

# ICES WGBIODIV REPORT 2016

SCICOM STEERING GROUP ON ECOSYSTEM PROCESSES AND DYNAMICS

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## Interim Report of the Working Group on Biodiversity Science (WGBIODIV)

8–12 February 2016

San Sebastian, Spain



**ICES**  
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International Council for  
the Exploration of the Sea

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## Contents

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Executive summary .....	2
1 Administrative details .....	3
2 Terms of Reference a) – z) .....	3
3 Summary of Work plan .....	4
4 List of Outcomes and Achievements of the WG in this delivery period .....	4
5 Progress report on ToRs and workplan .....	5
6 Revisions to the work plan and justification .....	5
7 Next meetings .....	6
Annex 1: List of participants.....	7
Annex 2: Summary of presentations.....	8
Annex 3: Summary of sub-group work .....	22
Annex 4: Development of an indicator factsheet .....	31

## Executive summary

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The Working Group on Biodiversity Science (WGBIODIV) met at AZTI-Tecnalia, San Sebastian, Spain, 8–12 February 2016. The meeting was chaired by Nik Probst and Oscar Bos and attended by 15 scientists from seven countries. This meeting was the first one of the new 3-year cycle (2016–2018). The overall aim of WGBIODIV for this period is to develop a number of operational indicators on the level of faunal communities (i.e. plankton, benthos and fish), which can be used to assess the state of biodiversity in the context of environmental assessments for the regional sea conventions OSPAR and HELCOM as well as the Marine Strategy Framework Directive (MSFD).

Development of new biodiversity indicators is important since the EC is currently revising the decision document 477/2010/EU, which describes the required indicators per MSDF descriptor. Until now biodiversity (MSDF Descriptor 1) was to be described on the level of species (D1.1), habitats (D1.2) and the entire ecosystem (D1.3). The revision of the EU Commission decision may lead to the proposal of additional indicators on the level of ecosystem components (communities), interacting with the ongoing development of OSPAR and HELCOM biodiversity indicators.

The focus of this year's work was directed towards the development of theoretical concepts, which should be used as scientific foundation for new biodiversity indicators. WGBIODIV presents a generic protocol how to develop community indicators based on ecological concepts and introduces several practical examples. The future work of WGBIODIV will build on these theoretical fundamentals to develop new indicators of biodiversity for plankton, benthos and fish communities.

Inspirations for new indicator approaches were obtained during plenary discussions and presentations by group members. These presentations included results of ongoing PhD thesis and outcomes of large EU research projects such as DEVOTES helping to shape the approaches to be taken. Presentations on indicator concepts or indicator related projects from the WG meeting are summarized in this report.

## 1 Administrative details

<p><b>Working Group name</b> Working group on biodiversity science (WGBIODIV)</p> <p><b>Year of Appointment within the current cycle</b> 2016</p> <p><b>Reporting year within the current cycle (1, 2 or 3)</b> 1</p> <p><b>Chair(s)</b> Oscar Bos, the Netherlands Wolfgang Nikolaus Probst, Germany</p> <p><b>Meeting venue</b> San Sebastian, Spain</p> <p><b>Meeting dates</b> 8–12 February 2016</p>
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## 2 Terms of Reference a) – z)

ToR	Description	Expected Deliverables
1	<p>Develop the use of biodiversity metrics (e.g. species richness and species evenness indices) to inform on the status of ecosystem components at the community level (fish, mammals, seabirds, plankton, epi-benthos, macro-algae) to support implementation of ecosystem-based management. This task encompasses:</p> <p>1a. Establish a sound theoretical basis relating variation in biodiversity metric values to changes in anthropogenic pressure on marine communities (e.g. incorporating components of community size and trophic structure into the derivation of biodiversity metrics, taking account of linkage to habitat types and consideration of spatial pattern).</p> <p>1b. Explore the issue of sampling size dependence to derive a robust protocol for calculating biodiversity metrics so that their sensitivity to underlying drivers is maximized, and the 'noise' associated with sampling effects is</p>	<p>1. Protocol on the development of theoretical concepts of biodiversity indicators (2016/2017).</p> <p>2. Combined analysis and review on impacts of sampling size on performance of biodiversity metrics (2016-2018).</p> <p>3. Analysis on aggregating biodiversity indicators at different levels (species group, community, ecosystem) (2017/2018).</p> <p>4. Quality assessment of investigated biodiversity indicators according to WGBIODIV criteria (2018).</p> <p>5. One or more operational indicators to assess biodiversity at the community and eventually the ecosystem level (2018).</p>

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minimized (e.g. procedures for sample aggregation, modelling of individual species distribution to derive point-diversity estimates).

1c. Assess the “ecosystem level” assessment of biodiversity by considering how community-level biodiversity metrics might be aggregated across communities (e.g. integrated ecosystem assessments of biodiversity).

1d. Apply the WGBIODIV quality criteria to assess the performance of state indicators to assess the performance of any biodiversity indicators proposed and developed by WGBIODIV to show whether previous weaknesses in such metrics have been addressed.

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### 3 Summary of Work plan

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- 1) This year’s meeting was about discussing and exploring theoretical concepts for the development of new biodiversity indicators. The aim was to lay conceptual foundations in order to be able to develop indicators based on biodiversity metrics, which are sensitive, responsive and predictable in their relationship to anthropogenic pressures. During this meeting theoretical approaches have been discussed for plankton, benthos and fish communities. These concepts will be further refined and applied to develop new biodiversity indicators.
- 2) The new indicators will be developed on a community basis and applied in regional case studies. Promising concepts emerged for indicators regarding the plankton, benthic and fish community, which will be further developed and used to design new indicators.
- 3) The new indicators will be evaluated against the WGBIODIV indicator quality criteria to test their usefulness for the assessment of environmental status and ecological ‘health’.

### 4 List of Outcomes and Achievements of the WG in this delivery period

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- Deliverable 1: Draft on protocol for the development of biodiversity indicators

A generic protocol for the development of theoretical concepts was drafted. This concept will be reviewed by WGBIODIV until the next meeting and be refined if necessary. It will be evaluated if this draft will be suited for publication in the primary literature.

- Development of concepts to lay a scientific foundation to develop new biodiversity indicators to inform on the status of plankton, benthic and fish communities

WGBIODIV agreed on working procedures to develop theoretical concepts as the first step to develop new biodiversity indicators. These concepts will be applied on data of plankton, benthos and fish communities. The overall aim of the 2016-2018 WGBIODIV working period is to produce new indicators of biodiversity which will facilitate the environmental assessment within the Regional Sea Conventions (OPSAR, HELCOM) and the Marine Strategy Framework Directive (MSFD) with regards to specific ecosystem components at the community level.

- Development of indicator factsheet

WGBIODIV will develop an indicator factsheet to summarise all relevant information on the developed indicators. It was briefly discussed that the template of such a factsheet should be based on the structure of the indicator sheets by OSPAR and HELCOM. A first version of the WGBIODIV indicator sheet is presented in Annex 4, a new templated was created shortly after the meeting. This template will be further developed and refined within the next two years.

## **5 Progress report on ToRs and workplan**

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ToR1a) and Deliverable 1 have been addressed by this year's work. Subgroups on plankton, benthos and fish communities have provided workplans for the development of theoretical concepts, which will be used to develop new biodiversity indicators.

ToR 1b & 1c may be not addressed with priority, as ToR1a will be in the focus of the current working period. This could imply that Deliverables 2 and 3 may not be fully addressed by 2018. However, during the technical development of the indicators it may possible that issues of scale and sampling effort (Deliverable 2) will be addressed e.g. in sense of sensitivity analysis. Deliverable 3 may be addressed in 2018 or in the subsequent working period of WGBIODIV, if at least two biodiversity indicators at the community level have been established either within WGBIODIV or within the MSFD or RSC.

ToR 1d and Deliverable 4 will be addressed in the last year (2018) of this working period, when new biodiversity indicators will be developed and can be evaluated based on the WGBIODIV indicator quality criteria. Indicators which are evaluated as suitable for the assessment of biodiversity at the community will fulfil Deliverable 5.

## **6 Revisions to the work plan and justification**

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Currently the workplan will not be revised but some ToR may be addressed prior to others (see Chapter 5).

## 7 Next meetings

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The next meeting is planned to be held in the first quarter of 2017 in Venice, Italy.

**Justification for venue (in a non-ICES member country):**

This venue was selected to facilitate the participation of scientists from the Mediterranean area and to improve the exchange of science and communication on biodiversity topics within Europe. The 2016 meeting was held in San Sebastian for the same reason and helped to recruit several new members to WGBIODIV.

