UNDERSTANDING DEEP ATLANTIC ECOSYSTEMS

ATLAS Deliverable 3.1
Good Environmental Status and Biodiversity Assessments

Project acronym:	ATLAS
Grant Agreement:	678760
Deliverable title:	Good Environmental Status and Biodiversity Assessments
Work Package:	3
Date of completion:	29.12.2018
Authors:	Covadonga Orejas and Georgios Kazanidis
Contributors	Ángel Borja, Oisín Callery, Marina Carreiro-Silva, Pablo Durán, Hrönn Egilsdóttir, Marina Gallardo-Núñez, Ana García-Alegre, Eva Giacomello, Anthony Grehan, Lea-Anne Henry, Ellen Kenchington, Lénaïck Menot, Telmo Morato, Francis Neat, Stefan Aki Ragnarsson, Steve Ross, Christopher Roterman, José Luis Rueda, Mar Sacau, David Stirling, Tanja Stratmann, Gerald Taranto, Javier Urra, Dick van Oevelen and J Murray Roberts. Participants in GES ATLAS breakout groups and ATLAS consortium

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 678760 (ATLAS). This output reflects only the author's view and the European Union cannot be held responsible for any use that may be made of the information contained therein.

Content

Executive summary

This deliverable aims to explore how best to define Good Environmental Status (GES) for deep-sea habitats, to review progress with indicator development for the deep sea, and to explore how better to assess GES in the deep sea considering four of the eleven Descriptors included in the Marine Strategy Framework Directive (MSFD): D1 Biodiversity, D3 Commercial species, D6 Seafloor integrity and D10 Marine Litter.

GES in the deep sea means the extraction of living marine resources is occurring at sustainable levels and the extraction of non-living resources does not produce significant adverse impacts that can cause serious harm in the whole ecosystem, i.e. the levels of extraction ensure the continued delivery of goods and services for future generations. In particular, deep-sea GES is achieved when habitat-forming species are in a 'good' condition, as defined by acting as biodiversity hotspots and ensuring the functionality of the system, including the associated benthic, suprabenthic and demersal components. Areas dominated by soft sediments (e.g. the abyssal plains) maintain biodiversity at a level that ensures persistence of functional groups and thus ecosystem function. Impacts on the seabed and their effects on benthos and fish (commercial and non-commercial species) do not increase the risk of an altered or lost ecosystem functioning, ensuring the sustainable use of deep-sea resources and the continued resilience of ecosystems in the face of a changing climate.

ATLAS adopted an indicator-based approach to evaluate GES in the deep sea and applied the Nested Environmental status Assessment Tool (NEAT) for assessing the environmental status (GES) of the ATLAS deep-sea case study European areas. After a careful and comprehensive review of the existing information, a selection of existing indicators was conducted and new indicators were proposed considering the specific constraints of working in the deep sea (e.g. remoteness, difficulties conducting scientific surveys and sampling in deep-sea areas, lack of baseline data, monitoring) and the main characteristics of these ecosystems. GES boundary values were defined for each indicator. However, in most cases this was a difficult task mainly because of the lack of pre-impact or historical information that can serve as baseline or reference conditions and guide case studies to suggest meaningful thresholds or just because there is limited knowledge on many aspects of deep-sea ecosystems. The application of the NEAT tool to the ATLAS case studies clearly highlighted the data scarcity for the deep-sea even taking into consideration that most of the selected case studies are areas where studies have been already conducted and at least some data are already available, which is clearly not the case for most of the deep-sea realm. The NEAT analyses also suggested that the selection of indicators, target values and a specific regional dimension, habitats and ecosystem components, can have a significant impact on the NEAT results.

Due to the data limited situation and challenges posed for monitoring, it may well be the case that GES in the deep sea will have to be assessed at habitat and ecosystem level (rather than at species level) and at large spatial and temporal scales (considering aspects as seasonality and the need to nest results of analyses conducted at different spatial and temporal scales) when compared to the shallower waters of the European Seas. For similar reasons, the type of indicators to be used may have to be simplified and likely be based on high-level analyses related to traits, pressures/risks, and habitat /ecosystem resilience.

