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

6–10 March 2017

Venice, Italy

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Contents

Executive summary

The Working Group on Biodiversity Science (WGBIODIV) met at the Ca'Foscari University of Venice, Italy, 6–10 February 2017. The meeting, chaired by Nik Probst and Oscar Bos, was attended by 19 scientists from 8 countries. This meeting was the second of the 3-year working 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).

The development of new biodiversity indicators is important to fill the assessment gaps currently existing within the MSFD. Neither the former nor the revised Commission Decision of the MSFD contain indicators on the biodiversity of faunal communities. The Commission Decision therefore is not fully aligned with the current developments of regional biodiversity indicators within OSPAR and HELCOM. WGBIODIV reviewed some of the gaps and inconsistencies that still exist between the OPSAR Common Indicators and the Commission Decision.

An important task of WGBIODIV is the development of diversity indicators, which are based on sound theoretical concepts. During this year's meeting, two trait-based indicator concepts for fish and benthic communities were explored. The fish community indicator is based on the distribution of life-history traits within different trophic guilds, which are or are not subject to fishing induced mortality. The benthic community indicator combines sensitivity to instantaneous mortality and the recovery potential based on life-history traits of species in a single metric.

WGBIODIV reviewed and analysed the effects of sampling effort on biodiversity metrics. Estimates of species richness can be strongly affected by applied methods of rarefaction and standardisation. A new approach based on spatial sample coverage, instead of sample size, to estimate true species richness was explored in a case study on North Sea fish surveys.

Furthermore, WGBIODIV began to create a generic protocol for developing community indicators based on ecological concepts. Experiences from the WGBIODIV process of designing new indicator concepts on fish and benthic communities will be included into the generic protocol, eventually helping future indicator developments.

1 Administrative details

Working Group name

Working Group on Biodiversity (WGBIODIV)

Year of Appointment within current cycle

2016

Reporting year within current cycle (1, 2 or 3)

2

Chair(s)

Wolfgang Nikolaus Probst, Germany

Oscar G. Bos, the Netherlands

Meeting venue

Venice, Italy

Meeting dates

6–10 March 2017

2 Terms of Reference

ToR	Description	Expected Deliverables
1	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: 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). 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 minimized (e.g. procedures for sample aggregation, modelling of individual species distribution	1. Protocol on the development of theoretical concepts of biodiversity indicators (2016/2017). 2. Combined analysis and review on impacts of sampling size on performance of biodiversity metrics (2016-2018). 3. Analysis on aggregating biodiversity indicators at different levels (species group, community, ecosystem) (2017/2018). 4. Quality assessment of investigated biodiversity indicators according to WGBIODIV criteria (2018). 5. One or more operational indicators to assess biodiversity at the community and eventually the ecosystem level (2018).

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.	

3 Summary of Work plan

1. The draft on developing generic theoretical concepts for biodiversity will be further reviewed and evaluated for publication in a scientific journal.
2. New community indicators for fish and benthos communities will be further developed and implemented in case studies.
3. These indicators will be evaluated against the WGBIDOV indicator quality criteria to test their usefulness for the assessment of environmental status and ecological 'health'.
4. The influence of sample size and sampling scale was evaluated in case studies and reviews and may receive further attention in 2018.

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

- Gap analysis on RSC biodiversity and MSFD indicators according to the revised EU Commission Decision;
- Draft generic protocol to develop concepts for trait-based indicators;
- Conceptual benthos indicator sensitive to impacts of fishing induced mortalities and disturbances;
- Concept for biodiversity indicators within trophic guilds of fish.

5 Progress report on ToRs and workplan

ToR1a: Establish a sound theoretical basis relating variation in biodiversity metric values to changes in anthropogenic pressure on marine communities

ToR1a and Deliverable 1 have been addressed by this year's work. A generic protocol on how traits can be used to develop theoretical concepts for biodiversity indicators was drafted.

Subgroups on benthos and fish communities have worked on the development of theoretical concepts, which will be used to develop new biodiversity indicators.