## Annex 1: List of participants

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ICES WGBIODIV 2016 (from left to right): Simon Greenstreet, Henrike Seidel, Nikolaus Probst, Felipe Artigas, Anaïs Aubert, Ángel Borja, Tim Spaanheden Dencker, Michaela Schratzberger, Gerjan Piet, Christopher Lynam, Oliver Beauchard, Andrea Belgrano, Oscar Bos.

## Annex 2: Summary of presentations

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During the meeting several presentations concerning new indicator developments, theoretical concepts were given.

### Summary of presentation

#### 1. DEVOTES main research on biodiversity: progress and findings

##### Ángel Borja, AZTI, Coordinator of DEVOTES

The FP7 EU project DEVOTES (Development of innovative tools for understanding marine biodiversity and assessing good environmental status; [www.devotes-project.eu](http://www.devotes-project.eu)), is dealing with the implementation of the Marine Strategy Framework Directive (MSFD). This four years project will end on 30<sup>th</sup> October 2016, and during this time has progressed considerably beyond the state of the art. All the outputs are public and available at <http://www.devotes-project.eu/deliverables-and-milestones/>. In the last year we have produced sea-specific matrices of pressure-impact links; how will climate change affect our ability to attain good environmental status (GES); we have identified the key barriers of achieving GES; we have reported on 29 new or refined indicators and methods for setting reference and target values; we have described spatial ecosystem models, linking habitats to functional biodiversity and modelling connectivity between regional seas; we have reported on the application of acoustic devices and visual imaging to assess abundance and diversity; we have optimized the protocols of molecular analyses of biodiversity; among other topics.

One of the important outcomes is the NEAT (Nested Environmental status Assessment Tool), which is a software allowing to aggregate information (ecosystem components, indicators, descriptors, etc.) and assess the status at different spatial scales. The software and guidelines are available at the web page.

Until now the DEVOTES consortium has published 109 papers, which are available at <https://zenodo.org/collection/user-devotes-project>. The final DEVOTES meeting (Marine Biodiversity, the key to healthy and productive seas) will be held in Brussels, 17–19 October 2016. Most of the outputs from this project can be very useful for this ICES WG on Biodiversity, since the ToRs are aligned with the objectives of DEVOTES project.

#### 2. Size composition in fish communities in response to fishing

##### Christopher Lynam, Centre for Environment, Fisheries and Aquaculture

Reference levels for indicators of marine biodiversity and food webs are difficult to determine and there is a pressing need to identify assessment thresholds for indicators that contribute to environmental assessments for the MSFD. Similarly, any newly developed indicators should provide thresholds in order to enable assessments and these should ideally incorporate knowledge of pressure-state relationships. Among the most promising tools to identify such assessment thresholds are multi-species and size-based models (ICES, 2015a). Ideally multiple models would be used to investigate the same issues such that outputs are not wholly dependent on the model structure.

A recently developed size-based fish community model of the North Sea has been used to investigate the underlying pressure-state relationship for indicators of fish size-structure (Large Fish Indicator, LFI, and slope of the size spectrum, SSS) and contrast the indicators performance given changes in fishing effort. In Thorpe *et al.* (2015) the SSS provided greater power than the LFI to detect changes in community-wide F. However, the two indicators perform similarly when tested over a wider range of fishing scenarios, where fishing pressure was disaggregated to fleet level (otter, beam, pelagic and industrial (Thorpe *et al.*, in press). The authors suggest that, if the contributions of the different fleets to total fishing mortality change over time, the relationship between overall fishing mortality and indicator values will not be constant. The model study also demonstrated that it was possible for a high risk of depletion on some stocks even with relatively high LFI values. Similarly, it was possible to have a community with relatively low LFI scores but a low-risk of depletion on stocks. So, signals from basic community indicators will not be interpretable without supporting information. This is in agreement with the study by Shannon *et al.* (2014) that considered the trend in mean trophic level of the community given catch data, survey data and model outputs for a range of marine ecosystems.

In addition to an understanding of the pressure and its temporal development in order to support assessments, it is clear that spatial variation in state at the scale of habitats (both seabed sediments and water column habitats e.g. eco-hydrodynamic zones) (van Leeuwen *et al.*, 2015) is present within a regional sea (Figure A2.1). This can be approximated by sub-divisional indicator assessments as suggested by ICES WGBIODIV 2015, but it should be noted that such assessments are a compromise between ecological realism and appropriate spatial scales for management. When indicators are computed on these sub divisions, it becomes evident that there is no constant assessment threshold that applies simultaneously for differing demersal fish and elasmobranch communities (Figure A2.2). Therefore, pressure-state relationships can differ temporally and spatially. Aggregation of indicator assessments at sub-divisions up to regional sea level presents additional problems and mirrors the problems present for aggregation of indicators within MSFD descriptors (e.g. Probst and Lynam, 2016).

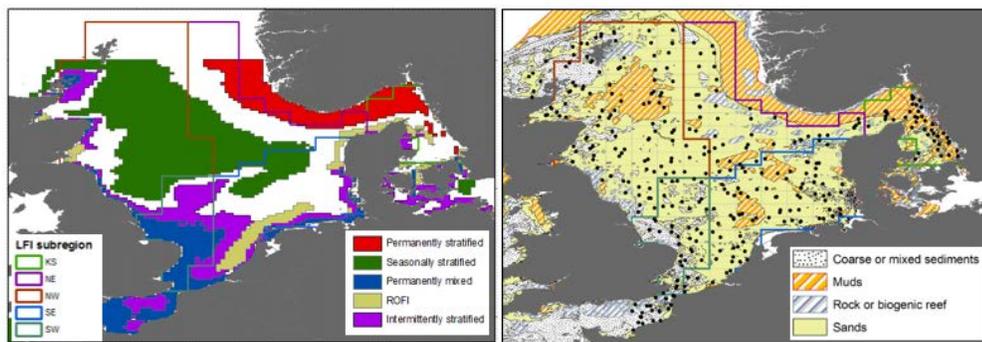


Figure A2.1. Eco-hydrodynamic zones (Left) and the simple broad scale sediment classifications (Right, from 'EUSeamap' ("phase 1" simple classifications <http://jncc.defra.gov.uk/page-5020>) overlaid with the boundaries of the LFI sub-regions once reduced to those rectangles sampled by the North Sea IBTS survey, where the black dots show the locations of the sampling stations for an example year (2014).

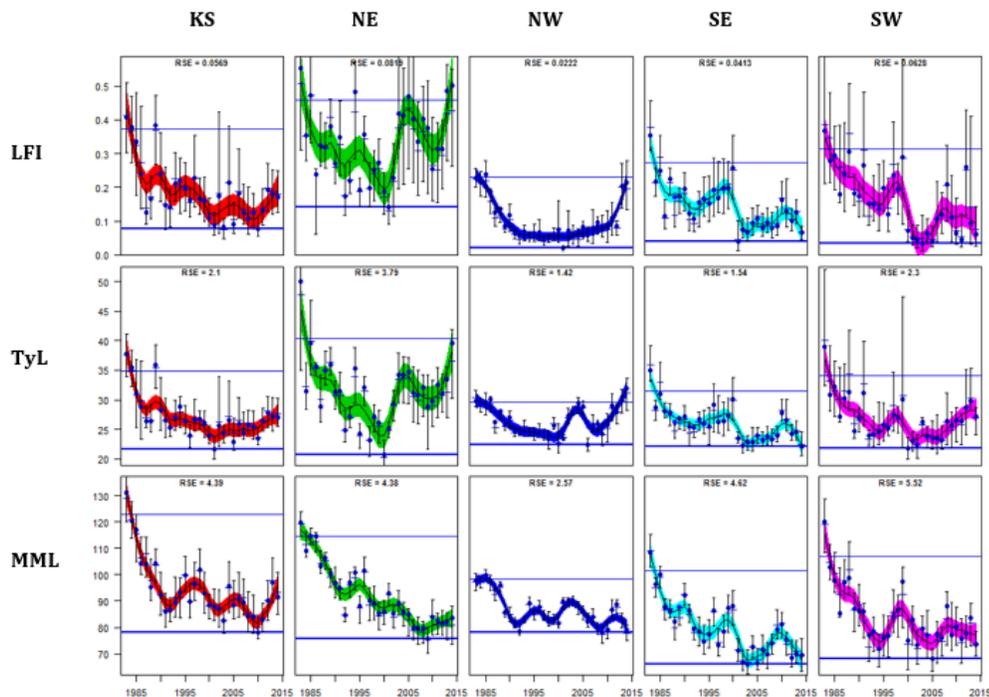


Figure A2.2. Trends in the LFI (top), Typical (geometric mean) Length (middle) and Mean Maximum Length (bottom) compared between the 5 LFI sub-divisions: Kattegat-Skagerrak (KS), and the NE, NW, SE, and SW North Sea. Indicator estimates are shown by blue circles with their bootstrap uncertainty given by the vertical error bars (which display the 95% confidence interval in the annual estimate with horizontal dash the mean of the bootstrap resamples). LOESS smoothers (with a “fixed span” of one decade) highlighting the inter-annual trend are shown by black lines (best fits) with coloured polygon displaying  $\pm 1$  standard error i.e. a 68% confidence interval; the pane subtitles give the Residual Standard Error from the LOESS. Thick blue horizontal lines represent the average value for the period 1983–1985 of the indicator in each stratum. Thin horizontal lines represent the minimum value during the period 1983–2014 of the indicator in each stratum. Note the LFI here assumes a fixed large fish threshold value of 40 cm in each sub-division.