Structure of the deliverable

The deliverable has been structured in 4 main sections. The first section includes a brief introduction on the MSFD as well as on the concept of GES and the Descriptors nominated to assess GES. A short summary (extracted from documents from the European Commission) on the main results of the initial evaluation from the Member States for the Descriptors considered within ATLAS is also included. The last part of this first section includes a summary of the main results and conclusions of the initial evaluation (IE) of the European Member States where ATLAS Case Studies (CS) are included: France, Ireland, Portugal (Açores), Spain, United Kingdom. Considering the challenges and opportunities already identified through the initial evaluation and the information already published, we considered it essential to include as much information as possible in order to properly evaluate and discuss the results obtained in ATLAS. This review serves a holistic view for the challenge named "Assessment of Good Environmental Status in the marine environment".

The second section is intended as a literature review (as comprehensive as possible) focussing on the challenge of assessing GES in benthic ecosystems with a specific section dedicated to the deep sea. Attention is drawn to the work conducted by International Council for the Exploration of the Sea (ICES) and the Joint Research Centre (JRC) as well as by the Oslo/Paris convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and the Helsinki Commission for Baltic Marine Protection (HELCOM). Further, a review of more than 70 scientific papers has been carried out, trying to cover as many aspects as possible on the assessment of GES in benthic ecosystems and specifically in the deep sea. This literature review includes the revision of the GES concept in a changing environment as well as the models and multimetric indexes developed to assess GES. In addition, the issue of assessing uncertainty of indicators is included, as well as the application of new sampling methodologies to assess GES. Several papers have revised the results of the IE of the different Descriptors; the information related to the "ATLAS Descriptors" is also included here. Further, due to the many common aspects shared by the MSFD and the Marine Spatial Planning Directive (MSPD), some text is dedicated to deal with the need to harmonise both European Directives, as well as a short reflexion on the ecosystem goods and services and their role within the MSFD and the GES assessment. This second section finishes with the assessment of GES in the deep-sea, a review on the aspects already published on GES assessment focused in the deep-sea and a brief mention to the IDEM project, that approach GES in the Mediterranean deep-sea.

The third section, which is the core of this deliverable, deal with the assessment of GES within 9 ATLAS case studies. In this section several aspects are included: 1) methodology used to assess GES in the CS, 2) the results of the analysis using the software NEAT, and 3) commenting and the results from the CS leaders are presented.

Finally section four includes a general discussion, conclusions and a list of suggestion regarding GES assessment in the deep-sea.

Appendix: Document Information

EU Project N°	678760	**Acronym**	ATLAS
Full Title	A trans-Atlantic assessment and deep-water ecosystem-based spatial management plan for Europe		
Project website	www.eu-atlas.org		

Deliverable	**N°**	3.1	**Title**	Good Environmental Status and Biodiversity Assessments
Work Package	**N°**	3	**Title**	Biodiversity and Biogeography

Date of delivery	**Contractual**
Dissemination level	Confidential

Authors (Partner)		**IEO**		**UEDIN**
Responsible Authors	**Name**	Covadonga Orejas	**Email**	cova.orejas@ieo.es
	Name	Georgios Kazanidis	**Email**	Georgios.Kazanidis@ed.ac.uk

Version log			
Issue Date	**Revision N°**	**Author**	**Change**

1 Marine Strategy Framework Directive

1.1 Definition of Good Environmental Status and overall summary of the initial evaluation[1]

The Marine Strategy Framework Directive (MSFD; EC 2008) is an ambitious European policy instrument that aims to achieve Good Environmental Status (GES) in the 5,720,000 km^2 of European seas by 2020, using an Ecosystem Approach (Newton et al. 2015). GES is to be assessed using 11 Descriptors and up to 56 indicators (European Commission, EC 2010), and the goal is for clean, healthy and productive seas that are the basis for marine-based development, known as Blue-Growth (BG).

