>15</td>
<td>18</td>
<td>NO</td>
<td>0.833</td>
<td>0.833</td>
<td>0.833</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>32</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>YES</td>
<td>1.071</td>
<td>1.071</td>
<td>1.071</td>
</tr>
<tr>
<td></td>
<td>CSBBraOT4</td>
<td>63</td>
<td>42</td>
<td>39</td>
<td>34</td>
<td>YES</td>
<td>1.147</td>
<td>1.147</td>
<td>1.147</td>
</tr>
</tbody>
</table>
Figure 6.1.2.1. Plots showing trends in the sensitive species abundance indicator, the number of species-specific abundance metrics meeting or exceeding their individual species-specific abundance metric-level targets of being within the upper 75%ile of all their own abundance data over the whole survey time-series, up to and including the year defined as the assessment year. Grey dashed lines indicate the sensitive species abundance indicator-level target for each survey, defined as the sensitive species abundance indicator value that represents a significant (at P < 0.05) departure from the binomial distribution. Plots are colour coded to distinguish between surveys carried out in different OSPAR regions.
6.2 Examination of Individual Species Trends

In the analysis presented above, individual species-specific abundance metric information is subsumed in the sensitive species abundance indicator, the number of species-specific abundance metrics meeting or exceeding their individual species-specific abundance metric-level targets (e.g. Figures 6.1.1.2 and 6.1.2.1). This raises several questions:

1) Within individual regions, do species-specific abundance metrics for the same species consistently meet, or consistently fail to meet, their species-specific abundance metric-level targets?

2) Are the species whose species-specific abundance metrics consistently meet, or consistently fail to meet, their species-specific abundance metric-level targets the same in different Regions?

3) Are species whose species-specific abundance metrics meet their species-specific abundance metric-level targets less sensitive than species whose species-specific abundance metrics fail to meet their species-specific abundance metric-level targets?

These questions are addressed for selected surveys in the Greater North Sea and Celtic Seas Regions in this section.
6.2.1 Within Region Consistency in Species Trends

In the Greater North Sea, species-specific abundance metrics for six species consistently met their species-specific abundance metric-level targets in all seven assessment years, 2010 to 2016 (Table 6.2.1.1). This included four elasmobranch species, red gurnard Chelidonichthys cuculus, and hake Merluccius merluccius. It is likely that increase in the abundance of hake is related to recent warming of sea temperatures in the Northeast Atlantic, rather than in response to improved fisheries management.

Five species consistently missed their species-specific abundance metric-level targets; this included cod Gadus morhua and haddock Melanogrammus aeglefinus (Table 6.2.1.1). These two species are major commercial species in the North Sea. They are managed directly through the Common Fisheries Policy, and as such they are subject to annual stock assessments to determine the quantity of fish that can be sustainably caught. A case could be made that species subject to formal stock assessment should be excluded from the “suites of sensitive species”. Assessments based on this indicator would then only provide information for non-target, non-assessed species, which otherwise might not be subject to any type of formal assessment of state. Cod and haddock failed to meet their species-specific abundance metric-level targets (upper 25%ile of all abundance values in the time-series) because the survey time-series included a period early on when these species were relatively abundant. This suggests that the species-specific abundance metric-level targets, as currently stated, do not just represent a trends-based target, they also infer an absolute abundance that each species-specific abundance metric must reach. Species that may have been more abundant during earlier parts of the time-series would find such targets more difficult to achieve.

Amblyraja radiata also consistently missed its species-specific abundance metric-level target (Table 6.2.1.1). This is an elasmobranch species, but it is one elasmobranch species that would be least likely to have been seriously impacted by fishing activity (Greenstreet and Rogers, 2000). If its population had not really been depleted, a trends-based target requiring its abundance to be increasing is unrealistic. This highlights the necessity of ensuring that, if trend-based targets are being used, the species in question really have been adversely impacted by human activity. This just leaves Anarhichas lupus and Brosme brosme as two potential causes for concern as sensitive species that consistently missed their recovery-related species-specific abundance metric-level targets in all seven assessment years (Table 6.2.1.1).
Table 6.2.1.1. The suite of sensitive species sampled by the GNSIntOT1 survey, and deemed sufficiently well sampled as to support formal assessment, showing years when each species *species-specific abundance metric* either met (green cells) or missed (red cells) its *species-specific abundance metric-level target*.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Chelidonichthys cuculus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>G</strong></td>
</tr>
<tr>
<td><em>Merluccius merluccius</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>G</strong></td>
</tr>
<tr>
<td><em>Mustelus asterias</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td><em>Raja brachyura</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td><em>Raja montagui</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td><em>Scyliorhinus canicula</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>G</strong></td>
</tr>
<tr>
<td><em>Scophthalmus rhombus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td><em>Dicentrarchus labrax</em></td>
<td></td>
<td></td>
<td><strong>R</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chimaera monstrosa</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Microstomus kitt</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Scophthalmus maximus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Squalus acanthias</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Zeus faber</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Molva molva</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lophius piscatorius</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Raja clavata</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Alosa fallax</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Argentina silus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Petromyzon marinus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Alosa alosa</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Leucoraja naevus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pollachius pollachius</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mustelus mustelus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dipturus batis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Galeorhinus galeus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pollachius virens</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Glyptocephalus cynoglossus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hippoglossus hippoglossus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Scomber scombrus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Anguilla anguilla</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cyclopterus lumpus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Amblyraja radiata</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Anarhichas lupus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Brosme brosme</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Gadus morhua</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melanogrammus aeglefinus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.2.2 Between Survey Consistency in Species Trends

Of the 14 species that met their *species-specific abundance metric-level targets* with some consistency in at least one of the surveys, 12 (86%) were included among the suites of assessed sensitive species in all four of the surveys (Table 6.2.2.1). Only one species, *Raja montagui*, consistently met its *species-specific abundance metric-level target* in all four survey suites and four species, *Chelidonichthys cuculus*, *Mustelus asterias*, *Raja clavata* and *Scyliorhinus canicula*, met their *species-specific abundance metric-level targets* in three survey suites (Table 6.2.2.1). Among the 23 species that missed their targets with some consistency in at least one survey, 12 (52%) were included among the
suites of assessed sensitive species in all four surveys (Table 6.2.2.1), and a further single species (4%) featured in three survey suites (Table 6.2.2.1). Of these species, only two (9%) species, *Glyptocephalus cynoglossus* and *Melanogrammus aeglefinus*, consistently missed their *species-specific abundance metric-level targets* in at least three of the surveys (Table 6.2.2.1). Six species (26%) were included in just a single survey’s suite (Table 6.2.2.1). Between survey consistency was higher among species meeting their *species-specific abundance metric-level targets* than it was in species failing their targets.
Table 6.2.2.1. Examination of consistency in species-specific outcomes between surveys. The table is split into two parts. The section with green species identification cells examines consistency in species whose *species-specific abundance metrics* consistently met their *species-specific abundance metric-level targets*. Dark green and pale green cells indicate species where the target was consistently met in all years, or in all but one year, respectively. The section with red species identification cells examines consistency in species whose *species-specific abundance metrics* consistently failed to meet, their *species-specific abundance metric-level targets*. Dark red and pale red cells indicate species where the target was consistently missed in all years, or in all but one year, respectively. Orange cells indicate where a species was included among the survey’s suite of sensitive species, but where it’s *species-specific abundance metric-level target* was not either consistently met or consistently missed. Grey cells indicate species not included in the suite of sensitive species for the survey in question.

<table>
<thead>
<tr>
<th>Species</th>
<th>GNSIntOT1</th>
<th>CSScoOT1</th>
<th>CS IreOT4</th>
<th>CSNirOT1</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Chelidonichthys cuculus</em></td>
<td>All Years</td>
<td>All Years</td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Dipturus batis</em></td>
<td>All Years</td>
<td>All Years</td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Gadus morhua</em></td>
<td>All Years</td>
<td>-1 Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Leucoraja naevus</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Merluccius merluccius</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Molva molva</em></td>
<td></td>
<td>-1 Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mustelus asterias</em></td>
<td>All Years</td>
<td>All Years</td>
<td>All Years</td>
<td></td>
</tr>
<tr>
<td><em>Raja brachyura</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Raja clavata</em></td>
<td>-1 Year</td>
<td>All Years</td>
<td>All Years</td>
<td></td>
</tr>
<tr>
<td><em>Raja montagui</em></td>
<td>All Years</td>
<td>All Years</td>
<td>-1 Year</td>
<td>-1 Year</td>
</tr>
<tr>
<td><em>Scaphthalmus rhombus</em></td>
<td>-1 Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Scyliorhinus canicula</em></td>
<td>All Years</td>
<td>All Years</td>
<td>All Years</td>
<td></td>
</tr>
<tr>
<td><em>Scyliorhinus stellaris</em></td>
<td></td>
<td>-1 Year</td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Squalus acanthias</em></td>
<td></td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Amblyraja radiata</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Anarhichas lupus</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Anguilla anguilla</em></td>
<td>-1 Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Brosme brosme</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chimaera monstrosa</em></td>
<td></td>
<td>-1 Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Conger conger</em></td>
<td></td>
<td>All Years</td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Cyclopterus lumpus</em></td>
<td>-1 Year</td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Gadus morhua</em></td>
<td>All Years</td>
<td></td>
<td></td>
<td>All Years</td>
</tr>
<tr>
<td><em>Galeorhinus galeus</em></td>
<td></td>
<td>-1 Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Galeus melastomus</em></td>
<td></td>
<td>-1 Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Glyptocephalus cynoglossus</em></td>
<td>-1 Year</td>
<td></td>
<td>-1 Year</td>
<td>-1 Year</td>
</tr>
<tr>
<td><em>Hippoglossus hippoglossus</em></td>
<td>-1 Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Leucoraja naevus</em></td>
<td></td>
<td>-1 Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lophius piscatorius</em></td>
<td></td>
<td>All Years</td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Melanogrammus aeglefinus</em></td>
<td>All Years</td>
<td>All Years</td>
<td>All Years</td>
<td></td>
</tr>
<tr>
<td><em>Merluccius merluccius</em></td>
<td></td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Microstomus kitt</em></td>
<td></td>
<td>All Years</td>
<td>All Years</td>
<td></td>
</tr>
<tr>
<td><em>Molva molva</em></td>
<td></td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Pollachius pollachius</em></td>
<td></td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Pollachius virens</em></td>
<td></td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Scomber scombrus</em></td>
<td>-1 Year</td>
<td></td>
<td>All Years</td>
<td></td>
</tr>
<tr>
<td><em>Trigla lyra</em></td>
<td></td>
<td></td>
<td>-1 Year</td>
<td></td>
</tr>
<tr>
<td><em>Zeus faber</em></td>
<td></td>
<td></td>
<td>All Years</td>
<td></td>
</tr>
</tbody>
</table>
6.2.3 Sensitivity and its Effect on Meeting or Missing Recovery Targets

Comparison of the PFS sensitivity scores of sensitive fish species that either met, or failed to meet, their species-specific abundance metric-level targets in each assessment year, 2010 to 2016, for the Greater North Sea GNSIntOT1 survey assessments revealed no significant difference (Figure 6.2.3.1: Mann–Whitney U test and One Way ANOVA). Examination of the box plots suggested that the direction of the difference in median PFS scores of species meeting and species failing their targets varied from year to year. Indeed, in the comparison that came the closest to being statistically significant (2013, MWU \( p<0.06 \), ANOVA \( p<0.07 \)), the direction of the difference was opposite to what might have been expected; species failing their species-specific abundance metric-level targets had the lower median PFS score (Figure 6.2.3.1).