It is important to note that all results given here are based on the currently available data with the ICES database of trawl surveys (DATRAS). These data are currently being processed by Marine Scotland and the final data-product for use in OSPAR assessments will differ for the data used here, therefore the time-series computed will differ.

### 3. The Community Sensitivity Index (CSI) of demersal fish in response to fishing

Henrike Rambo, Thünen-Institute of Sea Fisheries

Predicting the effects of fishing on biodiversity continues to being a challenge. Especially taxonomic biodiversity indices, at least as they have been derived in the past, have failed to show consistent relationships with fishing pressure. The hypothesis that increasing fishing pressure leads to a decrease in index values has been shown in a few cases; however, other studies have proven the opposite. The prevailing issue is that we do not fully understand the ecological underpinnings to move beyond surveillance indicators to fully operational indicators in a pressure-state context. Hence, a direct ecological link between fishing and biodiversity indicators is often lacking. We developed the community sensi-

tivity index (CSI) to fishing in an attempt to provide such a link. The CSI is based on life-history-traits that have been proven to increase a species' susceptibility to additional fishing mortality. The CSI is based on species specific sensitivity indices (SI) published in Greenstreet *et al.* (2012c). These SIs are based on ultimate body length ( $L_{\infty}$ ), length- and age-at-first-maturity ( $L_{mat}$ ,  $A_{mat}$ ) and the growth parameter  $k$ . The CSI is calculated as the sum of species SIs, weighted by the individual species' abundance, and standardised by the total number of individuals caught (see equation 1).

$$CSI = \frac{\sum_{i=1}^n n_i SI_i}{N}, \tag{1}$$

where  $n_i$  is the number of individuals of species  $i$ ,  $N$  is the total number of individuals and  $SI_i$  is the SI of species  $i$ . The SI and therefore also the CSI are classified into three categories, namely resilient (0–0.164), intermediate (0.165–0.31) and sensitive (0.311–1) based on 33percentiles of all species' SIs included in Greenstreet *et al.* (2012). We mapped the CSI using the German Autumn Survey for the EEZ (GASEEZ) which has the best spatial coverage for the study area (Neumann *et al.*, 2013). Here, we chose an indirect mapping approach in which we first modelled each species distribution individually with ordinary kriging and then derived index values per grid cell (Ferrier and Guisan, 2006). The CSI ranged from 0.085 (highly resilient) to 0.212 (intermediate). We then mapped mean annual fishing effort of the international beam trawl fleet based on VMS data (Figure A2.3a). We used a correlative approach to analyse the relationship between the CSI and fishing pressure. As expected, the CSI declined with an increase in fishing effort (Figure A2.3b).

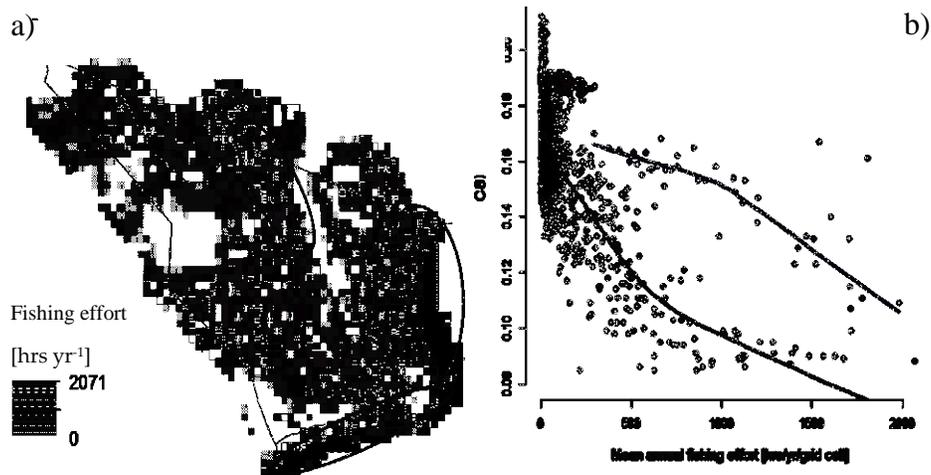


Figure. A2.3. a) Distribution map of fishing effort (mean hours year-1) of the international beam trawl fleet in and around the German EEZ of the North Sea, and b) relationship between the CSI and fishing effort. The fitted lines are based on polynomial least squares regression and the colour code corresponds to three distinct areas on the map where the relationship between declining CSI with increasing fishing effort differs.

Interestingly though, the relationship was not uniform. Most of the grid cell values declined asymptotically with increasing effort (green line). However, two different patterns were observed (red and blue line), that suggested a more resilient community. The spatial analysis allowed us to identify the areas from which these data originated (circled in red and blue).

While these were promising results, we also tested correlation of the CSI with depth and other environmental variables. Fishing in the German EEZ of the North Sea is highly depth-stratified with most intense pressure in shallower, coastal areas from 15 – 25 m depth. The CSI itself is also related to depth as more sensitive species such as rays and sharks mainly occur in the northern-most, deeper part of the EEZ. We analysed whether the relationship between the CSI, depth and fishing effort was significant by using a Generalised Additive Model (GAM). Here, we fitted three different models by using an interaction term for the three regions as identified from the data (green, red, blue) with depth and fishing effort.

While the overall model explained 72% of deviance, both variables were significant ( $p < 0.0001$ ) for explaining the main pattern (green, Figure A2.3b) with a negative relationship for total fishing effort and a positive relationship for depth and the CSI, respectively. The GAM analysis revealed that only depth explained the values of the red area, while fishing effort better predicted the blue area ( $p < 0.0001$ ) than depth ( $p < 0.01$ ). These results suggest that there is in fact a pressure-state relationship between fishing and the CSI which differs in space.

#### 4. Draft of an indicator factsheet: Vulnerability of demersal elasmobranchs in the North Sea

**Nikolaus Probst, Thünen-Institute of Sea Fisheries**

This presentation introduced the concept of an indicator factsheet, which may be used to summarize indicators developed by WGBIODIV (Table A2.1). The first WGBIODIV factsheet draft is presented by introducing a spatial indicator on the vulnerability of demersal elasmobranch species in the North Sea. The factsheet included fields from the WGBIODIV indicator evaluation sheet to inform on the indicator quality (ICES, 2013).

**Table A2.1. First draft of a WGBIODIV indicator fact sheet containing elements for quality evaluation.**

WG BIODIV Indicator factsheet	
Indicator name	Vulnerability of elasmobranch fish populations (North Sea)
OSPAR/HELCOM ecosystem component	Fish (Shelf demersal)
Description of indicator goals/objectives	This indicator analysis the spatial distribution of vulnerability hotspots of sensitive demersal fish species. In this case vulnerability is defined as the product of relative cumulative abundance and exposure to fishing pressure, the latter in turn being represented by fishing effort. Identifying areas of high vulnerability of sensitive species groups (e.g. elasmobranchs or other sensitive species) may help to define potential areas of interest for setting up fisheries closures or other fisheries management tools.