ToR 1b: Explore the issue of sampling size dependence

ToR 1b was addressed by a subgroup that revised the literature and performed a case study using the MSFD data product on fish trawl surveys. The case study compares estimates of species richness when comparing samples by sampling sizes vs. spatial sampling coverage.

ToR 1c: Assess the “ecosystem level” assessment of biodiversity

ToR 1c may not be fully addressed during this delivery period, as for the moment the development of community indicators is prioritised. The initial intention on combing community indicators into ecosystem indicators has thus not yet been pursued.

ToR 1d: Apply the WGBIODIV quality criteria to assess the performance of state indicators

ToR 1d will be addressed once any new indicator development is getting into a finalised stage in which all quality criteria can be assessed. This may occur in the next WGBIODIV delivery period (2018–2020).

In October 2016, WGBIODIV received the following recommendation from the Benthic Ecology Working Group (BEWG):

An area identified by the BEWG is with regards to structural and functional indicators (relevant to many aspects of the MSFD, mainly D1-biodiversity and D6 seabed integrity), particularly linking damage and functional attributes to support seabed integrity assessments. BEWG has been working on several aspects of indicators, monitoring and assessment. The BEWG suggests that better integration is fostered across EG’s (e.g. workshop or a targeted session for the next ICES in 2017). This activity will help to cascade ongoing developments and highlight the gaps for future work.

Addressed to: ICES EG’s with an interest in developing science to support the Marine Strategy Framework Directive (MSFD), mainly WGBIODIV and WGECO.

WGBIODIV will communicate the results of the WGBIODIV benthos indicator throughout the development process to ensure that BEWG will be aware of the developments within WGBIODIV.

6 Revisions to the work plan and justification

ToR1a may require further work beyond next years’ meeting and may extend into in the next delivery period (2018–2020), as the development of indicator concepts is time consuming.

ToR1c may not be addressed during the 2016–2018 delivery period as the development of trait-based indicators will not be completed until 2018.

ToR1d may have to be addressed in the next delivery period (2018–2016) as the development of the new WGBIODIV biodiversity indicators may not by finalised in 2018.

7 Next meetings

The next meeting is going to be held at the ICES HQ, Copenhagen, Denmark, 5–9 February 2018.

Annex 1: List of participants

NAME	AFFILIATION	EMAIL
Andrea Belgrano	Swedish University of Agricultural Sciences (SE)	andrea.belgrano@slu.se
Anik Brind'Amour	Ifremer (F)	Anik.Brindamour@ifremer.fr
Christopher Lynam	Cefas (UK)	Chris.Lynam@cefas.co.uk
Fabio Pranovi	Ca' foscari University of Venice (I)	fpranovi@unive.it
Felipe Artigas	Université Littoral (F)	felipe.artigas@univ-littoral.fr
Gerjan Piet	Wageningen Marine Research (NL)	Gerjan.piet@wur.nl
Gert Van Hoey	ILVO (B)	Gert.Vanhoey@ilvo.vlaanderen.be
Henrik Gislason	DTU Aqua (DK)	hg@aqua.dtu.dk
Hilde Trannum	NIVA (N)	hilde.trannum@niva.no
Isabelle Rombouts	MNHN (F)	isabelle.rombouts@univ-lille1.fr
Laura Pettit	JNCC (UK)	Laura.Pettit@jncc.gov.uk
Laura Robson	JNCC (UK)	Laura.Robson@jncc.gov.uk
Michaela Schratzberger	Cefas (UK)	michaela.schratzberger@cefas.co.uk
Nik Probst	Von Thünen Institute (D)	nikolaus.probst@thuenen.de
Olivier Beauchard	VLIZ (B)	Olivier.beauchard@vliz.be
Oscar Bos	Wageningen Marine Research (NL)	Oscar.bos@wur.nl
Paul Somerfield	Plymouth Marine Lab (UK)	pjso@pml.ac.uk
Saša Raicevich	Institute for Environmental Protection and Research, Rome (I)	sasa.raicevich@isprambiente.it
Simon Greenstreet	Marine Lab Schotland (UK)	s.greenstreet@marlab.ac.uk