The Marine Strategy Framework Directive (MSFD) (Commission Decision 2008/56/EC), defined Good Environmental Status (GES) as:

"The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations."

The aims of achieving and maintaining these conditions were described in Article 1 of the Marine Strategy Framework Directive (MSFD - 2008/56/EC) and the Member States were required to develop marine strategies to achieve these aims. Furthermore, in order to facilitate Member States interpreting what GES means as well as how marine waters will be when GES has been achieved, the European Commission (EC) has set 11 Descriptors (D) dealing with the crucial aspects of: biodiversity (D1), non-indigenous species (D2), commercial fish (D3), food webs (D4), eutrophication (D5), sea floor integrity (D6), hydrographical conditions (D7), contaminants in the environment and seafood (D8 and D9), marine litter (D10) and introduction of energy (D11).

In the meantime, an EC decision was published in September 2010 (2010/477/EU) in order to define criteria and methodological standards to address GES. By 15 October 2012, Member States had to report back to the EC's initial assessment of environmental status, the determination of GES and the establishment of environmental targets and associated indicators. The EC assessed the reports submitted from Member States in terms of (a) providing an appropriate framework to meet the requirements of the MSFD and (b) coherence of framework across regions/sub-regions. Assessment of Member States' reports and guidance for next steps towards achieving GES by 2020 were reported in the "Commission Staff Working Document Annex – *Accompanying the document* Commission Report to the Council and the European Parliament". Specifically, there was an assessment of Member States' reports for each of the 11 Descriptors about the definition of GES, the initial assessment of environmental status, the environmental targets as well as the consistency between GES, initial assessment, and targets.

[1] The information included in this general section was presented in the text of the Milestone 11.

Below we summarize the major findings from the initial assessment of environmental status for Descriptors 1, 3, 6 and 10 and targets. These are the four Descriptors (please see below for the associated indicators) that are used for the assessment of GES in the 9 ATLAS cases studies located in European waters: Case Study (CS) 1 and CS 2 (Norway[2]), CS 3, 4 and 5 (United Kingdom), CS 6 (France), CS 7 (Spain), CS 8 (Portugal), CS 9 (Iceland[3]) (**Fig. 1**). Addressing GES in the deep sea is a key aspect of ATLAS WP3. The WP3 task 3.3 includes the agreement on GES definition and Descriptor indicators. The three Descriptors mentioned above (D1, D3 and D6) are considered particularly relevant to deep-water ecosystems. In the GES assessment in ATLAS a fourth descriptor has been included (D10) due to the close relation to D6 and considering that most partners also recorded the information on litter, especially in the video and photographic material.