Relation MSFD Descriptor(s), Criteria and Indicators		D1 – C1.1 – I1.1.1/I1.1.2		
Indicator type (state, pressure, surveillance, response, other)		State indicator		
Theoretical background		Vulnerability usually combines metrics of occurrence for sensitive ecosystem components and their exposure to a pressure or stressor (Zacharias and Gregr, 2005; Stelzenmüller <i>et al.</i> , 2011; Stelzenmüller <i>et al.</i> , 2015). Thus vulnerability metrics combine pressure- and state elements into a single metric. In this case the relationship between the pressure and the sensitive ecosystem component (demersal elasmobranchs) has been validated by statistical modelling techniques.		
Used data/data sources		ICES Datras IBTS-Q1, OSPAR ICES fishing effort data for the North Sea		
Indicator metric (formula)		<p><b><i>Vulnerability = Sensitivity * Exposure</i></b></p> <p>Sensitivity is expressed as number of years in which a specific spatial area (rectangle of e.g. 1° * 0.5°) is classified as an abundance hotspot of cumulative relative abundance. Exposure is expressed as abrasion stress due to fishing represented by the swept surface area ratio (SAR).</p>		
Assessment benchmark		Currently no benchmark defined.		
Quality criteria		Score A	Score B	Justification
Quality of underlying data	Existing and ongoing data	3	0.5	IBTS-data available from 1984 ongoing, data available from fishing effort available from 2009. Some quality issues associated with FE-data.
	Metrics should be tangible	3	1	Sensitivity and exposure can be readily calculated from available data sources.
	Quantitative vs. qualitative	2	1	Fully quantitative.
	Relevant spatial coverage	3	1	Entire North Sea.
	Reflects changes in ecosystem component that are caused by variation in any specified manageable pressures	3	0.5	The impact of fishing on the abundance of sensitive species can be confirmed, though the abundance of species is also dependent on habitat parameters (habitat type, depth) and may be affected by environmental parameters (temperature, currents, salinity, turbidity, etc., food availability, predation pressure).
Management	Relevant to MSFD	2	1	This indicator may help to protect or replenish the abundance of

	management objectives			sensitive fish species.
	Relevant to management measures	2	1	This indicator can help to designate areas for fisheries closures, MPAs or by-catch mitigation measures in certain areas and seasons.
	Comprehensible	2	1	
	Established indicator	2	0	This indicator has not been used in any framework before.
	Cost-effectiveness	2	1	No additional sampling necessary.
	Early warning	1	0	No.
Conceptual	Theoretically sound	2	0.5	Several peer-reviewed publications on vulnerability of ecosystem components available. However, the way in how the terms <i>vulnerability</i> , <i>sensitivity</i> and <i>exposure</i> are treated, differs between studies, as does the way of calculating <i>vulnerability</i> .
	Metrics relevance to MSFD indicator	3	1	
	Cross-application	2	1	Yes, may find application within HD, CFP.
	Indicator correlation	2	1	No correlation to current indicators known.
	Total score	27/34 = 79.4 %		

### Preliminary results

Abundance hotspots of sensitive fish species can be calculated by aggregating the relative abundance of each species within cells of a spatial grid resulting in cumulative relative abundances per grid cell (Figure A2.4). Here sensitive species are represented by demersal elasmobranchs (Table A2.2), which due to their life-history can be considered to be vulnerable to anthropogenic impacts (Rogers, 2000; Greenstreet *et al.*, 2012b; Fock *et al.*, 2014).

**Table A2.2. List of species combined into the cumulative relative abundance of demersal elasmobranchs.**

Common name	Scientific name	Sensitivity category according to Greenstreet <i>et al.</i> (2012b)
Starry ray	<i>Amblyraja radiata</i>	Intermediate
Rabbit ratfish	<i>Chimaera monstrosa</i>	Sensitive
Skate	<i>Dipturus batis</i> (including <i>D. flossada</i> and <i>D. intermedia</i> )	Sensitive
Sandy ray	<i>Leucoraja circularis</i>	Sensitive
Shagreen ray	<i>Leucoraja fullonica</i>	Sensitive
Cuckoo ray	<i>Leucoraja naevus</i>	Sensitive
Blond ray	<i>Raja brachyura</i>	Sensitive
Thornback ray	<i>Raja clavata</i>	Sensitive
Spotted ray	<i>Raja montagui</i>	Sensitive
Undulate ray	<i>Raja undulata</i>	Sensitive
Lesser spotted dogfish	<i>Scyliorhinus canicula</i>	Sensitive
Nurse hound	<i>Scyliorhinus stellaris</i>	Sensitive
Spurdog	<i>Squalus acanthias</i>	Sensitive

To relativize the abundance of each species, the absolute abundance of each species in each grid cell is standardized to the maximum absolute abundance of the species of all grid cells. This standardization makes the abundances of common and rare species comparable. From the relative cumulative abundances areas of high abundance, hereafter referred to as hotspots, can be determined.



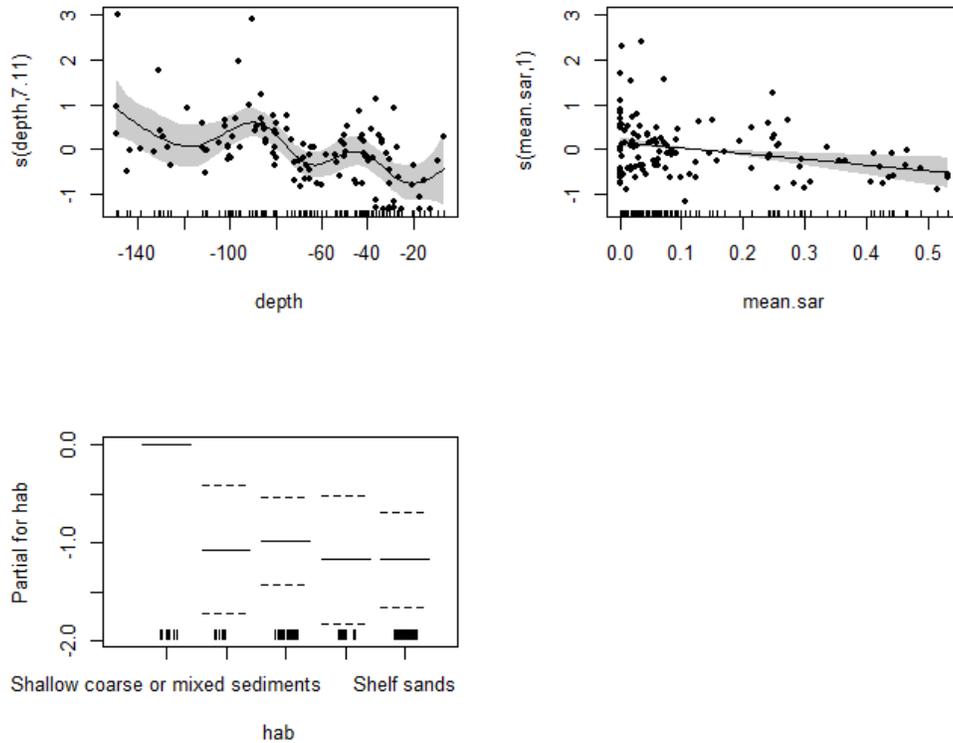
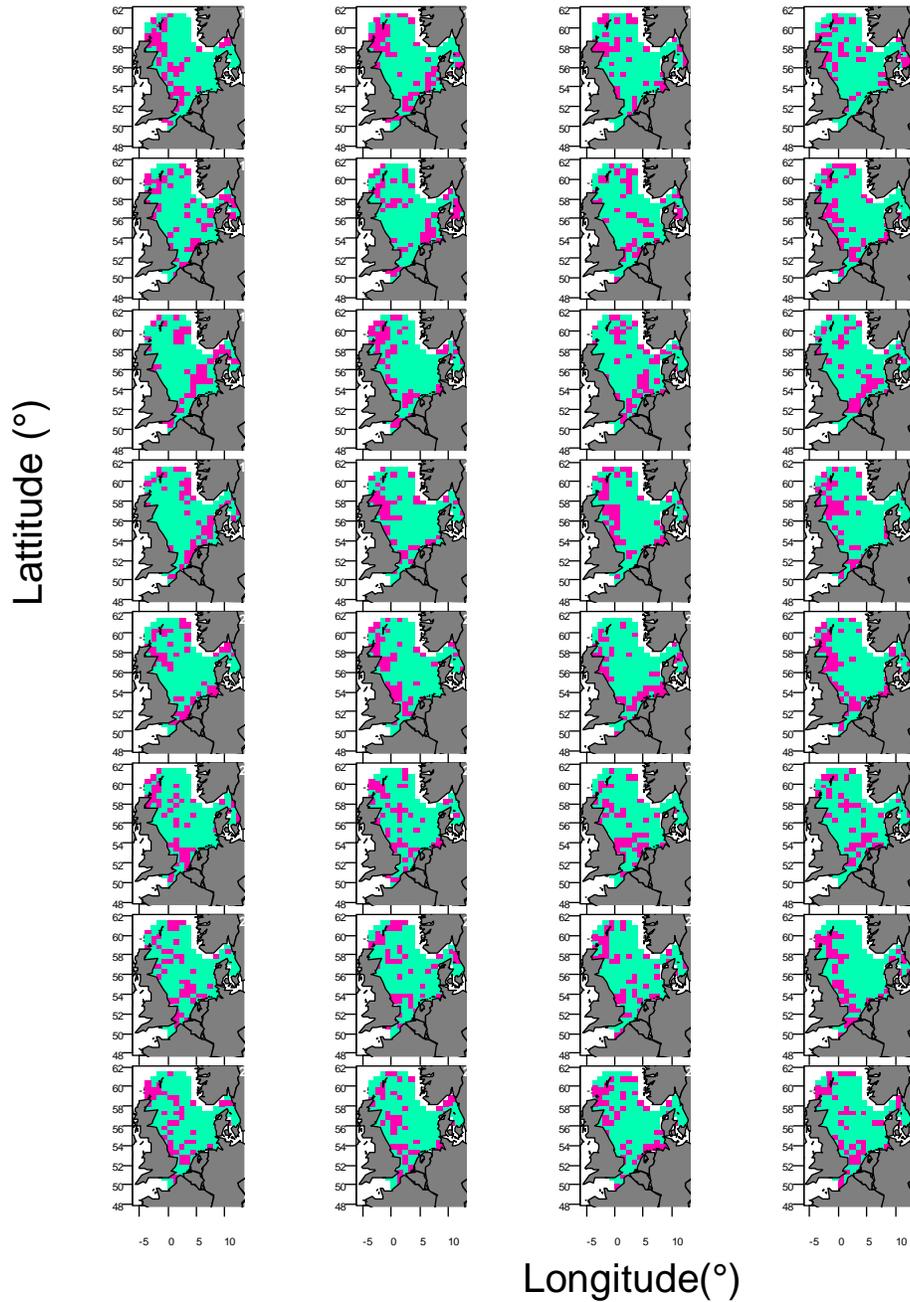