![Box plots showing the median (horizontal bar), 50\%ile (Grey box) and range (whisker) of PFS sensitivity metric scores for sensitive fish species sampled by the GNSIntOT1 survey for species whose species-specific abundance metrics met their species-specific abundance metric-level targets (Pass) and species whose species-specific abundance metrics failed to meet their species-specific abundance metric-level targets (Fail) in each assessment year from 2010 to the last year when data were available.](image)

6.3 Expanding the method of defining sensitive species to other areas – example of the Baltic Sea

The PFS sensitivity metric has been developed for fish in the Northeast Atlantic Area, but a long-term goal could be to facilitate advice on sensitive species throughout the entire ICES area. However expanding the method to further areas might require certain adaptation of the approach, which has to be carefully thought through in a region-specific context. In addition particular attention should be paid to the compilation of life-history-parameters, which usually vary among regions subject to different environmental conditions.
Certainly a good example for region-specific indicator requirements is the Baltic Sea ecosystem. The fish community in this semi-enclosed sea differs from “normal” marine communities, being specialized in several ways due to:

1) brackish water conditions with a salinity gradient decreasing from west to east;
2) environmental conditions characterized by often strong yearly variations due to irregular saltwater inflow events from the North Sea;
3) oxygen depletion in some areas, such as the deep basins, to varying extents.

Comparatively few fish species are adapted to and reproduce in this environment. Instead, many fish species in the Baltic Sea occur at the edge of their distribution area. This affects a range of marine species, migrating occasionally from the North Sea into the Skagerrak, Kattegat and parts of the Western Baltic Sea as well as many freshwater species migrating from rivers into the less saline coastal areas. Accordingly, the Baltic Sea ecosystem accommodates many different fish communities based on a latitudinal as well as depth gradient. Accordingly analysis on biodiversity should be clear about which area and community it is referring to and should aim at only evaluating status of resident species in order to ensure biologically meaningful assessment outcomes. Some data limitations might occur in the Baltic; e.g. assessing biodiversity of the demersal fish community would require the usage of Baltic International Trawl Survey (BITS) data. This survey programme is focusing on Baltic cod and the most abundant flatfish species, whereas other species (e.g. from coastal areas) might be caught less representatively.

A very preliminary analysis was conducted on defining suites of sensitive demersal species under different fishing scenarios in the Western Baltic Sea (ICES Subdivisions 22–24) based on BITS data from 2002 to 2017. During BITS more than 80 species were identified in the area from 2002 onwards, but only 41 of those species occurred in 50% of the years. From these only 22 species might be considered to be real resident species. Taking these residents as the first step to defining a suite of sensitive species, more or fewer species could be considered to be sensitive to fishing depending on the assumed size of entry in the fishery as well as the assumed fishery induced mortality (Figure 6.3.1). The underlying assumption for not being sensitive is that fish should be able to spawn at least once before being exposed to fishing.
6.4 Assessment conclusions

Evidence indicating recovery in the population size of a significant number of sensitive fish species is mixed, and is primarily restricted to the Celtic Seas Region. Evidence to support the contention that further declines in the abundance of sensitive fish species have at least been halted under current fisheries management regimes is more compelling and widespread, suggesting that further decline has been prevented across the whole Northeast Atlantic. Since population recovery has not been convincingly demonstrated among a significant number of sensitive fish species in most regions, many of these populations should still be considered to be in a depleted state. Any relaxation of fisheries management measures would therefore have to be carefully considered. Further restriction of fishing activity may yet be necessary to stimulate abundance increase in more populations of sensitive fish species, and this may be most necessary in the Bay of Biscay and Iberian Coast and Wider Atlantic Regions, and perhaps even in the Greater North Sea.

6.5 References


7 In support of providing ecosystem advice, define a list of relevant pressure, driver and state indicators to be estimated by relevant expert groups, including stock assessment groups (ToR e)

Summary

The aim of the work under this ToR was to provide a working list of indicators that could be developed and made operational by the ICES secretariat and/or selected assessment or ecology expert groups. The aspects covered were mainly biodiversity and foodweb indicators, but also included brief consideration of indicators of age and length structure in fish, and marine litter. Indicators of benthic pressure and state were addressed within ToR a and f.

WGECO based the work principally on the common indicators developed by OSPAR, but noted that a definitive and up to date list of these was difficult to identify. Candidate indicators were mostly ignored as these are not usually at an operational level, and again, no definitive list appears to exist. Evaluations of many, but not all, the indicators chosen have been carried out by WKFOOWI (ICES, 2014a) and WGBIODIV (ICES, 2015), based on criteria worked out by WGECO and WGBIODIV. These allowed an appreciation of both the “effectiveness” of each indicator and its potential to be used operationally.

Based on this selection WGECO used a polling approach to identify the best candidates for operationalisation based on their effectiveness and defined methods and data. The top five indicators comprised:

- Fish abundance - sensitive species indicator (OSPAR FC1);
- Mean weight-at-age of predatory or planktivorous fish species from data;
- Plankton biomass and/or abundance (OSPAR PH2);
- Guild level biomass;
- Size composition in fish communities (TyL pelagic and demersal, OPSAR FW3).

The top five are rather dominated by fish focused indicators, which probably reflects both the general focus of WGECO expertise, but also the maturity of the indicator development and the availability of good data.

WGECO also identified six other indicators that could be monitored by ICES:

- Abundance and distribution of seals (OSPAR M3);
- Cetacean abundance and distribution (OSPAR M4);
- Marine bird abundance (OSPAR B1);
- Phytoplankton primary production (OSPAR FW2);
- Changes in average trophic level of marine predators (fish and invertebrates) (OSPAR FW4);
- Region-specific indicators of abundance and spatial distribution.

This provides a wider ecological range including top predators, and phytoplankton, as well as trophic and distribution based indicators.
OSPAR uses the above codes to categorise the indicators. FC is for Fish and Cephalopods. PH is for Pelagic Habitat. FW is for FoodWeb. M is for Mammals, and B is for Birds.

WGECO notes that these all represent indicators of state not pressure (although OSPAR FW4 includes change in the average trophic level of the catch in addition to the state based on surveys). Pressure indicators do exist for commercial fish (fishing mortality) and for fishing pressure on the seabed (see ToR f).

Finally, WGECO revisited the indicator gaps analysis carried out by WGBIODIV, and identified a number of additional indicators that would merit further research.

7.1 Commercial fish

7.1.1 SSB and F-based indicators

7.1.2 Indicators addressing age and length structure

In recognition of the ongoing ICES D3C3 development, WGECO offers the following suggestions. The assessment of age and size distributions of individuals within commercially exploited stocks as required under MSFD criterion D3C3 currently lacks operational indicators with biologically meaningful thresholds. The data currently collected for stock assessment purposes (incl. surveys) are however suitable for assessing the age and/or size distribution of a stock and there are three potential size-based indicators identified for further testing. For these reasons it is currently advised to use D3C3 as surveillance indicator for age and/or size distribution. WGECO agrees that this criterion is worthy of further development, since in general it can be considered beneficial for a population to have a balanced age and length structure and to avoid adverse effects of exploitation on genetic diversity. The indicator for D3C2 (SSB) does not directly account for these aspects of fish stock status. Nevertheless there might not be a one-fits-all solution, but a necessity for stock-by-stock solutions to derive reference levels. In the case of species with intermittent recruitment (e.g. horse mackerel) an indicator for large/old individuals in the stock might be less useful. This is especially true if such an indicator is calculated on a proportional basis, since such a metric would be greatly affected by episodic recruitment events. WGECO therefore advises against developing a proportional indicator for D3C3 in isolation and suggests indicators are developed based on absolute abundance or biomass. The stock assessment working groups could be tasked with tailoring stock specific age- and size-based indicators where this was expected to provide relevant information for the stock and to calculate the time-trends following ICES advice (ICES, 2017).

7.1.3 Integration of indicators under the MSFD

The following discussion provides the WGECO perspective on combining commercial fish indicators in the context of them being relevant to both fisheries and MSFD management. Elaboration of advice could be a ToR for the next WGECO. ICES advised in May 2016 (ICES, 2016a) that “assessments of GES for D3 at an MSFD regional or subregional level should be based on the proportion of both criteria for each stock within a region or subregion achieving GES status”... “Agreed limits for each of these criteria to define GES is outside the ICES remit and should be decided at the policy level.” (ICES, 2016a). Subsequently, Commission (2016b) stated that “The extent to which good environmental status has been achieved shall be expressed for each area assessed as follows: (a) the populations assessed, the values achieved for each criteri-
on and whether the levels for D3C1 and D3C2 and the threshold values for D3C3 have been achieved, and the overall status of the population on the basis of criteria integration rules agreed at Union level;” In addition to this, it is stated that “For D3C1 and D3C2, the following shall apply: (a) for stocks managed under a multiannual plan according to Article 9 of Regulation (EU) No 1380/2013, in situations of mixed fisheries, the target fishing mortality and the biomass levels capable of producing maximum sustainable yield shall be in accordance with the relevant multiannual plan” (Commission 2016b).”

Together, these guidelines state that D3 integration should be compatible with the use of a target fishing mortality and biomass levels as stated in relevant multiannual plans. According to the agreed Baltic and Multiannual plan (Commission, 2016b), FMSY is the target fishing mortality except in cases where biological interactions, catch stability considerations or mixed fisheries considerations warrant the use of a fishing mortality in the FMSY-range which for some stocks includes values above FMSY. A fishing mortality below FMSY can always be used as a target. This poses issues to the evaluation of GES of D3.

As the Multiannual plan clearly defines FMSY as a target for fishing mortality, it is to be expected that this target is exceeded in half of the years or, equivalently, for half the stocks in any given year. The variation around FMSY depends on the accuracy of the stock assessment and implementation of the agreed TAC. Similar considerations apply to the use of biomass reference points for commercial stocks. In some cases, fishing the stock at FMSY should ensure that we are far above the relevant biomass reference points. However, this is not universally the case, particularly for pelagic fish, where fishing the stock at FMSY may lead to a substantial (though less than 50%) chance of being below the biomass reference point MSY Btrigger.

In the current setup, a stock like Baltic sprat fished according to the multiannual plan will in any year have a 50% probability of being fished at an F above FMSY and an almost 50% probability of having a biomass below MSY Btrigger. If longer term averages are used rather than average values, the deviations from the reference points decrease, but the fundamental problem of probabilities is not resolved. The current version of the fisheries overviews report any value of F above FMSY and any value of SSB below MSY Btrigger as being red, and hence supports the perception that following ICES advice will lead to a large proportion of ‘red’ stocks. This seems to provide an unfortunate image of ICES advice being unsustainable and in conflict with GES as even stocks where advice is followed without deviation may result in ‘red’ values.

### 7.2 Biodiversity and foodweb indicators

WKFOOWI (ICES, 2015a; Tam et al., 2017) rated indicators within three topic groups: energy flow, structure and ecosystem resilience. From these indicators, highly rated examples were chosen and cross referenced against OSPAR/HELCOM indicators. Finally, easily estimated indicators were described in more detail.

WGBIODIV carried out a similar exercise for “biodiversity” indicators given the technical specifications available at the time (ICES, 2015b). Many of these overlapped with those from WKFOOWI, and are included here as one indicator. Indicators were evaluated for “effectiveness” and for operational potential.