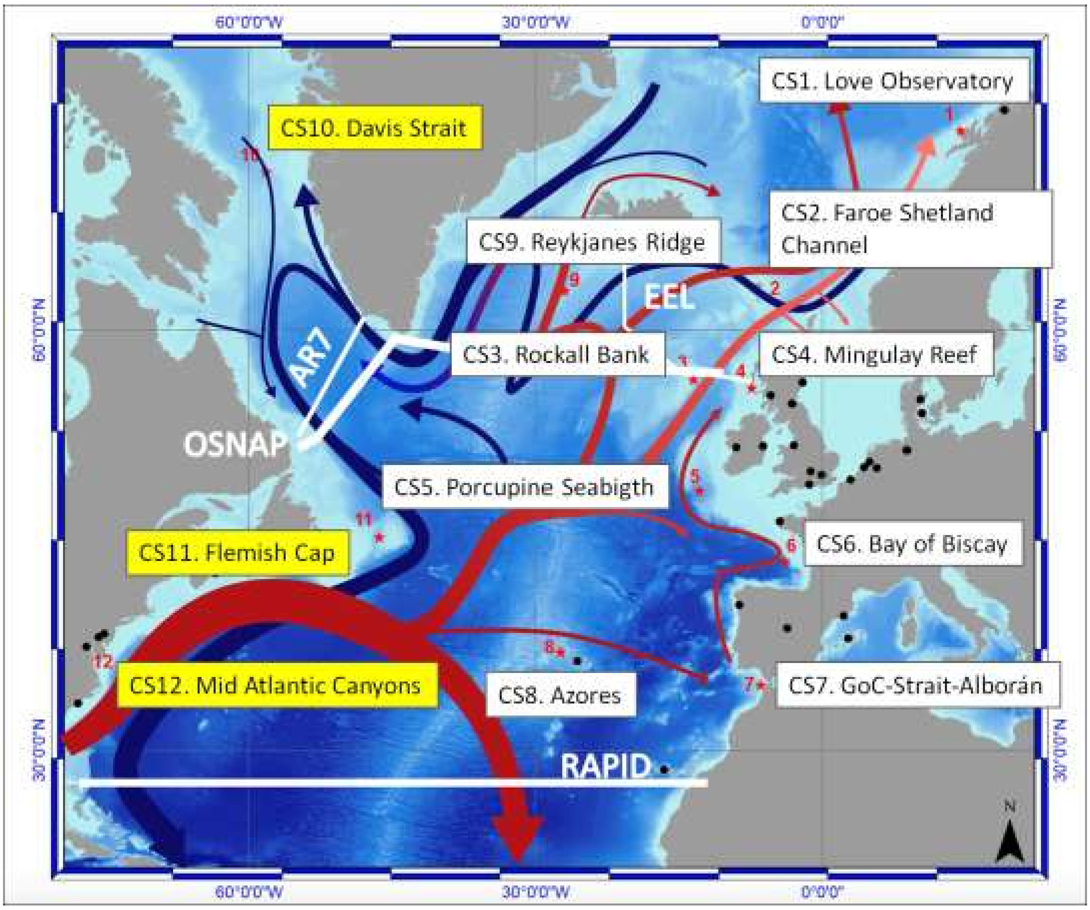

Fig. 1. *Black dots represent the ATLAS partner locations and Red stars represent the ATLAS Case Studies (CS), white labels display the European case studies where GES is being addressed within ATLAS. Yellow labels display the West Atlantic case studies.*

We briefly summarise below the overall results from the initial evaluation (considering all European countries involved in ATLAS), focusing on the "Initial assessment of environmental status", and "Environmental Targets" for the four Descriptors considered within ATLAS, only presenting the aspects relevant in the context of the ATLAS project. The full document can be downloaded following the link (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52014DC0097). In the next

[2] This country is not a member country of the EC, hence the MSFD does not apply to Norwegian waters.
[3] This country is not a member country of the EC, hence the MSFD does not apply to Iceland waters.

section (1.2) main results for D1, D3, D6 and D10 for France, Ireland, Portugal, Spain and United Kingdom are also summarised.

Biodiversity and Marine Ecosystems (Descriptor D1)

Marine ecosystems, their habitats and species throughout Europe continue to be under significant threat from the cumulative impacts of human activities. Only 10% of the assessment of marine habitats and 3% of the assessments of marine species protected under Natura 2000 are considered favourable. Similarly, abundant fish species are increasingly at risk. This combined information on biodiversity indicates that European marine ecosystems and their resilience are under significant threat from human activities. Fisheries, pollution (eutrophication; hazardous substances) and non-indigenous species are some of the main pressures on biodiversity with the effects of climate change threatening to further exacerbate existing impacts. Together, these pressures add to the cumulative impact on the marine ecosystem, resulting in the continued degradation and often unexpected ecological tipping points towards an undesired new steady state.

Commercial Fish (Descriptor 3)

Fisheries are among the most important pressures in the marine environment as they reduce biodiversity by directly affecting the mortality of fish populations and non-target species, and they modify ecosystem structure and functioning. Cumulative fishing levels have led to an alarming state of European fish stocks, where currently 39% in the North East Atlantic Ocean and 88% in the Mediterranean and Black Seas are overfished, threatening their future reproductive capacity. Furthermore, the continuous use of bottom trawling and other high impact fishing gear, has destroyed seafloor habitats and compromised their biodiversity.