ICES WGBIODIV 2017 (from left to right): Oscar Bos, Henrik Gislason, Christopher Lynam, Simon Greenstreet, Isabelle Rombouts, Andrea Belgrano, Laura Robson, Laura Pettit, Gerjan Piet, Olivier Beauchard, Hilde Trannum, Anik Brind'Amour, Felipe Artigas, Paul Somerfield, Gert van Hoey, Nikolaus Probst (not on this photo: Saša Raicevich and Fabio Pranovi).

Annex 2: Summary of the sub-groups

Analysing gaps between RSC Indicators and the MSFD revision

This project verifies if the current OSPAR biodiversity indicators correspond to the newly proposed criteria and indicators from the revision of Commission Decision (CD) EU/2010/477. The aim is to detect gaps in the coverage of CD and whether these gaps can be filled, e.g. by transferring existing diversity indicators to different taxonomic groups.

WGBIODIV created a table to identify gaps between existing indicators and MSFD requirements by highlighting which criteria were not met by any OSPAR common indicator.

WGBIODIV also identified existing indicators listed in the DEVOTES catalogue of indicators (DEVOTool) (http://www.devotes-project.eu/devotool/) and looked at which taxonomic groups these indicators have been applied to. This allowed identification of which concepts are not currently transferred across groups.

Top-down control and bottom up limitation: explaining the relationship between fishing pressure and fish species diversity

Extensive review of the fish ecology feeding ecology literature suggested that on average across the whole community, ontogenetic development of a piscivorous diet occurred at a body length of approximately 23 cm. As a general rule, the maximum size of fish prey consumed by piscivorous fish predators is approximately 0.3 times the predator's own body length (Daan, 1973; Hislop *et al.*, 1991; Greenstreet *et al.*, 1998; Scarf *et al.*, 2000; Floeter and Temming, 2005). So if a piscivory commences at a length of 23 cm, then the maximum size of prey 23 cm piscivore could consume is 7 cm. Applying this ratio also infers that if fish become piscivorous at a length of 23 cm, then they become apex piscivores (feeding on fish prey that are themselves piscivorous at a body length of 76 cm. The fish community sampled by Q1 IBTS surveys can now be partitioned into distinct groups (Table 1).

Table 1. Partitioning of the fish community sampled by the Q1 IBTS by length range into five groups subjected to different types of top-down and bottom-up control.

Length Range	Guild	Prey of Piscivores	Piscivorous	Apex Piscivore	Impacted by Fishing
3 to 22 cm	1	Yes	No	No	No
23 to 24 cm	2	Yes	Yes	No	No
25 to 31 cm	3	Yes	Yes	No	Yes
32 to 75 cm	4	No	Yes	No	Yes
76 to 105 cm	5	No	Yes	Yes	Yes

Trends in a range of community metrics applied to the species catch-at-length data provided by the ICES Q1 IBTS are shown in Figures 1 and 2. Relationships between these trends will be explored to test hypotheses derived from a new theory of fish biodiversity being developed by WGBIODIV. This theory considers the relationships between different guilds of fish within the whole fish community, where guilds are established by differences and similarities in the patterns of top-down control and bottom-up limitation that they experience.