#### Highly rated indicators

In Table 7.2.1a, the top five indicators (WKFOOWI) are divided into the topics they reflect. Ecosystem resilience indicators were considered to require more work, and
none of the suggested indicators reach 50% of the maximum rating and as a result, these were omitted from the table. Table 7.2.2 maps indicators used by OSPAR and HELCOM against the highly rated foodweb indicators, omitting one indicator from OSPAR which was rated low by WKFOOWI (FW4, Changes in average trophic level of marine predators).

In Table 7.2.1b, all indicators identified in the most recent OSPAR list are listed by topic together with their rating by WGBIODIV where available. This table includes some that are probably not technically “biodiversity” indicators.

Table 7.2.1a. Indicators receiving a top 5 rating (% of maximum rating from Tam et al. 2017), collecting indicators reflecting similar aspects under the highest rated of the indicators in the group.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>WKFOOWI rating</th>
<th>Foodweb aspect</th>
<th>Similar indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seabird breeding success</td>
<td>85</td>
<td>Energy flow, predatory seabirds</td>
<td>Productivity of key predators</td>
</tr>
<tr>
<td>Mean weight-at-age of predatory fish species from data</td>
<td>81</td>
<td>Energy flow, predatory fish</td>
<td>Mean condition of predatory fish, Productivity of key predators</td>
</tr>
<tr>
<td>Total mortality</td>
<td>73</td>
<td>Energy flow, all groups</td>
<td>Productivity of mammals</td>
</tr>
<tr>
<td>Productivity of key predators</td>
<td>69</td>
<td>Energy flow, all groups</td>
<td>Productivity of mammals</td>
</tr>
<tr>
<td>Primary production required to support fisheries</td>
<td>69</td>
<td>Energy flow</td>
<td></td>
</tr>
<tr>
<td>Productive pelagic habitat index</td>
<td>69</td>
<td>Energy flow</td>
<td></td>
</tr>
<tr>
<td>Guild level biomass</td>
<td>96*/77</td>
<td>Structure</td>
<td>Guild level biomass, scavenger biomass</td>
</tr>
<tr>
<td>Large fish indicator</td>
<td>96</td>
<td>Structure, size structure of demersal fish</td>
<td>Mean length of surveyed community, Proportion of predatory fish, Size spectra slope</td>
</tr>
<tr>
<td>Total biomass of small fish</td>
<td>88</td>
<td>Structure, prey fish abundance</td>
<td></td>
</tr>
<tr>
<td>Pelagic-to-demersal ratio</td>
<td>81</td>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Lifeform-based indicator for the pelagic habitat</td>
<td>77</td>
<td>Structure, pelagic habitat</td>
<td></td>
</tr>
<tr>
<td>Region-specific indicators of abundance and spatial distribution</td>
<td>73</td>
<td>Structure, biodiversity</td>
<td>Geometric mean abundance of seabirds</td>
</tr>
</tbody>
</table>

*Model-based.
Table 7.2.1.b. Biodiversity and related indicators from OSPAR list (From OSPAR Coordinated Environmental Monitoring Programme (CEMP) (available at https://www.ospar.org/work-areas/bdc) and where relevant with evaluation of “effectiveness” and “operationalization” by WGBIODIV (ICES, 2015a).

*Italics in column 4 represent changes in wording of the indicator*

<table>
<thead>
<tr>
<th>Biodiversity indicators</th>
<th>WGBIODIV effectiveness rating</th>
<th>BioD aspect WGBIODIV Operational score</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abundance and distribution of seals</td>
<td>70+</td>
<td>Mammals 90+</td>
<td>Previous description: Abundance of grey and harbour seal at haul-out sites</td>
</tr>
<tr>
<td>Cetacean abundance and distribution</td>
<td>60+</td>
<td>Mammals 80+</td>
<td>Previous description: Abundance at the relevant temporal scale of cetacean species regularly present</td>
</tr>
<tr>
<td>Grey seal pup production</td>
<td>70+</td>
<td>Mammals 80+</td>
<td>Previous description: Harbour seal and Grey seal pup production Productivity of key predators Grey seal pup production 7.2.2</td>
</tr>
<tr>
<td>Marine bird abundance</td>
<td>70+</td>
<td>Seabirds 90+</td>
<td>Previous description: Species-specific trends in relative abundance of non-breeding and breeding marine bird species</td>
</tr>
<tr>
<td>Marine bird breeding success/failure</td>
<td>70+</td>
<td>Seabirds 70+</td>
<td>Seabird breeding success (above) &amp; 7.2.2.</td>
</tr>
<tr>
<td>Fish abundance</td>
<td>70+</td>
<td>Fish 80+</td>
<td>Sensitive species indicator</td>
</tr>
<tr>
<td>Proportion of large fish (LFI)</td>
<td>90+</td>
<td>Fish (Commercial) 100</td>
<td>LFI above &amp; 7.2.2.</td>
</tr>
<tr>
<td>Condition of benthic habitat defining communities (MMI)</td>
<td>(70+)</td>
<td>Benthic Habitats (70+)</td>
<td>Previous description: Multi-metric indices, and was a candidate indicator</td>
</tr>
<tr>
<td>Physical damage of predominant and special habitats</td>
<td>55</td>
<td>Benthic Habitats 70</td>
<td>Pressure indicator</td>
</tr>
<tr>
<td>Plankton lifeforms</td>
<td>60</td>
<td>Pelagic Habitats 60</td>
<td>Lifeform-based indicator for the pelagic habitat (above) &amp; 7.2.2.</td>
</tr>
<tr>
<td>Plankton biomass and/or abundance</td>
<td>65</td>
<td>Pelagic Habitats 70</td>
<td>Productive pelagic habitat index 7.2.2.</td>
</tr>
<tr>
<td>Plankton diversity index</td>
<td>55</td>
<td>Pelagic Habitats 60</td>
<td></td>
</tr>
<tr>
<td>Biodiversity indicators</td>
<td>WGBIODIV effectiveness rating</td>
<td>BioD aspect</td>
<td>Comments</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Production of phytoplankton</td>
<td>70+</td>
<td>Foodwebs</td>
<td></td>
</tr>
<tr>
<td>Size composition in fish communities (TyL pelagic and demersal)</td>
<td>Not Evaluated</td>
<td>Not Evaluated</td>
<td></td>
</tr>
<tr>
<td>Changes in average trophic level of marine predators</td>
<td>70</td>
<td>Foodwebs</td>
<td></td>
</tr>
<tr>
<td>Marine litter on beaches</td>
<td>Not Evaluated</td>
<td>Not Evaluated</td>
<td>Not biodiversity. Probably operational</td>
</tr>
<tr>
<td>Marine Litter on the sea floor</td>
<td>Not Evaluated</td>
<td>Not Evaluated</td>
<td>Not biodiversity. Operationally possible using IBTS/BTS</td>
</tr>
<tr>
<td>Plastic Particles in fulmar stomachs (Appendix BE3);</td>
<td>Not Evaluated</td>
<td>Not Evaluated</td>
<td>Not biodiversity. Difficult to make operational</td>
</tr>
<tr>
<td>Trends in arrival of new non-indigenous species</td>
<td>Not Evaluated</td>
<td>Not Evaluated</td>
<td>Probably operational</td>
</tr>
</tbody>
</table>
Table 7.2.2. HELCOM and OSPAR together with the WKFOOWI equivalent, omitting indicators which WKFOOWI rated low not top 5, FW4 OSPAR.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>OSPAR equivalent indicator</th>
<th>HELCOM equivalent indicator (from <a href="http://www.helcom.fi/baltic-sea-trends/indicators">http://www.helcom.fi/baltic-sea-trends/indicators</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seabird breeding success</td>
<td>Marine bird breeding success/failure</td>
<td>White-tailed eagle productivity (related to contaminants)</td>
</tr>
<tr>
<td>Mean weight-at-age of predatory fish species from data</td>
<td>No indicator suggested</td>
<td>No indicator suggested</td>
</tr>
<tr>
<td>Total mortality (Production:Biomass ratio)</td>
<td>No indicator suggested</td>
<td>No indicator suggested</td>
</tr>
<tr>
<td>Productivity of key predators</td>
<td>Grey seal pup production</td>
<td>Nutritional status of seals Reproductive status of seals</td>
</tr>
<tr>
<td>Primary production required to support fisheries</td>
<td>No indicator suggested</td>
<td>No indicator suggested</td>
</tr>
<tr>
<td>Productive pelagic habitat index</td>
<td>Production of phytoplankton</td>
<td>Chlorophyll-a</td>
</tr>
<tr>
<td>Guild level biomass</td>
<td>Plankton biomass and/or abundance</td>
<td>Abundance of waterbirds in the breeding season Abundance of waterbirds in the winter season Population trends and abundance of seals Zooplankton mean size and total stock</td>
</tr>
<tr>
<td>Large fish indicator</td>
<td>OSPAR EcoQO proportion of large fish (LFI)</td>
<td>Seasonal succession of dominating phytoplankton groups Diatom/ Dinoflagellate index Phytoplankton community composition as a foodweb indicator</td>
</tr>
<tr>
<td>Total biomass of small fish</td>
<td>No indicator suggested</td>
<td>No indicator suggested</td>
</tr>
<tr>
<td>Pelagic to demersal ratio</td>
<td>No indicator suggested</td>
<td>No indicator suggested</td>
</tr>
<tr>
<td>Lifeform-based indicator for the pelagic habitat</td>
<td>Plankton diversity index Plankton lifeforms</td>
<td>Seasonal succession of dominating phytoplankton groups Diatom/ Dinoflagellate index Phytoplankton community composition as a foodweb indicator</td>
</tr>
<tr>
<td>Region-specific indicators of abundance and spatial distribution</td>
<td>Fish abundance Abundance and distribution of seals Cetacean abundance and distribution Marine bird abundance</td>
<td>Abundance of coastal fish key functional groups Abundance of key coastal fish species Abundance of salmon spawners and smolt Abundance of sea trout spawners and parr Abundance of waterbirds in the breeding season</td>
</tr>
<tr>
<td>Indicator</td>
<td>OSPAR equivalent indicator</td>
<td>HELCOM equivalent indicator (from <a href="http://www.helcom.fi/baltic-sea-trends/indicators">http://www.helcom.fi/baltic-sea-trends/indicators</a>)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Abundance of waterbirds in the wintering season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution of Baltic seals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population trends and abundance of seals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zooplankton mean size and total stock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 7.3 Indicators for biodiversity, foodwebs and commercial fish which are candidates for ICES to estimate routinely (automatically?) with present data resources