Sea Floor Integrity (Descriptor D6)

Sea-floor integrity is a relatively new concept, at least in the way it is expressed in the Directive, but is one which encompasses aspects of structure and function in seabed habitats and their communities. The range of threats to sea-floor integrity varies in nature and severity across the different regions of Europe. The degree of impact varies from sub-lethal effects on individuals to habitat-level effects. See also above in “Summary for Biodiversity and Marine Ecosystems (Descriptor D1)”.

Marine Litter (Descriptor D10)

Marine litter is found on beaches, on the seafloor and floating in the water, in all oceans. It is both a European and a global concern. Many marine species ingest marine litter or become entangled in debris. For some species, a considerable proportion of the population is affected due to damage caused to their body condition, ability to forage and reproduce. Litter, when visible to humans, creates a considerable reduction in recreational, aesthetic or educational values of an area, and sometimes it is also a health concern. To date systematic monitoring has not taken place across Europe, and this is only now being established with the MSFD.

After analyzing the results from the different Member States for this first evaluation of GES, the Commission presented in the same document (Report from the Commission to the Council and the European Parliament. The first phase of implementation of the MSFD (2008/56/EC). The European

Commission's assessment and guidance) a list of “Proposed actions from the European Commission as next steps for the Good Environmental Status at regional scale”. These are summarized below:

- Further develop region- and ecosystem-specific criteria for GES (or related targets and indicators) which are compatible with the MSFD, in particular for those descriptors or parameters where no EU legislation exists.
- Stimulate further coordination at regional or sub-regional level between EU MS in the region.
- Ensure that the results of the regional work benefit from the progress made at EU level and are systematically used in national implementation process.
- Systematically identify the gaps in knowledge that prevent a more ambitious, risk-based setting of GES and collaborate to close these gaps, whilst applying the precautionary principle in the meantime.

In the light of the results of the first evaluation of GES within the MSFD, in May 2017 a new commission decision has been published (2017/477/EU) repealing decision (2010/477/EU). This decision supplies new criteria as well as methodological standards to be considered when assessing GES.

Within ATLAS the four proposed actions from the EC are being considered to assess GES in the deep sea and to select suitable indicators as well as the decision (2017/477/EU).

1. 2 Summary of results of the initial evaluation of Good Environmental Status for D1, D3, D6 and D10 by the European Countries to which ATLAS Case Studies belong to

In this summary we present the results concerning the areas (i.e. regions, sub-regions, demarcations, depending on each country) of the different countries where ATLAS case studies are included for the descriptors D1, D3, D6 and D10. In the cases where the evaluation was presented by sectors, sub-regions, demarcations, we present here the conclusions related to those where ATLAS case studies belong (e.g. initial evaluation for the Azores and not for the whole of Portugal) and rather than the global ones for each country.
Furthermore, we summarised the results of the initial evaluation (IE) at habitat/ecosystem level (whenever possible) which are the ones considered in ATLAS, as for the deep sea it was agreed that, due to the difficulties in achieving a proper taxonomic classification of species the “species level” was not feasible.
In this deliverable, only the general aspects related to benthic habitats and ecosystems, and aspects of the initial evaluation specifically related to deep-sea benthic habitats, have been considered. Results are presented for each country and within each country for each descriptor. At the end of each Descriptor a blue box is included with the most significant results for this deliverable.

1.2.1 Main results of the MSFD initial evaluation from France

Descriptor 1

Important gaps were identified in basic knowledge at habitat level as well as regarding the sensitivity in front of anthropogenic pressures. Cartography for some areas is available but frequently based on old data. Physical pressures were identified in many cases but the distribution, intensity and frequency of these pressures needs to be explored.