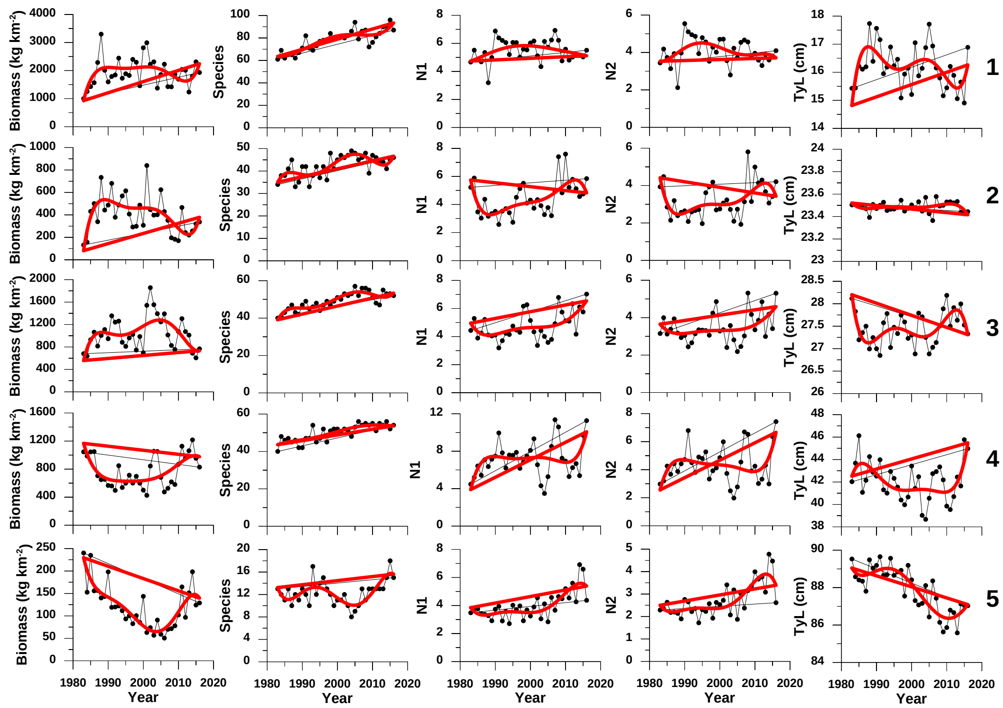

Figure 1. Trends in biomass density, species inventory, Hill's N1, Hill's N2 and Lynam's typical length (TyL) indices derived from the ICES IBTS Q1 between 1983 and 2016 for five fish guilds (see Table 1).