In Table 7.2.3, indicators from the previous tables are combined, and their potential as operational indicators for ICES to develop their use, are identified.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Data and method</th>
<th>Area</th>
<th>Reference for full description of methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>M3, Abundance and distribution of seals</td>
<td>No expertise in WGECO, and should be sent to appropriate WG for data, method and evaluation. Rated effective and operational by WKFOOWI and WGBIODIV.</td>
<td>All</td>
<td>WGMAMMAL</td>
</tr>
<tr>
<td>M4, Cetacean abundance and distribution</td>
<td>No expertise in WGECO, and should be sent to appropriate WG for data, method and evaluation. Not rated by WKFOOWI. Rated as not very effective but good operationally by WGBIODIV.</td>
<td>All</td>
<td>WGMAMMAL</td>
</tr>
<tr>
<td>M5, Grey seal pup production</td>
<td>No expertise in WGECO, and should be sent to appropriate WG for data, method and evaluation. Rated as fairly effective and operational by WGBIODIV and WKFOOWI.</td>
<td>All</td>
<td>WGMAMMAL</td>
</tr>
<tr>
<td>B1, Marine bird abundance</td>
<td>No expertise in WGECO, and should be sent to appropriate WG for data, method and evaluation. Rated as fairly effective and operational by WGBIODIV and WKFOOWI.</td>
<td>All</td>
<td>JWGBIRD,</td>
</tr>
<tr>
<td>B3, Seabird breeding success</td>
<td>Low operational score by WGBIODIV High effectiveness score by WKFOOWI Operational in OSPAR</td>
<td>All</td>
<td>WGSEABIRD</td>
</tr>
<tr>
<td>FC1, Fish abundance - sensitive species indicator</td>
<td>Data from bottom-trawl surveys - DATRAS. Methods developed for OSPAR interim assessments Not evaluated by WGBIODIV or WKFOOWI.</td>
<td>North Seas</td>
<td>WGECO (ICES, 2016). Greenstreet et al. (2012)</td>
</tr>
<tr>
<td>FC2, Proportion of large fish (LFI)</td>
<td>From DATRAS data using published methods. Fully operational at ICES</td>
<td>Surveyed areas, fully or partially developed for North Sea, Celtic Sea, Southern Bay of Biscay, Poland EEZ</td>
<td>Greenstreet et al., 2011; Shephard et al., 2011; Oesterwind et al., 2013; WGECO 2014.</td>
</tr>
<tr>
<td>Indicator</td>
<td>Data and method</td>
<td>Area</td>
<td>Reference for full description of methods</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>PH1, Plankton lifeforms Also FW5</td>
<td>From CPR programme WGBIODIV suggested low operational possibilities. WKFOOWI evaluated as medium to good.</td>
<td>All areas covered by CPR</td>
<td>Tett <em>et al.</em>, 2008; 2013 and procedures from SAHFOS</td>
</tr>
<tr>
<td>PH2, Plankton biomass and/or abundance</td>
<td>Analysis by Emodnet biology (under OOPS) on a zooplankton (main copepods) abundance time-series, based on SAHFOS data Evaluated previously as medium effectiveness and operational by WGBIODIV, but operational and effective by WKFOOWI</td>
<td>All areas</td>
<td>Methods under development by ICES OOPS</td>
</tr>
<tr>
<td>PH3, Plankton diversity index</td>
<td>Evaluated previously as low effectiveness and operational by WGBIODIV Not evaluated by WKFOOWI</td>
<td>All areas</td>
<td>Not known</td>
</tr>
<tr>
<td>FW2, Production of phytoplankton</td>
<td>Evaluated previously as low effectiveness and operational by WGBIODIV</td>
<td>All areas</td>
<td>Methods from SAHFOS, and ESA??</td>
</tr>
<tr>
<td>FW3, Size composition in fish communities (Typical Length pelagic and demersal)</td>
<td>Data should be available from DATRAS, and acoustic survey databases held by ICES Not evaluated by WGBIODIV or WKFOOWL Needs evaluation e.g. WGECO</td>
<td>All surveyed areas</td>
<td>WGECO could develop method, but should be straightforward</td>
</tr>
<tr>
<td>FW4, Changes in average trophic level of marine predators</td>
<td>Data from Stable Isotope analysis and stomach contents Probably not operational on a routine basis now. But if ICES data holdings or access provide this then very possible. Evaluated previously as medium effectiveness and high operational by WGBIODIV Low effectiveness score WKFOOWI</td>
<td>All</td>
<td>Jenning and van der Molen (2015)</td>
</tr>
<tr>
<td>Mean weight-at-age of predatory fish species from data Energy flow indicator</td>
<td>Data from stock assessment, indices aggregated across ages and stocks within guilds and geographic region. Not evaluated by WGBIODIV or WKFOOWL.</td>
<td>All</td>
<td>Shephard <em>et al.</em>, 2014</td>
</tr>
<tr>
<td>Total mortality Energy flow indicator</td>
<td>Historic data available from WGSAM key runs for a range of species. Indicator aggregating this between species (e.g. within guilds) not developed. Rated high by WKFOOWI</td>
<td>Baltic, Barents Sea, North Sea, Celtic Sea</td>
<td>Objective of indicator is unclear</td>
</tr>
<tr>
<td>Productivity of key predators Energy flow indicator</td>
<td>Rated high by WKFOOWI</td>
<td>WGMAMMAL</td>
<td></td>
</tr>
<tr>
<td>Productive pelagic habitat index</td>
<td>See PH2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 7.4 Benthic habitat

Several Benthic Ecosystem indicators were identified in the OSPAR list and that had been evaluated by WGBIODIV. WGECO has not included these in the analysis and selection process; however, these are discussed in detail in Chapter 8 (ToR f).

### 7.5 Marine litter

HELCOM and OSPAR have both suggested indicators of litter on the sea floor based on DATRAS data. Two indicators have been suggested, the probability of catching litter in each of the categories plastic, metal, glass, rubber, natural and miscellaneous and the average number caught per area trawled. Similar to fish catches, litter catches are zero inflated and highly skewed, and hence a delta-estimator (Pennington, 1985) seems more appropriate than the observed mean. This indicator is estimated as the probability of catching litter multiplied by the geometric mean of non-zero catch numbers. Corresponding maps of litter abundance can be produced. Care should be taken not to assume that catchability is identical in different survey gear (including different groundgear), and hence catch rates in e.g. the Baltic and North Sea are not comparable, and neither are northern and southern IBTS in the North Sea, as these are carried out with different GOV groundgear. Trends within areas and spatial distribution in areas where the same groundgear is used can be compared if the absolute level cannot. These three litter indicators could be made available in the DATRAS data products and maps on the ICES website.

### 7.6 Comparison with literature reviews of indicators

The WKFOOWI list was compared to the list of commonly encountered indicators given by Hayes et al. (2015):

- Abundance/biomass of:
  - alien and invasive species;
  - zooplankton/planktivores;
  - aquatic flora/macroalgae, separated in opportunistic and perennial;
  - fish (including spawning biomass);
  - key/important/indicator species/populations;
  - harbour porpoise.
- Area of key/important/main habitat;
• Area of protected habitat;
• Catch (total fish);
• Concentration of:
  • Chlorophyll a;
  • dissolved oxygen;
  • Nitrogen/Nitrate;
  • Phosphorus/Phosphate.
• Harmful Algal Bloom (frequency/extent);
• Number species (Invasive);
• Number/percent species (Threatened/Endangered Protected).

7.7 **Important gaps in indicator availability**

In identifying the most important indicators for operational use by ICES, WGECO also felt that it was important to identify where the main gaps existed in the availability of indicators.

WGBIODIV identified a number of gaps. These were mainly based on weaknesses in the monitoring and hence in the data needed to calculate metrics for a range of indicators. The gaps were principally under the following headings:

• Benthic communities - addressed under ToR f of this report.
• Genetic diversity.
• Coastal and inshore fish communities - addressed to some extent under HELCOM indicators, but still subject to a weakness in consistent monitoring and sampling.
• Sensitive species - the indicator is addressed under FC1, but data needs for monitoring of sensitive species other than fish (those monitored with the trawl surveys), e.g. benthic invertebrates.
• Communities in rocky habitats. These are not monitored by the surveys that cannot operate in rough ground. Species which inhabit these areas therefore tend to be unrepresented in biodiversity and foodweb indicators. Quantitative sampling methods do exist, e.g. pots and traps etc. but are not consistently or routinely applied (possibly with the exception of some specific inshore species e.g. crustacea).
• Deep-water habitats and species. Some deep-water surveys are carried out, but biodiversity and foodweb indicators for these communities need to be derived. These habitats are also often considered vulnerable and sensitive, and may be covered under BH3 under ToR f, but routine monitoring and hence indicator tracking is likely to be difficult.
• Highly migratory species - in particular species like tuna, large elasmobranchs, etc. These are poorly monitored in many areas. Possibly collaboration with other organisations such as ICCAT, NEAFC and NAFO would be appropriate. Salmonids would also be a possible case, where monitoring in the coastal and aquatic stages is well monitored but the oceanic phase is weakly monitored.
• Microplankton and microbenthos. Theoretically covered in PH1 for the microplankton, but monitoring is minimal. As with benthos in general, moni-
toring for microbenthos is largely absent. Indicator gaps exist as a con-
sequence.
- Cephalopods. These are sometimes monitored in trawl surveys, but the
surveys may not be designed for this monitoring. Species like octopus are
poorly monitored.
- Cetacean productivity. There are proposed indicators for seal and seabird
productivity, albeit with poor monitoring. No such indicators, or monitor-
ing, exists for cetaceans.
- Spatial occupation by seals. Most distributional metrics and indicators are
based on haul outs, etc. Small and disjoint studies exist for at sea use of the
ecosystem, mainly based on ARGOS tagging.

Based on the analysis carried out for this ToR, WGECO also identified a number of
biodiversity indicators that could be potentially valuable, but currently lack devel-
oped methodology. These include:
- Total mortality.
- Productivity of key predators.
- Primary production required to support fisheries.
- Guild level biomass.
- Total biomass of small fish.
- Pelagic-to-demersal ratio.

7.8 Selected indicators

As requested in the ToR, WGECO used the above tables to provide a prioritised list of
ecosystem indicators that had potentially high value and utility, and that were readi-
ly calculable by ICES using existing or available data holdings. Where possible, the
chosen indicators were identified with sources for calculation methods. WGECO
have also attempted to list these in order of priority, but it should be emphasised that
this prioritization was based on the expert judgement of the group. The prioritization
was made using a blind poll of the WGECO membership. These represented sci-
entists from the Baltic, North and Celtic Seas, as well as the wider North Atlantic. There
were no participants from the Mediterranean, or the Iberian and Biscay areas. It is
quite possible that a different group would make a different prioritization.

It is very important to note that WGECO is NOT suggesting these are the most im-
portant or most suitable ecosystem indicators in general. They are selected purely
on the basis that they are appropriate to operationalisation with the ICES data sys-
tem.

Indicators in order of priority:
- Fish abundance - sensitive species indicator.
- Mean weight-at-age of predatory or planktivorous fish species from data.
- Plankton biomass and/or abundance.
- Guild level biomass.
- Size composition in fish communities (TyL pelagic and demersal).
These represent the top five indicators proposed for operation by ICES. The following indicators were also identified as having operational potential.

- Abundance and distribution of seals.
- Cetacean abundance and distribution.
- Marine bird abundance.
- Phytoplankton.
- Changes in average trophic level of marine predators.
- Region-specific indicators of abundance and spatial distribution.

Proportion of large fish (LFI) was also identified, but is already in operation at ICES.