A high variability in the level of information available was identified, depending on the species and habitats considered. Regarding the habitat level (which is the one considered in this deliverable), indicators (see Table 1 in **Annex I** for list of indicators of the MSFD) 1.4.2, 1.5.1, 1.6.1, 1.6.2, 1.6.3 were considered suitable whereas it was unclear how suitable indicator 1.4.1 (distribution area for the habitats) as well as 1.5.2 (habitat volume) are.
For the IE an integration of indicators for D1 and D6 was performed (this will be later reflected in the new criteria published in May 2017 by the EC, merging D1 and D6 for the benthic realm).
The indicators 6.2.1 and 6.2.2 (presence of species specially sensitive or tolerant and multimetric indexes to evaluate the functionality of the benthic community as well as the diversity and species richness and the proportion of opportunistic species *vs* sensitive species) were evaluated but the imprecision defining these indicators (e.g. what is sensitive or tolerant? To which stressors?) and the level of information available at the time of the IE prevent these indicators from being addressed.
Indicators 6.2.3 and 6.2.4 were also analysed (biomass proportion or number of individuals of the macrobenthic populations under a specific size and parameters describing the features of the size spectrum of the benthic community). These two indicators were not considered useful for D1 but potentially useful for D6.
The need for the development of methodology protocols and standardization was highlighted.

Considering the available information and the definition of D1 from the MSFD, 7 main criteria have been defined to support the GES assessments/definition, defining for each the parameters/index to measure the evaluation unit and what is GES for each criteria. As these are some of the main outputs of the IE for D1 in France, the criteria selected regarding the habitat and ecosystem level are the following:

Habitat
Criteria 1.4: Habitat distribution
Criteria 1.5: Habitat dimensions
Criteria 1.6: Habitat status

Ecosystem
Criteria 1.7: Ecosystem structure
More details can be found in the IE document from France.

At the time of the initial evaluation, quantitative evaluation was not considered possible due to the lack and fragmentary knowledge. The same was concluded regarding the risks and pressures. Lack of taxonomists has been identified as one of the main problems in assessing biodiversity

Descriptor 3

Considering the need to have reference values to assess GES, only the indicators 3.1.1 and 3.2.1 (Table 1 in **Annex I**) could be addressed. For the remaining indicators this would be possible only after analyzing the indicators across time. Until the reference points have been defined (at international level), it will be not feasible to address the evolution of the indicators.

For D3 it was considered that the most useful concept is fish stock instead of species. The evaluation can be done at "stock scale" (this does not necessarily correspond to the sub-regional scale) and GES will be assesed, as the MSFD demands, at the sub-regional scale.

The first criteria used by the MSFD to define GES is based on fish mortality due to fisheries, which is a variable of pressure, whereas stage variables should also be taken into account. The definition of thresholds is fundamental to be able to evaluate tendencies and stages. Thresholds for stocks also need to take into account other aspects, as for instance the biomass changes of their predators.

The main knowledge gaps highlighted were: (1) the need to validate and harmonise the criteria to select stocks, (2) assure the availability of indexes to estimate qualitative indicators and (3) estimate thresholds.

It was considered that until a reference point has been defined (at international level) it will be impossible to address the evolution of the indicators. D3 should be evaluated at stock scale. There is a need to validate and harmonise the criteria to select stocks, as well as to assure the availability of indexes to estimate qualitative indicators and set up/estimate thresholds

Descriptor 6

The main characteristic to define the benthic "compartments" was based on the granulometry of the substrate and luminosity. GES should be addressed for each sub region (following the MSFD), but evaluation scale will be different for the different indicators.

The information regarding the description of the biological impacts and pressure sources (here we mention only those related to the deep areas) are: (1) potential deployment of sediments obtained from dredging in a specific area, litter/chemical products and (2) trawling.

Difficulties in defining a reference stage for D6 were also highlighted. Coverage values for biogenic habitats (known for some specific habitats, in the case of the deep sea mostly for cold-water corals (CWC) habitats) were suggested as a measure for indicator 6.1.1. Related to the definition of the state for the benthic community (6.2), the initial evaluation refers to the work developed for indicators for other descriptors (D1, D2 and D4), adapting those to the habitats considered in the evaluation of D1, D2 and D4.