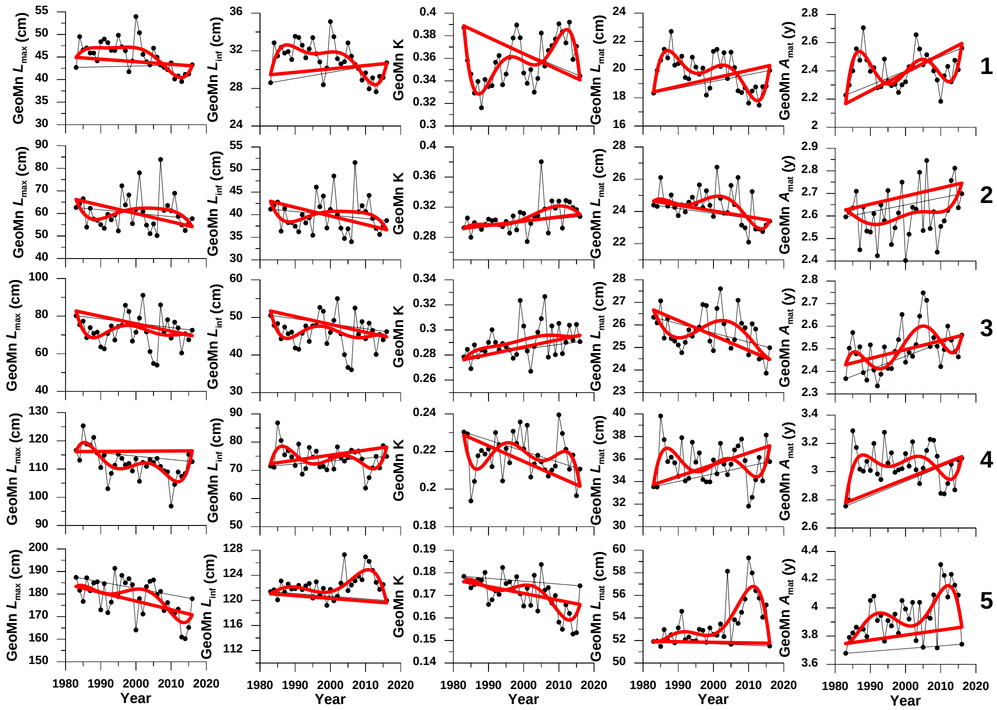

Figure 2. Trends in geometric mean maximum length (L_{max}), geometric mean von Bertanffy length infinity (L_{inf}), geometric mean von Bertanffy growth (K), geometric mean length at maturity (L_{mat}), and geometric mean age at maturity (A_{mat}) indices derived from the ICES IBTS Q1 between 1983 and 2016 for five fish guilds (see Table 1).

Standardizing sampling design and analysis to obtain unbiased estimates of species diversity

Although the quantification of changes in biodiversity often is central to studies of human impacts on marine ecosystems, biodiversity has proven exceptionally difficult to quantify reliably. Limiting this discussion to richness, whether taxonomic or functional, these difficulties are not only related to problems involved in species identification or functional classification, and sampling. Many of the problems arise because the statistical properties of richness estimators are poorly known and because standardization of richness estimates is essential.

Richness is curtailed by the number of individuals sampled, because if only x individuals are caught, only x species can be identified. Drawing samples from a diverse assemblage, richness will increase with the number of individuals sampled and with the number of samples collected. Sometimes the relationship is asymptotic and a value of total richness characterizing the assemblage in a delimited area at a given time can be derived. But when species migrate across the borders of the area investigated, and when samples have been collected over a period of time, no asymptotic richness value can often be obtained.

Because richness is an increasing non-linear function of abundance, models are needed to extrapolate or rarefy the number of samples or individuals to a common standard or a comparable size (see Figure 3).

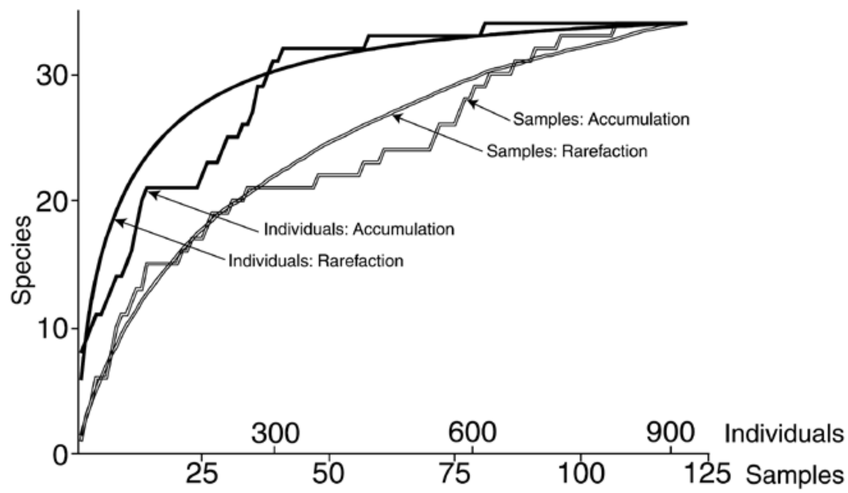

Figure 3. Sample- and individual-based rarefaction and accumulation curves. The smooth curves represent the statistical expectation of the number of species encountered based on cumulated number of collected individuals or samples (solid lines). The jagged curves represent a single ordering of the individuals or samples as they are successively pooled. Copy of figure from Gotelli and Colwell (2001).

Classical rarefaction or extrapolation of samples is, however, subject to a number of factors influencing the result. Apart from differences in the local species pool generating a need for additional samples in high diversity areas, intra- and interspecific correlations and differences in aggregation patterns can violate multinomial assumptions and change the number of samples or individuals required to produce an unbiased result. Most species have aggregated distributions, and random distributions are very rare in nature (Preston, 1962). The shape of the species accumulation curve (the SAC) will both depend on the species abundance distribution (the SAD) and the species area relationship (the SAR). In addition multicollinearity of environmental variables, differences in sampling efficiency/catchability, non-linear responses of species richness to different stressors, and effects of spatial scale may complicate the analysis (Gotelli *et al.* 2009).