7.9 HELCOM indicators

- Abundance of coastal fish key functional groups
- Abundance of key coastal fish species
- Abundance of salmon spawners and smolt
- Abundance of sea trout spawners and parr
- Abundance of waterbirds in the breeding season
- Abundance of waterbirds in the wintering season
- Chlorophyll-a
- Distribution of Baltic seals
- Hexabromocyclododecane (HBCDD)
- Inputs of nitrogen and phosphorus to the basins
- Metals (lead, cadmium and mercury)
- Nitrogen/DIN
- Number of drowned mammals and waterbirds in fishing gears
- Nutritional status of marine mammals
- Oil-spills affecting the marine environment
- Oxygen
- Perfluorooctane sulphonate (PFOS)
- Phosphorus/DIP
- Polybrominated biphenyl ethers (PBDE)
- Population trends and abundance of seals
- Radioactive substances: Cesium-137 in fish and surface waters
- Reproductive status of seals
- Trends in arrival of non-indigenous species
- Water clarity
- White-tailed eagle productivity
Zooplankton mean size and total stock

7.10 **OSPAR indicators**

From OSPAR Coordinated Environmental Monitoring Programme (CEMP) (available at https://www.ospar.org/work-areas/bdc):

- M3, Abundance and distribution of seals (Appendix BB1-M3);
- M4, Cetacean abundance and distribution (Appendix BB2-M4);
- M5, Grey seal pup production (Appendix BB3-M5);
- B1, Marine bird abundance (Appendix BB4-B1);
- B3, Marine bird breeding success/failure (Appendix BB5-B3);
- FC1, Fish abundance (Appendix BB6-FC1);
- FC2, Proportion of large fish (LFI) (Appendix BB7-FC2);
- BH2, Condition of benthic habitat defining communities (MMI) (Appendix BB8 BH2);
- BH3, Physical damage of predominant and special habitats (Appendix BB9-BH3);
- PH1/FW5, Plankton lifeforms (Appendix BB10-PH1/FW5);
- PH2, Plankton biomass and/or abundance (Appendix BB11-PH2);
- PH3, Plankton diversity index (Appendix BB12-PH3);
- NIS3, Trends in arrival of new non-indigenous species (Appendix BB13 NIS3);
- FW3, Size composition in fish communities (TyL pelagic and demersal) (Appendix BB15-FW3);
- FW4, Changes in average trophic level of marine predators (Appendix BB16-FW4);
- BE1, Marine litter on beaches (Appendix BE1);
- BE2, Marine Litter on the sea floor (Appendix BE2);
- BE3, Plastic Particles in fulmar stomachs (Appendix BE3);

Candidate indicators requiring further development:

- M6, Marine mammal bycatch
- BH4, Area of habitat loss
- BH5, Size–frequency distribution of bivalve or other sensitive/indicator species
- FC3 (pilot assessment made), Mean maximum length of demersal fish and elasmobranchs
- FC6, Proportion of mature fish
- FC7, Distributional range
- FC8, Fish distributional pattern
- B2, Breeding success of kittiwake
B4, Non-native/invasive mammal presence on island seabird colonies
B5, Marine bird bycatch
B6, Distribution marine birds
FW1, Reproductive success of marine birds in relation to food availability
FW2 (pilot assessment made), Production of phytoplankton (Appendix BB14-FW2)
FW6, Biomass, species composition and spatial distribution of zooplankton
FW7, Fish biomass and abundance of dietary functional groups
FW8, Biomass trophic Spectrum
FW9, Ecological Network Analysis diversity

7.11 References


ICES. 2016a. Special Request Advice. EU request to provide guidance on the practical methodology for delivering an MSFD GES assessment on D3 for an MSFD region/subregion. 2016.


ICES. 2017. Special Request Advice. EU request to provide guidance on operational methods for the evaluation of the MSFD criterion D3C3 (sr.2017.07).


8. **WGECO is requested to review three ICES workshop reports, WKBENTH (28 February–3 March 2017), WKSTAKE (23 March 2017), and WKTRADE (28–31 March 2017) (ToR f)**

WGECO interpreted the request as capturing two aspects of the advisory work:

1) Assessment of fishing pressure and seafloor status, which is reflected in the first part of the request, i.e. “Evaluate a set of indicators for assessing physical disturbance pressures from bottom-contacting fishing gears and their environmental impacts on seabed habitats/sea floor integrity”. This aspect is based on WKBENTH. For the evaluation of the indicators WGECO considered the available knowledge base to calculate indicators for:
   - Physical disturbance pressures;
   - The impact of fishing on seabed habitats/sea floor integrity based on the methods to determine habitat sensitivity.

2) Guidance for management to mitigate this pressure and its impact, which is reflected in the second part of the request, i.e. “develop an approach on how to demonstrate the trade-off between catch/value of landings per unit area and the environmental impact and recovery potential of the seafloor”. This aspect is based on WKSTAKE and WKTRADE.

### 8.1 **WKBENTH**

The report is very comprehensive but still seems like a work in progress. Several potentially useful approaches are presented. In summary, the physical disturbance indicators appear to be sufficiently well advanced to be used for advice whereas the impact indicators have often not matured to the point where they can be used for advice. There are several impact indicator variants and the methodological difference between them is often minor. As yet, there is insufficient scientific basis for choosing one over the other, but the choice of indicator produces vastly different results.

#### 8.1.1 **Physical disturbance pressures**

For the pressure “physical disturbance caused by fishing” it appeared that different names were used to describe the same indicator, i.e. “fishing intensity”, “fishing effort”, “mean abrasion”, expressed as the area swept per unit area. The same name should be used consistently for the indicator. WGECO considers that the most likely candidate is fishing intensity as fishing effort usually refers to hours fishing or days-at-sea while abrasion caused by fishing is only one of the pressures that make up physical disturbance. The indicator was calculated as the area of the seabed in contact with the fishing gear relative to the surface area of the grid cell (“c square”). The workflow to produce these fishing intensity maps is given in Figure 6.2.1 in the WKBENTH report. From these maps three pressure indicators (1–3) were calculated:

1) The percent of c-squares affected by mobile bottom contacting gears (MBCG) is calculated as the total number of squares within an ICES Ecoregion and depth interval compared to the number where the fishing effort from MBCG is larger than 0. The indicator provides information on the proportion area impacted by fishing. As every c-square touched by fishing is included, this is likely to provide an overestimate of the physical dis-
turbance, which is expected to be higher at coarser spatial resolution. The indicator can be calculated for any spatial subunit within the Ecoregion and we assume that the (arbitrary) decision to estimate this indicator by depth interval rather than EUNIS habitat is just intended as an example.

2) To calculate the percent of c-squares affected by the 90% highest fishing effort, the fishing effort is ordered by c-square with decreasing fishing effort, and the number of c-squares with the 90% highest fishing effort is compared to the total number of c-squares. This indicator adds information on the aggregated nature of fishing. Again, to provide information by habitat, it will need to be estimated by habitat.

3) For calculation of the %footprint area on the seabed, the surface swept-area is used. If the swept-area in a c-square is larger than the area of the c-square, the swept-area is set to the area of the c-square. The total swept-area in an ICES Ecoregion and depth interval is compared to the area of the ICES Ecoregion and depth interval to calculate the %footprint on the c-square. Note that this indicator uses the term footprint to denote a different indicator than the footprint referred to in WKTRADE, which describes the number of c-squares where the swept-area is >=1 divided by the total number of c-squares. This ambiguity in naming is confusing to the reader.

All the above indicators describe the fishing effort in terms of its interaction with the seafloor. An additional indicator could be one that reflects the fishing pressure in terms of its potential to disturb the seafloor:

4) Total swept-area of the fishing fleet, not taking account of how this is distributed over any c-squares, possibly distinguishing between surface and subsurface.

The calculation of these indicators per depth-range and/or per habitat provides a comprehensive assessment of the fishing pressure, i.e. physical disturbance. The data quality issues and caveats spelled out in Section 6.4 are considered comprehensive and relevant.

A general point is that the value of these indicators depends on the spatial and temporal resolution applied. Now the choice was to use c-squares (0.05 x 0.05 degree grid, about 15 km² at 60°N latitude) but higher resolution will give overall lower pressure values and result in a smaller impacted area. Therefore, WGECO recommends that any reporting of pressure indicators should be accompanied by the resolution at which they were derived, even in cases where the resolution of habitat maps are coarser. High resolution fishing effort data are essential to evaluate fishing pressures accurately at fine spatial resolution.

8.1.2 Fishing impact indicators

The WKBENTH report presents a suite of benthos indicators that were developed to assess bottom-trawling impacts of northern boreal habitats (ICES, 2017). Three sets of benthic indicators (i.e. Long-LL 1–2, Long-SBI1–2 and PD1–2) which evaluate changes in benthos relative biomass alone or combined with species longevity were discussed. Two additional indicators applied by OSPAR were also discussed; the BH2 which uses conventional quantitative diversity indices (e.g. Margalef’s D, AMBI, and Shannon–Wiener’s H’), and the BH3 which uses categorical impact scores based upon ex-
pert judgements. These indicators are presented with the relevant information pertaining to their suitability to calculate fishing impact on the benthic community.

Table 8.1.2.1. Relevant characteristics of the indicators proposed by WKBENTH.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Approach and information used</th>
<th>Sensitivity aspect distinguishing between Resistance/Depletion and Resilience/Recovery</th>
<th>Part of the community covered and calculated variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD1 quantifies biomass recovery as a proportion of the assumed full carrying capacity, % of K (biomass/carrying capacity) and a recovery rate, r. PD1 evaluated the recovery rate from bottom trawling in relation to individual EUNIS Level 3 habitats.</td>
<td>Mechanistic based on meta-analysis</td>
<td>Both</td>
<td>Whole community biomass</td>
</tr>
<tr>
<td>PD 2 similarly estimated biomass recovery from bottom trawling but using continuous habitat variables (%gravel, tidal shear stress, depth).</td>
<td>Mechanistic based on meta-analysis</td>
<td>Both</td>
<td>Whole community biomass</td>
</tr>
<tr>
<td>SBI1 (simple longevity approach) is estimated using the longevity distribution for the untrawled situation and provides a worst case situation as it assumes that taxa trawled during their lifespan will always be impacted.</td>
<td>Correlative using trait-based information</td>
<td>Resilience/Recovery only</td>
<td>Whole community biomass</td>
</tr>
<tr>
<td>SBI2 is estimated using the longevity distribution for the observed trawling intensity at each grid cell.</td>
<td>Correlative using trait-based information</td>
<td>Resilience/Recovery only</td>
<td>Whole community biomass</td>
</tr>
<tr>
<td>LL1 estimated the decrease in the biomass of long-lived taxa for each grid cell as a ratio of the untrawled biomass using the parameter estimates of the longevity relationships fitted (Table 7.2.2). The method attempts to take account of depth and tidal shear stress.</td>
<td>Correlative using trait-based information</td>
<td>Resilience/Recovery only</td>
<td>Subset, long-lived only, biomass</td>
</tr>
<tr>
<td>LL2 estimated the decrease in biomass of long-lived taxa if bottom trawling would sweep the grid cell one time more (marginal impact). This indicator may be particularly useful when exploring the trade-off between the impact of trawling and the yield of the fishery (see 7.2.1.7).</td>
<td>Correlative using trait-based information</td>
<td>Resilience/Recovery only</td>
<td>Subset, long-lived only, biomass</td>
</tr>
</tbody>
</table>
BH2 was developed based on an approach that assesses sensitivity to several pressures (fisheries, organic enrichment, sedimentation, etc.). Margalef D is a biodiversity index that performs best in terms of sensitivity and precision for the pressure caused by fisheries and was used as the indicator.

BH3 creates a sensitivity layer indicating species or (when information on species level does not exist) habitats, defined to be sensitive to physical damage (fishing).

### 8.1.3 Review of the presented information on impact indicators

The following general observations apply to the work presented:

1) The rationale for the parameterization of these indicators is often poorly documented, their pros and cons rarely are provided, and there is limited guidance for which situations (e.g. habitat settings) these should be used.

2) The trends in the distribution of sensitivity and impact scores in time and space can vary greatly between some methods. In many cases, the choice of parameters is not logical and may affect comparability and evaluation of their performance.

3) While the specific attributes of these indicators are compared, there is no attempt to evaluate their operational ability.

4) The methodology for calculating the two indicators based on longevity (LL1 and LL2), differ only slightly. There is limited comparison of the performance of these two indicators and little guidance provided when they should be used and why. In Table 7.3.1 the sensitivity scores of both these indicators are combined, but it is uncertain how and why that was done.