No direct evaluation of GES for D6 has been included. Instead more reference is made to the work developed for indicators for descriptors D1, D2 and D4, adapting those to the habitats considered in the evaluation of D1, D2 and D4.

Descriptor 10

The definition of GES for D10 was considered difficult, as it integrates many different factors. Few common metrics exist and to define GES for this descriptor many aspects should be considered (e.g. source, type of litter, distribution, transport and effects). The local evaluation should be also considered (not only sub-regional) in order to address local peculiarities and develop proper monitoring measures. Priority areas should be also defined, considering the level of current knowledge.

It was considered difficult to define GES as it integrates many different factors and many aspects should be considered. Local evaluation should be carried out and priority areas should be defined.

1.2.2 Main results of the MSFD initial evaluation from Ireland

The initial evaluation carried out by Ireland used as data sources information produced within the projects MESH, INSS and INFORMAR.

Descriptor 1

At the time of the IE, the status of the benthic communities in shallow and shelf subtidal areas was evaluated as spatially and temporally variable. However, the extent of biological variability associated with these communities was not determined and it was therefore not possible to make an assessment of the current status or condition of shallow and shelf predominant habitat types. Regarding the deep-water habitats (greater than 200m), these habitats extend over large latitudinal ranges in Ireland's assessment area. For the purpose of the IE report, they comprise the continental upper slope, bathyal and abyssal habitats. The distribution and composition of these habitats are not well characterised because of their depth, remoteness and considerable extent. Consequently, at the time of the IE the current status/condition (GES) could not be assessed.

The IE from Ireland includes a section with the "OSPAR threatened and declining habitats". Among those, the carbonate mounds are included briefly and highlighted here as they are relevant deep-sea features.

Carbonate Mounds

Giant mounds have been documented in the Porcupine Seabight between 700 and 1,200 m depth. Mound clusters are known to be present along the fringes of the upper continental slope of the Rockall Trough and Porcupine Seabight. The main mound building coral in the Irish Assessment Area is *Lophelia pertusa* with lesser amounts of *Madrepora oculata*. The carbonate mound structures have a high degree of complexity supporting over 2,800 species, forming patches of high biodiversity in a low diversity deep-water environment. Fishing activity in the area associated with carbonate mounds is moderate compared to the rest of the assessment area. The effect of bottom trawling gear on carbonate mound communities depends on the morphology of the mound and the frequency of disturbance, but sustained fishing pressure will have a severe impact on the habitat. Carbonate mounds are sensitive to abrasion and may take hundreds to thousands of years to recover from trawling, or there may be no recovery at all. However, due to their depth and remoteness, carbonate mounds of the Irish Assessment Area are not well characterised and it is therefore not possible to make an assessment of the current status or condition of these habitats (GES).

The distribution and composition of deep-sea habitats were not well characterised because of their depth, remoteness and considerable extent; consequently GES could not be assessed.

Descriptor 3

ICES carry out assessments of the status of commercially exploited fish and shellfish stocks within defined fishery management areas. The Irish Groundfish Survey (IGFS), which is part of the

international bottom trawl survey, monitors both commercially and non-commercially exploited species and provides data for the ICES assessments. The IGFS in its current form commenced in 2005 and covers two survey areas (ICES Area VI and VII). The reporting period used for the IE corresponds to the time series of current monitoring (2005-2012). The Irish Deep-water Survey (IDS) was conducted between 2006 and 2009 and monitored shelf edge, slope and deep-water fish off the northwest and west coasts.
Using IGFS and IDS data, direct assessments of the status of fish species distribution, population size and population condition in the context of GES targets were not possible due to short time series data. The short time series did not cover a reference period at which the fish community was exploited at a sustainable level, preventing the setting of meaningful GES targets and thresholds. Instead, significant increasing or decreasing trends were determined using the methodology described in Trenkel and Rochet (2009).
For commercial species, ICES assessments and advice were used to assess trends in population abundance and fishing pressures under D3. Whenever it was possible, ICES assessments were aligned with GES. The IDS data at the time of the IE for deep-water species did not cover a sufficient period to allow trends in population attributes to be determined with confidence. Instead, IDS data supplemented by ICES assessments were used to provide descriptions of trends in population abundance. For more detailed information on the species stock selected (in the case of the commercial ones) as well as the non-commercial, please check the IE document from Ireland. A brief summary on demersal skates and rays as well as on the deep-sea species is presented below.