The problems involved in rarefaction and extrapolation are particularly important when the effects of environmental or anthropogenic drivers are being analysed, because the shape of the SAR and SAD may change in response to changes in a driver. Sometimes SACs generated by samples obtained at different levels of, say organic enrichment, will intersect providing a negative response to a change in the driver below the intersection, and a positive above the intersection point, leading to opposing conclusions about the effect, Figure 4. But even when they do not intersect the relative difference between the curves may change as a function of the number of individuals or samples collected, giving rise to scale dependent conclusions generating inflated confidence limits in meta-analyses and unnecessary controversy about the impact of the driver.

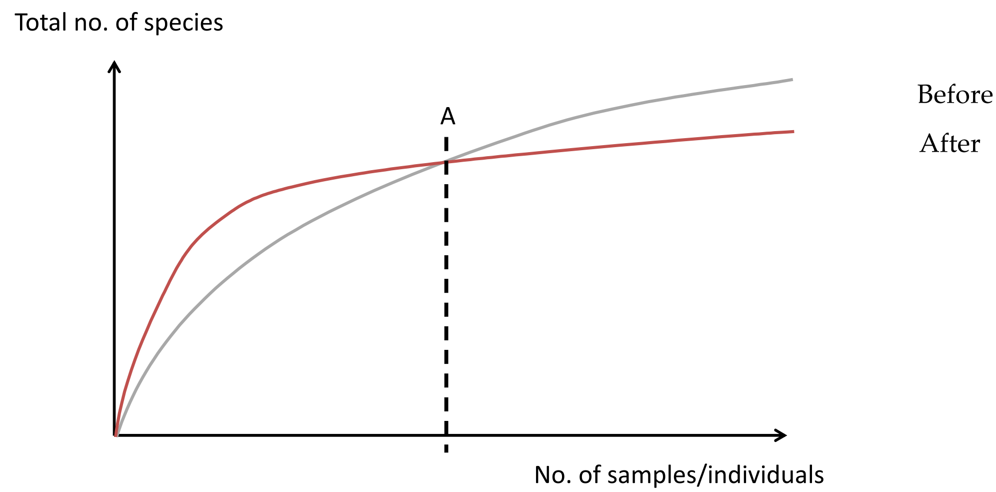

Figure 4. Species accumulation curves obtained at two levels of an anthropogenic driver illustrating the conflicting conclusion that may be drawn. At a sampling effort below A the community affected by the driver appears to be more species rich than before, above A the opposite is true. The different SACs may result from changes in aggregation, with less aggregation before than after.

Chase and Knight (2013) summarize the problems related to scale dependency caused by sampling units that differ in size and spatial extent and argue that many of the problems related to identifying the direction and magnitude of biodiversity responses may be seen as resulting from the using scale-dependent methods and procedures. Except when the SACs are parallel effect sizes will be scale dependent, creating ambiguity in estimated effect sizes.

Despite the importance of correcting for differences in spatial scale, sampling effort, and overall abundance, biodiversity samples are often not adjusted in a way that will make them comparable and allow conclusions to be drawn about changes in richness, evenness and other biodiversity measures. For the reasons given above, even samples that are standardized by area or individuals cannot generally be used without further consideration. E.g. Gray *et al.* (1997) showed that dominance is greater in small than in large sample sizes, which leads to an overestimating of species richness especially from small samples with the rarefaction method.

WGBIODIV will try to summarize the problems and their possible solution by reviewing the literature, providing examples of how the problems may influence the results, and give recommendations on how to best to analyse the impacts of environmental and anthropogenic drivers on marine biodiversity.