Figure A2.5. GAM-results of relation habitat type (hab), depth and swept area ratio (mean.sar) against the relative cumulative abundance of demersal shark species.

Having confirmed a valid-pressure-state relationship between the abundance of sensitive fish species, in this case demersal elasmobranchs, and fishing intensity, it can be considered as legitimate to calculate the vulnerability of these species under the current fishing regime. However, an evaluation of the annual pattern of cumulative relative abundance displays great inter-annual variability (Figure A2.6). In order to determine the areas in which the relative cumulative abundance of demersal elasmobranchs has been constantly high between 1984 and 2015, it is therefore necessary to determine how many years each rectangle lied above the 75%-percentile (Figure A2.6). Vulnerability (Vul) could then be calculated as:

$$Vul = \log((No. of years > 75\% - percentile * \overline{SAR}_{2009-2013}) + 1) \quad (1)$$

with  $\overline{SAR}_{2009-2013}$  as the average swept surface area ratio between 2009 and 2013 (ICES, 2015c).



**Figure A2.6. Inter-annual variability of the 75%-percentile abundance hotspots of demersal elasmobranchs in the North Sea.**

There is a strong west-east gradient in the abundance of demersal elasmobranchs within the North Sea with high abundances in the western North Sea (A2.7, left panel). An exception to this pattern is found in the high abundance of elasmobranchs in the Skagerrak. The swept surface area ratio is highest in the Skagerrak, the eastern English Channel (Figure A2.7, central panel). Given the available time period of VMS-data, fishing effort

did not reveal significant inter-annual variability i.e. that fishing grounds remained fairly constant throughout the years (ICES, 2015c). The vulnerability map for the North Sea indicates that the vulnerability of demersal elasmobranchs is highest around the northern Shetland Islands, the eastern English Channel and the Swedish west coast (A2.7, right panel). There are further areas of increased vulnerability along the east coast of the UK, at Horn's Rev, the Fladen Ground and Devil's Hole.

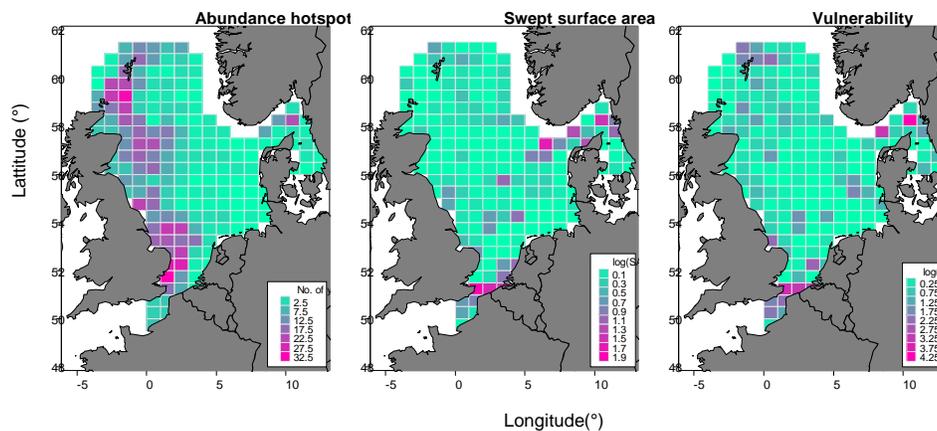


Figure A2.7. Spatial distribution of cumulative abundance hotspots of demersal elasmobranch species (left), swept surface area ratio (SAR) (middle) and resulting vulnerability score (right).

## 5. Three decades of taxonomic and functional diversity in the North Sea demersal fish community

Tim Spaanheden–Dencker, DTU–Aqua

By breaking down the biotic components of ecosystems into functional traits rather than species, we can gain new inform about the relationship between biodiversity and ecosystem functioning. A selection of multivariate indices for trait richness, evenness and divergence were calculated for a study period of 33 year period to investigate temporal and spatial patterns in functional diversity in a demersal fish community. Several matches and mismatches were identified. The results indicate that functional diversity complements more traditional measures of biodiversity, such as taxonomic diversity, and is important to consider in management and conservation efforts.

## 6. Developing phytoplankton diversity indicators under the MSFD

Isabelle Rombouts, Laboratory of Oceanography and Geosciences Wimereux

Phytoplankton is one of the crucial biological elements considered within the Water Framework Directive (WFD) and is also considered in 4 descriptors of the Marine Strategy Framework Directive (MSFD): Biodiversity (D1), Non-indigenous species (D2), Food webs (D4), and Eutrophication (D5). Within the WFD, phytoplankton should be expressed through phytoplankton biomass, composition, abundance, and bloom frequency.

Hence, to respond to this demand, several multi-metric indicators have been developed as assessment tools (Ninčević-Gladan *et al.*, 2015), especially in freshwater systems and transitional waters. Lagging behind, the development of marine phytoplankton indicators is currently underway to assess the state and change in pelagic diversity (D1), to quantify food web dynamics (D4) and to measure the extent of eutrophication impacts (D5).

The choice of the metrics for phytoplankton indicators will not only depend on the objective of the assessment but also on its performance, e.g. link with pressures, and its applicability and practicality, e.g. data availability, coherence across Member States. Chlorophyll *a* concentration became the most commonly and routinely used indicator of trophic conditions, being easily measurable and well-correlated with nutrient enrichment (e.g. Ferreira *et al.*, 2011 and references therein). However, this metric poses some constraints when using it in isolation for the assessment of biodiversity. First of all, only the autotrophic compartment of the phytoplankton is considered and it does not provide us with information on the community structure, an essential metric to assess the state and change in pelagic diversity. Indicators to assess community structure are currently underdeveloped mainly because of the lack of reliable taxonomic information needed for the description of community composition and the difficulty of setting reference levels (Garmendia *et al.*, 2013). This aim is to identify whether abundance and richness are predictable across seasons and typology, and whether the deviation away from a reference condition in different risk condition is sufficient to apply phytoplankton measurements into a management tool for assessment of environmental quality (Devlin *et al.*, 2009). Whilst more studies agree on the use of phytoplankton community structure as an essential metric for water quality assessment (Devlin *et al.*, 2009; Bazzoni *et al.*, 2013; Facca *et al.*, 2014), further work is needed in this respect (Caroppo *et al.*, 2013; Garmendia *et al.*, 2013).