5) The strength and weaknesses of these methods are not compared. The WKBENTH Table 9.1.1 states that it uses various well established criteria to evaluate the indicator performance. However, it appears that the table provides baseline information on the specific properties of each of these indicators but does not evaluate their performance.

6) The indicators are not grouped according to which aspects of benthic impact they reflect. This makes the evaluation difficult as an indicator may be the best available for a specific aspect of the benthic community though it performs worse in the evaluation than an indicator for another of those aspects.

7) The quantitative benthos indices were all developed based on grab or corer samples collected in soft sediments (ICES, 2017; Rijnsdorp et al., 2016). The
densities of larger bodied species, deep-burrowing infauna and mobile epifauna, and species that are highly patchily distributed, are thus underestimated (Eleftheriou and Moore, 2013).

8) The WKBENTH comments in Table 9.1.1 on whether the different indicators reflect trends over time seem to be based on the assumption that habitat maps are well known and remain static. This may not necessarily be true as may be discovered if habitat sampling is continued.

8.1.4 Considerations on the suitability of proposed indicators

The following issues and considerations apply to the suitability of the proposed methods and their indicators. Each of these has relevance to the information presented in Table 8.1.2.1.

- There are restrictions on the applicability of the different methods. The quantitative indices were applied to what are often the most common habitats, i.e. A5.1 – Coarse sediment; A5.2 – Sand; A5.3 – Mud; A5.4 – Mixed sediment, but cannot be applied to other habitat types (ICES, 2017), such as pebbles, boulders, bedrock and biogenic habitats (e.g. sponge bottoms, bivalve and cold-water coral reefs and limestone deposits).

- All the quantitative benthos indices were based on biomass measures (i.e. biomass in the samples), except for BH2, which was based on abundance (i.e. density of individuals in the samples).

- The BH2 uses the Margalef diversity index, although this index is sensitive to density (i.e. sampling effort), (Gamito, 2010). Furthermore, the reference values were set so the Margalef diversity index results were dependant on trawling intensity (ICES, 2017). Species richness is highly correlated with density of individuals. Thus, without accounting for species accumulation curves reflecting how changes in macrobenthos density affects the number of species recorded at individual sites, classical species richness and diversity indicators are likely to be subject to variation due to interannual changes in recruitment success (Gislason et al., 2017).

- In general, WKBENTH prefers quantitative continuous methods over qualitative methods. While WGECO agrees that this is appropriate to data-rich systems, it may not be possible in all areas and in areas without data, expert judgement may still be required in the parameterization of the methods. Therefore BH3 may serve as the ‘best available information’ of benthos and benthic habitats in data poor areas, and for sediment habitats not properly represented or covered by the above quantitative benthos indices.

- For all methods, the change over time is determined by the underlying pressure layer. However, only the mechanistic approach can be expected to give a realistic progress in time as this approach includes the actual speed of recovery. For example a sudden major decrease in pressure would cause a sudden increase in the indicator which, notably for the LL1 representing species with very slow (<10 year) recovery, is not expected in reality.

- Methods that explicitly include both Resistance/Depletion and Resilience/Recovery can be considered more specific to the physical disturbance pressure as recovery applies to any pressure causing additional mortality. Methods only including recovery are not specific to physical disturbance.
There is an element of gear specificity in the estimation of fishing pressure, which is reflected in the contribution of different gears to the total swept-area, distinguishing surface and subsurface. However, when calculating impact based on the fishing pressure estimates there are distinct differences between the methods in terms of their capacity to handle different gears. The SBI1/LL1/BH2/BH3 methods do not distinguish between gears when calculating impact based on fishing intensity. In contrast, the PD method distinguishes fishing gears in terms of the depletion they cause based on their penetration depth.

The quantitative indicators (or rather methods) all have their merits and flaws. For example, the population dynamics (PD) approaches appear to be more useful in integrated assessments as they are specific for one pressure, i.e. physical disturbance. The problem with the PD approaches is that they only provide information on the total biomass of the benthic community, which is only one aspect of seafloor integrity and not necessarily the most appropriate one to assess fishing impact. The PD method is a more generic method as its parameters are based on a global meta-analysis but suffers from the assumption that each habitat is a homogenous unit. In contrast, the correlative approaches can be based on empirical data (if available) but there is an issue applying formulas from one (part of an) Ecoregion to another.

8.1.5 Set reference levels

The use of GES and non-GES to signify which c-squares are impacted is confusing and premature as the methodologies are not sufficiently developed and the knowledge base is lacking for the identification or setting of any GES thresholds.

8.2 WKSTAKE

The methods are well explained (with the exception of the lack of naming of chairs and facilitators) in the report. However, the link to original task and the objectives of the discussion is unclear. The introduction does not mention the same purposes of the workshop as the request: 1) operational challenges of the suggested indicators, 2) regional (RSC) and cross-regional (EEA) requirement of the assessment, 3) scientific robustness of procedure, and 4) usefulness of indicators in a management context. WGECO therefore decided to evaluate the general input from WKSTAKE to the workshop process instead of the progress on ToRs and objectives.

WKSTAKE identifies that caveats should be clearly listed in advice, maps should be in compatible formats and that colour schemes should not convey value (e.g. red-yellow-green). Priority actions were:

- identify uncertainty associated with maps and how to communicate this uncertainty,
- the development of sophistication so that local specifics can be taken into account;
- the need to consider the displacement of vessel activity and gear changes;
- the lack of coverage of smaller (<12 m) vessels, and recreational fisheries.

Effort is required to build in further industry input, greater dialogue with stakeholders’ standardization across countries. Finally, the ideal approach should accommodate the possibility and consequences of gear changes.
8.3 **WKTRADE**

The objective of WKTRADE was to propose approaches on how to inform managers about trade-offs between benthic impacts and the landings or revenue of the fisheries, considering both spatial and temporal aspects for MSFD broad habitat types. The intention was to provide guidance on methods that would allow managers to explore the trade-offs between the provision of catch/value and the impact on seafloor habitats.

WGECO specifically reviewed and suggested edits for the draft advice format, as this was the approach suggested to inform managers. The draft advice sections were identified as difficult to understand for stakeholders when WGECO members found them difficult to interpret.

8.3.1 **Draft advice format (WKTRADE Section 5)**

Overall, the advice sheet looks sensible and contains the necessary information. There are, however, several places where the advice can be made easier to understand and more precise in its use of terms. Further, while WGECO appreciates that the example provided was only meant to illustrate what the advice format could look like for one aspect of the benthic community (in this case biomass), other aspects (e.g. biodiversity) may also need to be covered. This necessity for several indicators is addressed in detail in WKBENTH, which also concludes that it is necessary to ensure that spatial management measures do not encourage the reallocation of effort into previously lightly or non-impacted areas. This issue should be repeated in the advice format to avoid the possibility that focusing on single indicators (i.e. less than half of the biomass left compared to undisturbed) encourages closure of medium fished areas causing effort to move to currently unfished areas.

The figures and text refer to pressure, impact and state indicators more-or-less at random, and the draft advice does not use these terms consistently. WGECO considers that it is preferable to use pressure and impact or pressure and state in a consistent manner. From the request, pressure and impact seem to be most relevant, but for consistency with other indicators under the MSFD, pressure and state seems preferable, particularly as this allows the importance of different areas to be judged according to their biomass. However, as only relative estimates of state and impact are available, an area with a carrying capacity (assumed undisturbed biomass) K of 2 which is impacted by 0.5 (resulting biomass 1) will be judged as having a lower state than an area with a K of 200 impacted by 0.25 (resulting biomass 50).

There are numerous abbreviations in the report which are not explained, and which furthermore seem unnecessary as they are generally only mentioned once. WGECO has suggested simplifications to focus the entire document on the pressure indicators ‘times swept per year’ and ‘trawled footprint’, together demonstrating overall pressure and concentrated pressure, and on the impact indicators landings, value and benthic impact. Benthic impact indicators are currently not considered sufficiently developed to be used in operational advice; however, once indicators become available, the description should be applicable to any method. To identify high management cost/benefit areas, the ratio of value to swept-area is used for each habitat. This corresponds to assuming that impact of swept-area is identical in all parts of the habitat. Using value downplays the leverage of the high biomass-low price per kg industrial fisheries.

As information, Table 5.1 is very good and could be given in the summary, removing the ‘state’ row and replacing the c-squares with area fished (swept-area in km²).
8.3.1.1 Pressure

All figure numbering in this section refers to numbers in the example advice sheet at the very end of Section 5 of the WKTRADE report (p. 22 onwards).

Figure 1. The left panel inserted key does not describe what all colours mean and this should be added. The insert on the right panel is unlikely to mean much to the recipient of advice and is furthermore too small to make out. Star in the caption is not explained. As the annual footprint may vary in particular locations, it would be informative to include both the annual swept-area map and the five-year summed swept-area map, as this may be of relevance to longer lived species and also demonstrates that areas currently appearing not to be trawled may have been impacted in other years. Furthermore, when making decisions on spatial management measures, using the final year map only is clearly inadequate. Other time periods could also be considered, but having a short period limits the effects of poorer coverage in the early years of vessels between 12 and 15 m.

Figure 2. Add one more panel showing times swept per year per habitat (left) and footprint per habitat on the right. The current figure legend text is difficult to understand and it is suggested to be rephrased as: “The figure shows the footprint area as a proportion of the habitat area in the region for each year and habitat type for habitats A5.1 – Coarse sediment; A5.2 – Sand; A5.3 – Mud; and A5.4 – mixed sediments and across all habitats (including other habitats). Footprint is defined as the areas swept more than once, on average, in a year.” As no trend is apparent, it could be considered to replace Figure 2 with a bar chart or table showing the footprint for each habitat.

The left panel of Figure 3 is confusing (as it excludes non-fished areas) and is difficult to interpret for both scientists and non-experts. Further, having state indicators in this section on pressures is confusing (Figure 3 right panel) and cumulative curves are difficult to understand for non-experts. WGECO assumes that the main message of this figure is the aggregation of fishing effort and suggests replotting of Figure 3 to show on separate panels, the total swept-area/landings/value as a function of area bins, as shown in the hypothetical panels below:

![Hypothetical panels](image)

This shows the uneven distribution of fishing; if all areas had almost the same fishing effort, the columns would be almost the same size. It could also be considered whether value and landings are both needed or one would be sufficient as this would simplify the figure. There should be one figure for each habitat since the request is specific about the need for habitat based indices. To link these figures to the concept
of footprints, the columns could be shaded where Swept-area ratio >1. Further, the five-year summed values could be inserted as bars in each plot to show if the currently unfished areas have been consistently unfished in the previous period.

8.3.1.2 Impact

Figure 4. This figure should show impact, not state, to make it consistent with the section header. The left figure (a) is very strange: how can the average status be substantially lower than the status of the individual habitats which make up most of the habitat? The message of the right figure is not clear to non-experts (including WGECO). WGECO suggests showing, for each habitat, the average impact on the left panel and on the right panel, the area impacted by more than e.g. 0.5 and not calling this footprint, as footprint is defined above as something different. We have used ‘impacted area’ below as a suggestion.

Figure 5. Making the figures refer to changes only within the impacted area is confusing unless the figures are shown in pairs (one showing % impacted area, another average impact within impacted area), and even then, stakeholders will not find these easy. WGECO suggests to keep the focus on habitats and make the panels each show one habitat, with the fleets appearing as different lines and then adding a summed line for the habitat.

Page 24, below the figure: “Time-series of the footprint where the seafloor status is above a GES threshold value (once a GES threshold has been set)”: These proposed time-series figures can be replaced by inserting a reference line in the panels showing impacted area with the agreed reference level (which WGECO agrees is a policy decision to define).