References

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Protocol on the development of theoretical concepts for biodiversity indicators

The aim of this project is to identify a generic approach for developing biodiversity indicators. Currently, many biodiversity indicators are built on qualitative ecological concepts or non-validated assumptions and hence make the interpretation of indicator metrics with regards to good environmental status difficult. Especially the interpretation of classical biodiversity metrics such as Hills Numbers have been associated with ambiguity. Here a multi-step framework is envisioned, which can generally guide the development of new indicator concepts based on biological traits of species assemblages. The multi-step framework will be exemplified on the WGBIODIV fish and benthos community indicators.

Developing a benthic impact indicator

For the seafloor including its benthic community and how this is impacted by the pressure "Physical disturbance" the MSFD criterion supposed to describe the state of the seafloor is D6C3, which states "Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions (e.g. through changes in species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), by physical disturbance". Here we present the development of an indicator describing the species composition including the relative abundance, absence of particularly sensitive or fragile species in relation to physical disturbance. A good indicator of state should be both specific and sensitive to a particular pressure. We calculate indicators based on the physical disturbance caused by fishing as this is the most wide-spread human activity causing this pressure. Through this approach the impacts of fishing pressure on the state of the seafloor can be intuitively understood based on a mechanistic understanding of the processes that cause the impact, i.e. physical disturbance. However, the same principles and approach apply to physical disturbance arising from any other human activity.

Moreover, the state of the seafloor should be captured by an indicator that captures species composition (or rather taxonomic composition) such that it reflects a deterioration in quality if the pressure increases but can also show an increase in quality if the pressure decreases through mitigation and hence track progress toward some target state at which policy objectives are achieved.

To that end the indicator is based on the same conceptual approach as was developed to determine the impact of physical disturbance due to fishing. In this so-called population-dynamics approach the change in biomass (i.e. impact) of any benthic population or community caused by physical disturbance (i.e. fishing) is captured by two processes, a depletion of benthic community biomass caused by the instantaneous mortality and a recovery due to reproduction. Depletion is gear- and habitat-specific, recovery is only determined by the type of habitat. The result is that the quality of the seafloor, i.e. seafloor integrity, is based on the biomass of the entire benthic community and expressed in relation to an undisturbed situation equal to carrying capacity. In order to describe the composition of the benthic community specifically in relation to the relative abundance of sensitive species (or taxa) we use trait-based information to estimate the relative sensitivity of taxa in the benthic community. We specifically focus on those traits and their modalities that respond to physical disturbance. The assumption is that species that differ in those traits will be impacted differentially by varying intensities of fishing pressure.

Depletion is assumed to be shaped by three traits:

1) The extent to which the organism is directly exposed to the disturbance is determined by the vertical position of the organism on or in the sediment (burrowing depth, BD), with deeper-burrowing species being depleted less.
2) The fragility (FR) of an organism, with more fragile species being more depleted.
3) The mobility (MO) of the organism which determines its ability to avoid or escape the disturbance, with more mobile organisms capable of avoiding disturbance thereby reducing their depletion.

Recovery is determined by two life history traits, age at sexual maturity (AM) and life span (LS) which together determine the period the species can reproduce. A species with late AM has a higher probability of dying from physical disturbance before reproducing successfully. This together with a short life span results in a low reproductive capacity and thus low recovery potential.

The performance of the sensitivity index was reflected in amount of the indicator variance explained by fishing intensity. Variation in composition of benthic community biomass was explained for more than 10% by fishing over the entire area but for more than 15% in the deep muddy areas less affected by natural sheer stress.

This example based on one benthic dataset in the North Sea was considered “proof of concept” but in order to develop and apply this indicator in other regions we attempted to develop a similar indicator for the Bay of Biscay where the available dataset consisting of somewhat different taxa and traits required a “cross-walk” between the two databases. This was feasible resulting in a comparable sensitivity index proving that this indicator can be developed and applied in different regions.

Although these first results look promising, further developments, tests and a comparison with other potential indicators are required before this indicator can become operational.