Community diversity analysis for biodiversity assessment consists of describing its structure but also by measuring a significant change from “normal” conditions (Figure A2.8). Classic diversity indices based on the number of species and their abundances have been commonly used to describe phytoplankton community structure. Theoretically, environmental disturbance such as nutrient enrichment will lead to high dominance and low richness in the community since only a few species can cope with these new conditions (Facca *et al.*, 2014). Whilst many diversity indices exist in the literature, no consensus has yet been achieved how to select the “best” index for water quality assessment using phytoplankton count data. As an example, Shannon and Simpson indices are widely used in descriptive studies to quantify community diversity but were found inappropriate as water quality monitoring assessment tools due to their erratic behaviour along an eutrophication gradient (Spatharis *et al.*, 2011). Using three coastal time-series in the English Channel and Bay of Biscay, we tested and selected diversity indices based on (1) the ecological information they provide on the state: richness, dominance, evenness; (2) the mathematical consistency, (3) the link with hydrological conditions, and (4) its management friendliness. Since considerable community changes can occur without being reflected in compositional diversity, we also calculated measures of variance between consecutive years to quantify significant temporal changes.

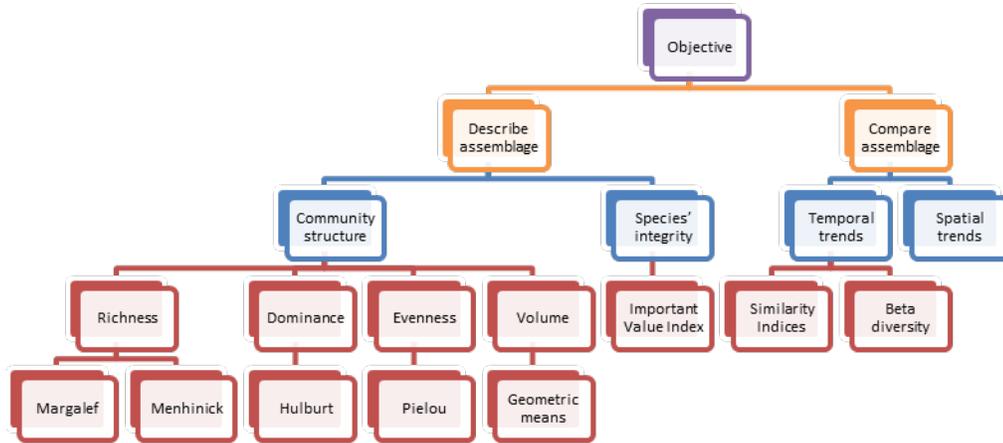


Figure A2.8. Categorization scheme for biodiversity indicators.

## Annex 3: Summary of sub-group work

### 1. Benthos

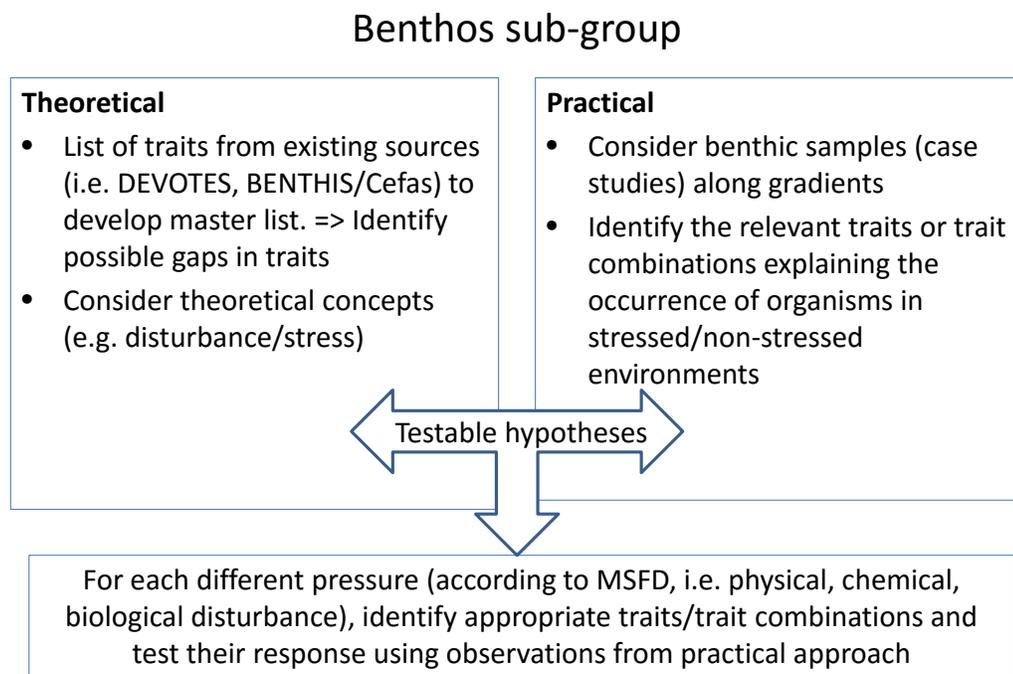
#### 1.1 The mechanistic approach

The here presented approach to develop indicators for the benthos is based on a mechanistic understanding of how the benthos is impacted by the various pressures. The pressures considered are based on the MSFD (Table A3.1), the mechanisms of influence are based on a suite of traits that have recently become available through various projects (e.g. DEVOTES, BENTHIS).

**Table A3.1. The list of pressures identified in the Marine Strategy Framework Directive.**

Pressure specific	Pressure general
Smothering	Physical loss
Substrate Loss	
Changes in siltation	Physical damage
Abrasion	
Selective Extraction (non-living) resources	
Death or injury by collision	Other physical disturbance
Underwater noise	
Marine Litter	
Electromagnetic changes	
Emergence regime change	Interference with hydrological processes
pH changes	
Water flow rate changes	
Thermal regime changes	
Salinity regime changes	
Change in wave exposure	Contamination
Synthetic compounds	
Non-synthetic compounds	
Radionuclides	Enrichment
Nitrogen and Phosphorus enrichment	
Input of organic matter	Biological disturbance
Microbial pathogens	
Non-indigenous species	
Selective extraction of species	Other physical disturbance
Barrier to species movement	

The actual approach consists of two complementary pathways, one theoretical (or top-down) the other more practical (or bottom-up, i.e. based on observations in the field) (Figure A3.1).



**Figure A3.1. Mechanistic approach of the benthos subgroup to develop biodiversity indicators.**

The theoretical approach begins with the development of a “master traits-base” where existing traits-databases are combined and harmonized. For the suite of traits and modalities occurring in that master traits-database will then consider how these might respond to the eight general pressures outlined in the MSFD. A first attempt based on expert opinion and the scientific literature was done by ICES WGEKO (see example Table A3.2) showing that traits respond differently to the different pressures. Mobility was deemed an indicator for 7 of the 8 general pressures, while Living Habitat and Size responded to 6 and 5 pressures respectively. Sensitivity to all pressures, except ‘Other physical disturbance (underwater noise, marine litter, electromagnetic changes)’ was affected by at least one of the traits, and sensitivity to Physical Damage could be directly assessed using 10 of the 13 traits. This existing table will be scrutinized and complemented based on literature and expert judgement.

The practical approach is based on several (or at least one, i.e. Beauchamp) case studies where benthic samples are studied along a gradient of some anthropogenic or environmental pressure. This should reveal which traits or combinations of traits are most sensitive to the pressures studied.

Finally the combination of the findings from the two complementary pathways should result in the development of a suite of indicators that can be tested using existing monitoring datasets.

## 1.2 Development steps

**Table A3.2. Biological traits of benthic marine invertebrate species which may respond to the pressures identified in the Marine Directive (2008/56/EC Annex III Table 2).**

Trait	Pressure								Total Pressures Measured by Trait
	Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination	Enrichment	Biological disturbance	Barrier to species movement	
Size range (mm)		X		X		X	X	X	5
Morphology		X							1
Morphology (Epifauna)		X							1
Longevity (years)									0
Larval development strategy							X		1
Egg development location					[X]			X	2
Living habit	X	X		X	X		X	X	6
Sediment position	X	X		X	X			X	5
Feeding mode		X			X	X	X		4
Mobility	X	X		X	X	X	X	X	7
Protection		X			X				2
Bed/reef formers		X		X	X				3
Bioturbation	X	X		X	X				4
Total Traits Responding to Pressure	4	10	0	6	8	3	4	6	

“Theoretical” steps involve:

Step 1: Create a list of traits from existing sources

- a) Using primary literature, compile a list of all traits that are known from the marine environment (Olivier’s master list);
- b) Compile a list of soft-bottom infaunal traits commonly used in the NE Atlantic (DEVOTES, BENTHIS/Cefas, Olivier’s);
- c) Explore utility of traits information from other benthic habitats (i.e. MERP);
- d) Identify gaps in traits lists.