8.3.1.3 Status across habitats

The naming of B/K as B lim should be avoided as the phrase is already used in a fish assessment context. Further, it is unclear why there would be a B-target; would we then aim to impact more if B/K exceeded this value?

The figures integrating trade-offs in a single figure are difficult to interpret (Figure 3 left panel) and stakeholders tend to want to see a map. A possible way to demonstrate the area which is currently lightly fished would be to show two figures with maps similar to Figure 4.6, but based on 5-year averages. The first figure could show black squares depicting the least value/swept-area c-squares which together account for 5% or 10% of the total swept-area for each habitat. By using value/swept-area to rank the c-squares, areas with high value are given priority for continued fishing over those with low value if swept-area is the same. Similarly, areas with low swept-areas are given priority for continued fishing over areas with high swept-areas when value is the same. Alternatively, ranking can use value directly, but this would not account for differences in high value/low impact and high value/high impact areas.

The figures could show the distribution of effort of the fleets in separate panels from top to bottom overlaid with the areas (which are defined across all fleets). A table below could give the summed area, effort, landings and value by each fleet and habitat for each of the 5% and 10% swept-area decreases in the above figures. It will be key to keep the number of presented percentages low, as the number of habitats and fleets on their own means that the number of maps is already rather large.

In addition to the maps, the information currently in Figure 3 right panel can be given. These figures cannot show the actual trade-off between total swept-area and value when closing increasingly large areas starting from the least cost/benefit
(value/swept-area). However, they do give some indication of the maximum order of magnitude of loss and gain (losses and gains can be less as fleet redistributes or if areas are located differently) and can be presented as such ‘envelope’ estimates, stating the caveats in drawing conclusions on actual losses and gains clearly. The figures should be based on c-squares ordered according to value/swept-area similar to the maps to avoid seemingly conflicting results. They should show value, swept-area and the ratio between the two, and to link to the new Figure 3, they could be given as bar charts.

The suggested figures will encourage thinking about protecting low-impact areas as first suggested by managers and industry (industry refers to areas not fished due to other activities, but the results should be the same) in WKSTAKE. They will also give a perception of how the patchy nature of the fisheries and impact means that to obtain significant decreases in impact. Protecting very large areas may be impractical where fishing is very aggregated (right plot below) but smaller areas can be protected where fishing is more evenly distributed (left plot below). For the two examples below, the least value areas resulting in 5% of the impact cover 30% and 75% of the area, respectively.

![Graphs showing swept per year and % of habitat](image)

If the focus on the footprint indicator becomes too large, there is a danger that to improve this indicator, medium fished areas are suggested for closures, causing reallocation of effort into both previously heavily and lightly impacted areas.

It should be clear in the advice that these figures are not to be used to suggest closed areas without evaluating the effects of redistribution of the fleet (the effort scenarios suggested by the industry at WKSTAKE) and habitat characteristics of the proposed closed area. The annexes of the report suggest several methods which are specifically designed to address this issue, and these methods would seem relevant in an evaluation of spatial management measures. WGECO would recommend a gradual introduction of closed areas as part of an adaptive approach to spatial management. The maps can be seen as a starting point for discussions.

### 8.3.2 Incorporation of WKSTAKE advice

WKSTAKE identifies that caveats should be clearly listed in advice. They also suggested to depict uncertainty (particularly about the habitat map), and to include effects of changes of gear and redistribution of the effort. These recommendations have not been addressed.
Lines 1171–1181: These methods specifically fail to take account of the dynamics of fishing effort distribution and gear choice, two important issues pointed out by WKSTAKE. The reason for assigning the descriptions of models capable of evaluating these aspects to the appendix is not clear.

8.4 Conclusions and the way forward

Several indicators have been put forward for the assessment of fishing pressure and seafloor status to provide guidance for management.

The indicators for the assessment of fishing pressure affecting the seafloor, i.e. physical disturbance, are sufficiently well developed to be used as basis for advice. The suggested impact indicators can provide a different perspective to fishing pressure and as such should be considered complementary. It seems unlikely that one indicator will be sufficient to address all desired aspects of the benthic status, and therefore, a suite of indicators will probably be necessary.

The potential indicators for seafloor integrity and how it is impacted by physical disturbance from fishing, have not matured to the point that they can be used as basis for advice. The different indicators are based on different methods, each with their pros and cons and there is insufficient scientific basis to select among them. WGECO supports the recommendation that the quantitative methods should be used whenever sufficient data are available. However, the expert judgement-based method (BH3) can be applied in data-poor situations or for those habitats (e.g. VMEs) where the parameters required to apply the quantitative methods are lacking. The quantitative indicators (or rather methods) all have their merits and shortcomings. As a way forward WGECO recommends that the process to (further) develop these indicators should focus on combining, where possible, the strengths of the different methods. A first attempt to explore this is presented in ToR a.

8.5 References


Annex 1: WGECO 2017 Agenda

**AGENDA FOR 2017 MEETING OF WGECO, APRIL 5TH TO 12TH, REYKJAVÍK**

The ToRs that are being referred to in the agenda are given in the bottom of the document.

**Wednesday April 5th**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>Opening of the meeting</td>
</tr>
<tr>
<td></td>
<td>Adoption of ToRs and Agenda</td>
</tr>
<tr>
<td></td>
<td>Assignment of ToR leaders and subgroups formed</td>
</tr>
<tr>
<td></td>
<td>Overview of presentations</td>
</tr>
<tr>
<td></td>
<td>Initial discussion of ToRs a and b</td>
</tr>
<tr>
<td>1230</td>
<td>Lunch</td>
</tr>
<tr>
<td>1400</td>
<td>Reconvene. Initial discussions on ToRs c and d</td>
</tr>
<tr>
<td>1530</td>
<td>Coffee</td>
</tr>
<tr>
<td>1600</td>
<td>Initial discussions on ToRs e and f</td>
</tr>
<tr>
<td>1730</td>
<td>Preliminary workplan presented</td>
</tr>
<tr>
<td>1800</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

**Thursday April 6th**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900</td>
<td>Subgroup work</td>
</tr>
<tr>
<td>1030</td>
<td>Coffee</td>
</tr>
<tr>
<td>1230</td>
<td>Lunch</td>
</tr>
<tr>
<td>1400</td>
<td>Subgroup work</td>
</tr>
<tr>
<td>1530</td>
<td>Coffee</td>
</tr>
<tr>
<td>1800</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

**Friday April 7th**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900</td>
<td>Plenary: status update from all subgroups</td>
</tr>
<tr>
<td>1030</td>
<td>Coffee</td>
</tr>
<tr>
<td>1230</td>
<td>Subgroup work</td>
</tr>
<tr>
<td>1400</td>
<td>Lunch</td>
</tr>
<tr>
<td>1530</td>
<td>Reconvene</td>
</tr>
<tr>
<td>1800</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

**Saturday April 8th**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900</td>
<td>Subgroup work</td>
</tr>
<tr>
<td>1030</td>
<td>Coffee</td>
</tr>
<tr>
<td>1230</td>
<td>Subgroup work</td>
</tr>
<tr>
<td>1400</td>
<td>Lunch</td>
</tr>
<tr>
<td>1530</td>
<td>Subgroup work</td>
</tr>
<tr>
<td>1630</td>
<td>Coffee</td>
</tr>
<tr>
<td>1800</td>
<td>Plenary: status update from all subgroups</td>
</tr>
<tr>
<td></td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
### Sunday April 9th

Writing day, no plenaries, field trip

### Monday April 10th

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900</td>
<td>Subgroup reporting ToRs a–f</td>
</tr>
<tr>
<td>1030</td>
<td>Coffee</td>
</tr>
<tr>
<td>1230</td>
<td>Drafting session/plenary/subgroup work</td>
</tr>
<tr>
<td>1400</td>
<td>Lunch</td>
</tr>
<tr>
<td>1530</td>
<td>Coffee</td>
</tr>
<tr>
<td>1800</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

### Tuesday April 11th

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900</td>
<td>Subgroup reporting</td>
</tr>
<tr>
<td>1030</td>
<td>Coffee</td>
</tr>
<tr>
<td>1230</td>
<td>Drafting session/plenary/subgroup work</td>
</tr>
<tr>
<td>1400</td>
<td>Discuss next year and future future ToRs of WGECO. Long-term vision of WGECO</td>
</tr>
<tr>
<td>1530</td>
<td>Coffee</td>
</tr>
<tr>
<td>1800</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

### Wednesday April 12th

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900</td>
<td>Drafting session/plenary (if needed)</td>
</tr>
<tr>
<td>1030</td>
<td>Coffee</td>
</tr>
<tr>
<td>1300</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
## Annex 2: Participants list