Step 2: Consider theoretical concepts relating to

- a) the presence/distribution of organisms with specific traits in the marine environment;
- b) their response to natural conditions and
- c) their response to different types, intensities and frequencies of disturbance.

“Practical” steps involve:

**Step 1:** Consider benthic samples (case studies) along natural/anthropogenic gradients

Source information in the primary literature grey literature illustrating the response of traits/trait combinations to such gradients.

**Step 2:** Identify the relevant traits or trait combinations explaining the occurrence of organisms in stressed/non-stressed environments

Combine findings from “theoretical” and “practical” steps: Formulate testable hypotheses regarding the expected response of traits/trait combinations to those pressures that are relevant to the MSFD. Identify appropriate indicators based on traits/trait combinations that have a relationship with specific pressures

### 1.3 Breakdown in tasks

See section 4 below.

### 1.4 Planning

Task	Who	When	Others involved
1. Compile trait master list	Olivier	29/2/2016	
2. Combine existing trait lists	Piet	29/2/2016	All Benthos members
3. Explore availability of traits information on non-soft bottom habitat	Michaela (MERP?)	29/2/2016	MERP consortium members
4. Consider ecological concepts			
Draft list of concepts	Olivier	31/3/2016	
Finalise text on concepts	All Benthos members		
5. Source information in the primary literature grey literature illustrating the response of traits/trait combinations to such gradients.	Olivier	30/6/2016	All Benthos members
6. Identify the relevant traits or trait combinations explaining the occurrence of organisms in stressed/non-stressed environments	All Benthos members	30/9/2016	
7. Agree testable hypotheses (to be tested at WGBIODIV 2017)	All Benthos members	31/12/2016	
8. Source suitable data sets for testing hypotheses	Michaela	31/12/2016	All Benthos members + MERP

### 1.5 Timeline

See section 4 above.

## 2. Plankton

### 2.1 Approach

The pelagic ecosystem boundaries are open and fluctuate in a pluri-dimensional frame. Their plankton communities change rapidly in time (i.e. life cycle, sporadic events, blooms, seasonality, inter-annual variability, long-term shifts) and different types of pressures can be considered to impact these communities. In the frame of the MSFD, the main pressures considered to have a potential impact on pelagic communities are biological extraction (D3) Eutrophication (D5), hydrographical conditions (D7), and contaminants (D8) but also pressures related to harmful effects such as toxin production by harmful algal blooms (HAB) (D8) and invasive species (D2).

The overall objective of the plankton group is to develop indicator(s) of the state of the plankton community which reflects changes that can be related to human pressures.

The chosen approach consists of three pathways based on (1) the taxonomic composition, (1) the size-spectra approach and (3) a trait-based approach. Traditionally, simple community diversity indices have been used to study the taxonomic structure of plankton assembly. Whilst required by the WFD, phytoplankton composition-based tools are poorly developed and their potential application in marine waters is still underway (Devlin *et al.*, 2009).

Plankton size structure has been described in terms of size fractions or in terms of size spectra, by grouping cells into logarithmic size classes. Recent studies have used the size spectra approach to assess the phytoplankton ecological status in transitional waters (Lugoli *et al.*, 2012; Vadrucci *et al.*, 2013). The multi-metric index of size spectra sensitivity (ISS-phyto) integrates size structure metrics with others such as phytoplankton diversity, biomass and sensitivity of size classes to anthropogenic disturbance. This index has successfully demonstrated the pressure–impact response along salinity and enrichment gradients in transitional waters but examples from the marine environment are scarce. Other plankton functional traits could be tested related to their sensitivity to pressures and/or information about the community (i.e. trophic transfers, resilience, adaptations). One of the theoretical basis like the metabolic theory (MTE) could be potentially applied.

Functional traits of plankton define their growth, reproduction and survival (Violle *et al.*, 2007), and determine their fitness for given biotic and abiotic conditions (Westoby and Wright, 2006; Litchman and Klausmeier, 2008; Barton *et al.*, 2010). Size and shape-linked traits are currently most frequently considered in the plankton, probably because it is easily measurable.

### 2.2 Development steps

The theoretical approach begins with an exploration of the most explanatory functional traits for phytoplankton and zooplankton (in theory, in practice from the data available). This is done in relation to the idea of sensitivity to general pressures outlined in the MSFD. A clear definition of functional groups or functional types related to the objective should be then delivered. The level of taxonomic diversity to consider needs also to be defined during this first process step since it will shape the traits data-base. A metadata-base will be constructed that list existing traits-databases and their metadata. Several

case studies have also investigated anthropogenic or environmental pressures on plankton communities which can be useful to consider for the choice of relevant traits.

For the size-based approach, far more published works are available for plankton and a first step will consist to build a literature data base and to extract the most relevant information.

Finally the combination of the findings from the three pathways should result in the development of a suite of indicators that can be tested using existing monitoring data. The feasibility of the operational testing part will depend on the type of data available and usable considering the taxonomic level required for the size structure, functional groups and indexes previously chosen.

There are already data supporting partly these approaches through monitoring programmes and existing indicators in development (OSPAR common plankton indicators), indicators from the FP7-DEVOTES project).

### **2.3. Breakdown into tasks**

Task 1: Revision of literature about functional traits, size-spectra, metabolic theory, and diversity indices for marine plankton

Task 2: Examining the theoretical relationship between traits and pressures (assumptions) and between size classes and pressures

Task 3: Building a table of the most explanatory sensitive traits/size-groups to pressures (theoretical background)

Task 4: Formulate a potential theoretical framework for developing plankton indicators

Task 5: Find the data available to test the theory

Task 6: Testing of the theory on existing data-sets. Combining findings from “theoretical” and “practical” steps: formulate testable hypotheses regarding the expected response of traits/trait combinations/size classes/indices to those pressures that are relevant to the MSFD

Task 7: If the result is robust, then work with the data to develop plankton indicators

## 2.4 Timeplan

Task	Who	When	Others involved
1. Revision of literature	Isabelle Rombouts Felipe Artigas Anaïs Aubert	29/06/2016	No
2. Theoretical relationships between traits/size class/indices and pressures	Isabelle Rombouts Felipe Artigas Anaïs Aubert	29/06/2016	?
3. Table building	Isabelle Rombouts Felipe Artigas Anaïs Aubert	29/06/2016	?
4. Theoretical background	Isabelle Rombouts Felipe Artigas Anaïs Aubert	?	
5. Find data to test of the theory			
6. Test of the theory			
7. Development of indicators			

## 3. Fish

The subgroup on fish community discussed two theoretical approaches and decided to develop these further within the next two years:

- The size-structured approach:** This approach is based on the productivity of fish species in different size-classes. Life-history traits of the species ( $L_{inf}$  and  $K$ ) will determine how the species will be able to sustain a certain level of biomass removal from fishing within a size-class. Depending on the intensity of fishing, slow-growing species (with high  $L_{inf}$ ) will eventually disappear from the larger size classes because their intrinsic productivity rates may become too low to sustain certain levels of fisheries removal. Due to the low productivity of many large-bodied species, species richness will diminish in large size-classes even at low levels of exploitation. The removal of large piscivores will lead to a trophic cascade releasing small fish from predation pressure and will increase diversity in small size-classes.

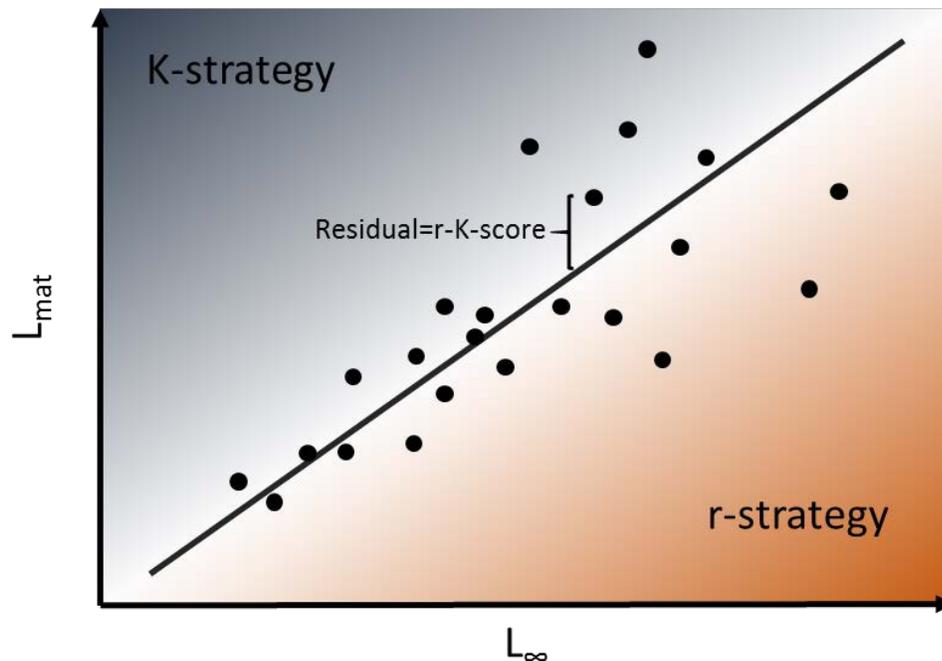


Figure A3.1. Calculation of sensitivity based on the r-K score. Species which mature later at any given  $L_{\infty}$  than the average relationship between both life-history traits (LHT) indicates, can be designated to the K-strategy. These species are putting energy into reproduction at a later point in their life-history traits. The position of each species on the r-K gradient can be determined by the deviation from the regression between two LHTs.

- The r-K-strategy approach:** Fish species are adapted differently to disturbances. Due to their life-history some species can tolerate high levels of disturbance (r-strategists), while others are adapted to more stable environments (K-strategists). Life-history traits allow to assign the species within a community to be assigned along a gradient of these two strategies (r-K-gradient). The deviation of a species from the general relationship would indicate the magnitude of association with the r- or K-strategy (Figure A3.1). By analysing the relationships between different life-history parameters (e.g.  $L_{\infty}$  vs.  $L_{mat}$ ,  $L_{\infty}$  vs.  $k$  or  $L_{\infty}$  vs. egg size) across as many species as possible a combined r-K score could be calculated for each species. The r-K score should be sensitive to fisheries induced disturbances leading to an increased proportion of r-strategists and a decreasing proportion of K-strategist with increasing intensity of fishing (Figure A3.2). The abundances of r- and K-strategists could be used to calculate the ratio between r- and K-species. The degree of disturbance at which this ratio is balanced could be potentially set to identify a GES-limit.

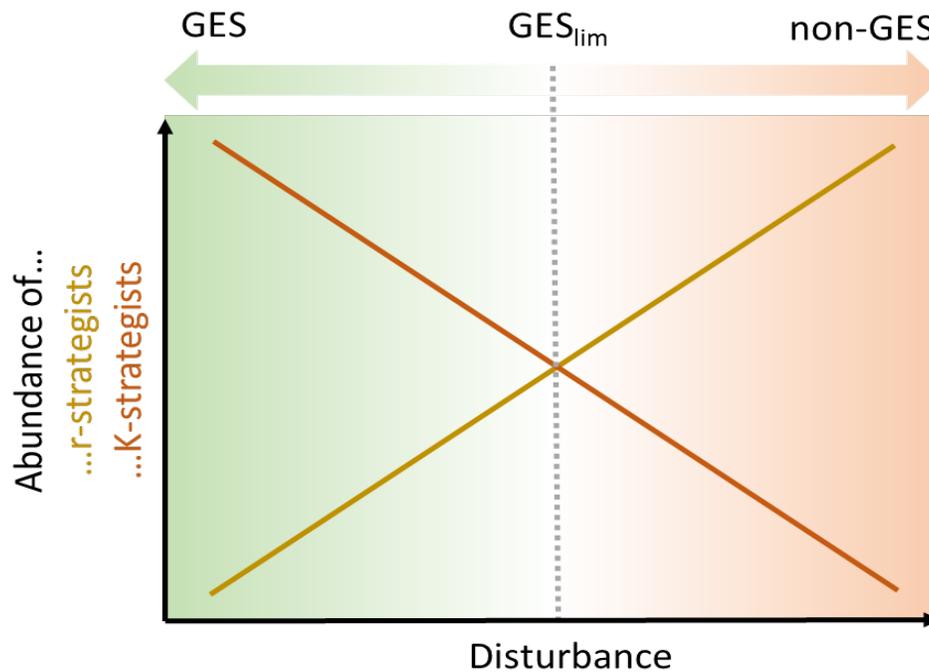


Figure A3.2 The hypothesized relationship between the magnitude of disturbance and the abundance of sensitive K- and less-sensitive r-strategists. According to the hypothesis communities with dominated by K-strategists are at GES, GES<sub>lim</sub> demarks a point at which r-and K-strategist species are in balance and which could be used as a limit reference point.

Both approaches contain potential for several indicators based on biodiversity and abundance metrics. Therefore both approaches were considered as relevant for the future work of WKBIODIV and will be progressed until the next meeting.

Furthermore, three indicator approaches were presented at this meeting which may be eventually related to any of the two theoretical concepts. Accordingly, the subgroup on fish dedicated itself to the following tasks:

- R/K-ratio concept: Analysis and manuscript draft by the next WGBIODIV meeting, maybe combined with results from OSPAR WK for OSPAR interim assessment on fish community in the north Sea (Tim, Henrike, Chris, Simon, Nik)
- Size-based structure: Present a worked example on size-structure analysis (Simon)
- Develop Cumulative Sensitivity Index (Henrike)
- Develop indicator of elasmobranch vulnerability (Nik)

## Annex 4: Development of an indicator factsheet

Table A4.1. Template for a WGBIODIV indicator factsheet.

Chapter Level 1	Chapter Level 2	Chapter Level 3	Type of information required
Indicator name			<i>name indicator (+ OSPAR/HELCOM code)</i>
Authors			<i>name author</i>
Reference to this report			<i>[Author's name(s)], [Year]. [Title]. HELCOM Core Indicator Report. Online. [Date Viewed], [Web link].</i>
Chapter 1	Overview	Key message	<i>key outcome, including results on performance</i>
		Ecosystem component	<i>fish, benthos, etc</i>
		MSDF descriptor	<i>D1, D3, etc</i>
		MSDF criteria	<i>D1.1, D1.2, etc</i>
		MSDF indicator	<i>D1.1.1, D1.1.3, etc</i>
		Development status	<i>new/refined/existing</i>
		Indicator type	<i>state/pressure/surveillance/reponse/other</i>
Chapter 2	Indicator description	Indicator goals/objectives	<i>description of goals/objectives</i>
		Theoretical background	<i>description of theoretical background, including graphs, etc based on peer-reviewed literature</i>
		Description of the indicator	<i>Description of the relation between indicator and environment; relation of indicator to pressure; does it allow for early warning?</i>
		Relation to pressure	<i>describe relationships to pressures</i>

		Policy relevance	<i>description of the relation to MSDF, ASCOBANS, OSPAR, HELCOM, TMAP, ...</i>
Chapter 3	Determination of GES	Description of GES	<i>How is GES determined (conceptual approach to determine an absolute reference point, time series based assessment, other)?</i>
		Assessment benchmark	<i>What is the actual benchmark for GES?</i>
Chapter 4	Data and monitoring	Data source	<i>show data source or link to data</i>
		Data description	<i>description of data</i>
		Data metadata	<i>link to metadata website</i>
		Data quality	<i>description of data quality</i>
		Monitoring	<i>description of monitoring programmes</i>
		Costs of monitoring	<i>description of costs (if possible)</i>
		Geographical coverage	<i>geographical scale of monitoring programmes</i>
		Temporal coverage	<i>temporal coverage of monitoring programmes</i>
		Data analysis	<i>how are data analysed, from raw data to data used to calculate indicator</i>
		Indicator metric	<i>formula plus unit</i>
		Assessment units	<i>Unit of assessment, e.g. ICES rectangle</i>
		Strengths and weaknesses of data	<i>strengths and weaknesses of data</i>
Chapter 5	Protocol for assessment		<i>description of the protocol for assessment; shortly describe steps to derive indicator value from monitoring data</i>
Chapter 6	Assessment results		<i>show results including graphs and tables for a case study</i>

Chapter 7	Evaluation of indicator performance (using WGBIODIV criteria)		<i>assess indicator using WGBIODIV methods; in this section an assessment table should be included; describe results in text</i>
Chapter 8	Further work required		<i>description of future steps to improve indicator</i>
Chapter 9	References		<i>list of references</i>