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Phone/Fax</th>
<th>E-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeremy Collie</td>
<td>Graduate School of Oceanography South Ferry Road Narragansett RI 02882 USA</td>
<td>+1 (401) 874-6859</td>
<td><a href="mailto:jcollie@gso.uri.edu">jcollie@gso.uri.edu</a></td>
</tr>
<tr>
<td>Jochen Depestele</td>
<td>Institute for Agricultural and Fisheries Research (ILVO) Ankerstraat 1 8400 Oostende Belgium</td>
<td>+32 59569838</td>
<td><a href="mailto:jochen.depestele@ilvo.vlaanderen.be">jochen.depestele@ilvo.vlaanderen.be</a></td>
</tr>
<tr>
<td>Mark Dickey-Collas</td>
<td>ICES H.C. Andersens Blvd. 44–46 1553 Copenhagen V Denmark</td>
<td>+453338675 Fax +453393421 5</td>
<td><a href="mailto:mark.dickey-collas@ices.dk">mark.dickey-collas@ices.dk</a></td>
</tr>
<tr>
<td>Grete Dinesen</td>
<td>DTU Aqua - National Institute of Aquatic Resources Jægersborg Allé 1 2920 Charlottenlund Denmark</td>
<td>+45 35 88 33 59 Cell +45 21 31 51 37</td>
<td><a href="mailto:gdi@aqua.dtu.dk">gdi@aqua.dtu.dk</a></td>
</tr>
<tr>
<td>Simon Greenstreet</td>
<td>Marine Laboratory 375 Victoria Road Aberdeen AB11 9DB UK</td>
<td>+44 1224 295417 Fax +44 1224 295511</td>
<td><a href="mailto:S.Greenstreet@MARLAB.AC.UK">S.Greenstreet@MARLAB.AC.UK</a> <a href="mailto:Simon.greenstreet@gov.scot">Simon.greenstreet@gov.scot</a></td>
</tr>
<tr>
<td>Ingibjörg Jónsdóttir</td>
<td>Marine and Freshwater Research Institute PO Box 1390 Skúlagata 4 Reykjavik 121 Iceland</td>
<td></td>
<td><a href="mailto:ingibjorg.g.jonsdottir@hafogvatn.is">ingibjorg.g.jonsdottir@hafogvatn.is</a></td>
</tr>
<tr>
<td>Ellen Kenchington by correspondence</td>
<td>Fisheries and Oceans Canada Bedford Institute of Oceanography PO Box 1006 1 Challenger Drive Dartmouth NS B2Y 4A2 Canada</td>
<td>+1 902 426 2030</td>
<td><a href="mailto:Ellen.kenchington@dfo-mpo.gc.ca">Ellen.kenchington@dfo-mpo.gc.ca</a></td>
</tr>
<tr>
<td>Tobias van Kooten</td>
<td>Wageningen University PO Box 68 1970 AB Ijmiuden Netherlands</td>
<td></td>
<td><a href="mailto:tobias.vankooten@wur.nl">tobias.vankooten@wur.nl</a></td>
</tr>
<tr>
<td>Chris Lynam</td>
<td>Cefas Pakefield Road Lowestoft Suffolk NR33 0HT UK</td>
<td>+44 1502 524514 Fax +44 1502 313865</td>
<td><a href="mailto:chris.lynam@cefas.co.uk">chris.lynam@cefas.co.uk</a></td>
</tr>
<tr>
<td>Name</td>
<td>Address</td>
<td>Phone/Fax</td>
<td>E-mail</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------</td>
<td>-------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Meadbh Moriarty</td>
<td>Marine Science Scotland</td>
<td></td>
<td><a href="mailto:M.Moriarty@marlab.ac.uk">M.Moriarty@marlab.ac.uk</a></td>
</tr>
<tr>
<td></td>
<td>Marine Laboratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PO Box 101</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>375 Victoria Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aberdeen AB11 9DB</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scotland, UK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cormac Nolan</td>
<td>Marine Institute</td>
<td></td>
<td><a href="mailto:cormac.nolan@marine.ie">cormac.nolan@marine.ie</a></td>
</tr>
<tr>
<td></td>
<td>Rinville</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oranmore</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Co Galway</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GerJan Piet</td>
<td>Wageningen University</td>
<td>+31 317 487188</td>
<td><a href="mailto:gerjan.piet@wur.nl">gerjan.piet@wur.nl</a></td>
</tr>
<tr>
<td></td>
<td>PO Box 68</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1970 AB ljmunden</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Netherlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stefán Áki Ragnarsson</td>
<td>Marine Research Institute of Iceland</td>
<td></td>
<td><a href="mailto:steara@hafro.is">steara@hafro.is</a></td>
</tr>
<tr>
<td>Chair</td>
<td>PO Box 1390</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Skúlagata 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reykjavik 121</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iceland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andrea Rau</td>
<td>Thünen Institute</td>
<td></td>
<td><a href="mailto:andrea.rau@thuenen.de">andrea.rau@thuenen.de</a></td>
</tr>
<tr>
<td></td>
<td>Institute of Baltic Sea Fisheries</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alter Hafen Süd 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18069 Rostock</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>David Reid</td>
<td>Marine Institute</td>
<td>+353 91 387431</td>
<td><a href="mailto:David.Reid@Marine.ie">David.Reid@Marine.ie</a></td>
</tr>
<tr>
<td></td>
<td>Rinville, Oranmore</td>
<td>Fax +353 91 387201</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Co Galway</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anna Rindorf</td>
<td>DTU Aqua - National Institute of Aquatic</td>
<td>Phone +45 35883378</td>
<td><a href="mailto:ar@aqua.dtu.dk">ar@aqua.dtu.dk</a></td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>Fax +45 35883333</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jægersborg Allé 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2920 Charlottenlund</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Denmark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Håkan Wennhage</td>
<td>Swedish University of Agricultural Sciences</td>
<td></td>
<td><a href="mailto:hakan.wennhage@slu.se">hakan.wennhage@slu.se</a></td>
</tr>
<tr>
<td></td>
<td>Institute of Marine Research</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PO Box 4</td>
<td>+46 761 33 4455</td>
<td></td>
</tr>
<tr>
<td></td>
<td>453 30 Lysekil</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sweden</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Annex 3: Vision for WGECO

Background

WGECO is a curiosity-driven, conceptual development group, whose work has influenced other ICES working groups (WG) and the wider scientific community. It has also played a key role in providing ecosystem based advice across a range of issues that have been much wider than the group name would suggest. It has played a crucial role in developing ecosystem indicators within the DPSIR framework. The MSFD has become a legal framework around which much of the work has been centred, but the remit of WGECO is larger than just further developing the MSFD, given that five ICES countries are not in the EU. The MSFD also to some degree limits conceptual development by constraining discussions within its legal framework. WGECO is the key catalyst for developing the knowledge base for ecosystem-based fisheries management in the ICES area.

Role of WGECO

WGECO should retain its central role in evaluating the ecosystem effects of fishing activities. This is a broad remit. WGECO should also continue to be the “go-to” WG for ecosystem advice. The group should couple together science and advice, and move beyond MSFD, OSPAR, and HELCOM by looking at advisory processes in North America, Iceland and Norway as well. While there are large numbers of pressures other than those caused by fishing affecting the ecosystem, the general consensus was that it was sufficient task for WGECO to confine the emphasis to fishing impacts. There was a suggestion that WGECO should include socio-economics, but it was argued against that as 1) establishing a separate socio-economic group that would be affiliated to WGECO would not be useful 2) inclusion of socio-economics in WGECO would dilute the issues raised by WGECO. There was a discussion of strategic initiatives to recruit scientists working on ecosystem components (e.g. seabirds and marine mammals), which are currently lacking.

WGECO needs to be more proactive in communicating its results to ICES and to the broader community (e.g. via the ICES website). A mechanism needs to be found to allow the annual evaluations and discussions at WGECO to permeate through to the rest of the ICES community. Likewise, a communication route back to WGECO should be developed.

WGECO should continue to work at the interface of science and management by retaining science-based ToRs to keep people interested and motivated. The trick is to identify the science questions of today that will become the policy issues of tomorrow. So we should choose science ToRs that have management (or future) implications. It was suggested to adopt ToRs for three years with rolling start times. There was a debate on the usefulness of this policy. The ToRs that are made by WGECO have “evolved” from year to year depending on the scientific process and attendance. It may difficult to determine a long-term plan.

ICES and EBM/EBFM

In a recently written document, ICES described its role in the provision of knowledge for EBM/EBFM (http://www.ices.dk/explore-us/Documents/ICES%20and%20EBM.pdf). It did not define the terms EBM/EBFM but said that certain key phrases illustrate the central tenet of the ecosystem approach:
management of human activities, consideration of collective pressures, achievement of good environmental status, sustainable use, optimization of benefits among diverse societal goals, regionalization, trade-offs, and stewardship for future generations. ICES role is to provide the evidence of ecosystem-based decision-making for the management of fisheries and other sectors in the ICES area. The evidence is required to explore the consequences of likely trade-offs (central to EBM) in the management of and between sectors and their impacts and services from the biodiversity of species and habitats. This is to support sustainable development aimed at both human and ecosystem well-being and stewardship of marine ecosystems.

ICES provides three main outputs to support EBM: advice on fishing opportunities, fisheries overviews, and ecosystem overviews. These products are continually developing to address new information as well as changes in the ecosystem, legislation, and the drivers of fisheries. Spatial management and regional priorities are addressed as all of the advice is given by ecoregion. The ecoregions reflect both the biogeography of the ICES area and the management of the area by national and regional authorities. WGECO could use these three “advice products” as a way to guide future research directions.

**Action areas for WGECO**

WGECO should continue to work on developing the knowledge base for EBFM/EBM; this is one of the key action areas highlighted by ICES Council. Other action areas highlighted by ICES that WGECO should take note of, but that the actual work may be better suited for more specialized working groups include, Ecosystem effects of Aquaculture, Arctic science and management and Socio-economics. As ICES as a whole moves forward on these action areas, clearly WGECO will have a role in conceptual development and building robust frameworks for the provision of the best knowledge for advice. With this in mind, the members of WGECO suggested the following scientific research areas.

**Scientific Research Areas**

- Cooperative fisheries research to collect ecosystem data.
- The ecological consequences of recovering fish stocks: What are the effects on the foodweb? Incorporation of predator–prey interactions.
- The ecological effects of the discard ban.
• Examine interactions between ecosystem components, with emphasis on understanding linkages between benthos and fish. What are the integrated impacts on fish and benthos? Consider these issues in a management context.

• Consider fishing impacts on benthos in relation to climate forcing (i.e. risk averseness in changing times).

• A central challenge of our time is how to implement EBFM. How can ecosystem approaches be consistently applied to fisheries management?

• Consideration of Marine Spatial Planning of fisheries and fish stocks that are moving with climate change (e.g. analyse VMS data).

• How can conservation and fishery objectives be reconciled for benthos, fish, bird and mammal concerns?

• Fishery and environment trade-offs, e.g. in respect to spatial distributions.

• Target settings for management purposes given the tools we have now. What would the ideal ecosystem look like? Involves model work. Are there win-win solutions?

ToRs should remain MSFD relevant and prepare for the future iterations of the MSFD.
Annex 4: WGECO ToRs for 2018

a) Investigate the ecological consequences of stock rebuilding, with particular emphasis on benthivorous fish and invertebrates.
   i) Make first-order estimates of predation pressure on benthos;
   ii) Examine evidence of food limitation and density-dependent growth;
   iii) Compare the footprints of trawling to the footprints of predation pressure on benthos.

Scientific Justification: Many stocks are rebuilding and will likely have higher abundance and biomass than we have seen in recent times. This in turn will likely have effects through trophic interactions both up and down the foodweb. At ICES, WGECO and WGSAM have been tasked previously with similar ToRs. WGECO will investigate the potential consequences of stock recovery of benthivorous fish and invertebrates, their ensuing risks for fish stock management and the use of MSFD indicators. It is hypothesized that a large increase in benthivorous fish will have an impact on benthic productivity and biodiversity. This ToR requires data on the spatial distribution of benthivorous predators, their prey consumption rates and diet composition. This ToR links to ToR d.

b) Use empirical data and available multispecies models to examine how the degree of fisheries balance relates to ecosystem status.
   i) Compare the length composition of total catch (landings and discards) to the length composition in the survey for one region (e.g. Irish Sea);
   ii) Use multispecies models (developed by WGSAM) to identify targets for ecological indicators of state (i.e. status) that relate to an acceptable risk of species diversity loss; and
   iii) Use output of multispecies models to investigate how proposed management strategies affect fisheries balance.

Scientific Justification: Identifying thresholds and limits for ecosystem indicators remains a central challenge for ecosystem based fisheries management. This ToR will examine if MSY targets implemented in the current management regime will lead to acceptable ecosystem status. This ToR aims to identify reference levels for a range of ecosystem indicators with the use of size-based models. This proposed ToR links to new ToR d and to WGSAM.

c) Examine individual species abundance trends to improve interpretation of assessment outcomes based on the “abundance of a suite of sensitive fish species” indicator. Apply the sensitive species indicator in additional ICES areas.

Scientific Justification: This work involves further development and refinement of the sensitive species indicator. This includes consideration of including species reproductive potential, but to date the indicator only uses mortality prior to spawning. The current suite of sensitive species includes species that experience any fishing mortality prior to spawning. It would be of interest to examine the effects of using various levels of fishing mortality. This ToR should also evaluate whether commercial species
that are managed directly under the CFP should be included in suites of sensitive species (i.e. species with a TAC that have a stock assessment).

d) Investigate and report on potentially valuable ecosystem indicators for which full methodology has yet to be developed, and propose methodologies and data sources. To include inter alia: Total mortality, Productivity of key predators, Primary production required to support fisheries, Guild level biomass, Total biomass of small fish, Pelagic-to-demersal ratio, and Benthic indicators. The current progress in the development of distributional indicators will be reviewed. Furthermore, this ToR should scope and evaluate methods to integrate indicators.

Scientific justification: WGECO has traditionally had a leading role in developing and testing indicators, and their use for provision of advice. The work of this ToR facilitates operationalization of these indicators, by identifying data sources, refining, evaluating their strengths and weaknesses and gaps in indicator availability.

WGECO will meet from 12–19 April 2018 in Copenhagen, Denmark.