18 species of demersal skates and rays are known to occur in Irish waters, alongside 12 species of demersal and pelagic sharks (ICES 2012). An additional 27 species of deep-water sharks, skates and rays have been reported from surveys in Irish waters (Ebert and Stehmann 2013), although this is probably an underestimation of the true number. The status of many elasmobranches' species in the northeast Atlantic is a major concern with 11 resident species included on OSPAR's list of Threatened and Declining Species (OSPAR 2008). IGFS data and ICES assessments suggest that the lesser spotted dogfish has been increasing steadily in abundance from 2005 to 2012 and throughout the survey area. Population condition showed no significant trends. Biomass and fishing mortality of spurdog is assessed at a commercial stock level. Based on IGFS catches, its distribution and condition has been stable throughout the data time period. For thornback ray and cuckoo ray IGFS data indicate that distributional range and pattern and population condition are stable since 2005. ICES trend analysis of population size suggests the status of thornback ray is improving while that of the cuckoo ray is deteriorating.

Ireland's deep-water seabed features, including banks, seamounts and carbonate mounds, attract diverse fish communities. Due to their low reproductive rates and longevity, many deep-water fish species are very vulnerable to overfishing and past high levels of exploitation have led to the depletion of many populations. Current species reporting focused on five teleost (bony fish) and two elasmobranch fish species. Teleost species include orange roughy (*Hoplostethus atlanticus*), black scabbard (*Aphanopus carbo*), roundnose grenadier (*Coryphaenoides rupestris*), blue ling (*Molva dypterygia*) and greater forkbeard (*Phycis blennoides*). Elasmobranch species include leafscale gulper shark and Portuguese dogfish. No trends in distributional range and patterns, or population condition could be reported due to restrictively short time series data. Instead, descriptions of species population attributes are based on four years of deep-water survey data (2006 to 2009) supplemented by recent ICES assessments. ICES quantitative measures of population size suggest that the status is good for black scabbard and roundnose grenadier. The status of orange roughy, blue ling and greater forkbeard is not known, but ICES qualitative evaluation conducted at the time of the IE suggested that the population size of blue ling is increasing. Leafscale gulper sharks and Portuguese dogfish are slow-growing species, which are particularly vulnerable to overfishing. ICES evaluations suggested biomass levels of both species are depleted.

The short time series did not cover a reference period at which the fish community was exploited at a sustainable level, preventing the setting of meaningful GES targets and thresholds.
For deep-sea species different trends have been observed in the four years' survey data supplied by ICES.

Descriptor 6

There is insufficient data on the status and condition of seabed habitats and their associated communities in the Irish assessment area to evaluate quantitatively the impact from fishing. However, in the IE report results are included of an evaluation of the spatial overlap of bottom contacting fishing activity by vessels greater than 15 m in length with different predominant habitat types. The IE also included a discussion on the potential impacts of bottom fishing on seabed habitats.

There is insufficient data on the status and condition of seabed habitats and their associated communities in the Irish Assessment Area to evaluate quantitatively the impact from fishing.

Descriptor 10

Based on the recovery of litter items from the IGFS, combining data for two years (2010 and 2011), the average seabed litter density by weight is 0.99 kg km^{-2}, of which the primary materials (in descending order by weight) were plastic, wood, metal and paper. Abundance and distribution of marine litter on the seabed exhibits considerable spatial variability. Whether taken separately or combined, the 2010 and 2011 surveys indicated areas of possible increased accumulation, or "litter hotspots", in particular in the southeast, where possible density hotspots were observed. Areas of increased litter density were observed to the north and north-west of Ireland in the IGFS 2011 survey, with a single haul consisting of 27.55 kg of plastic.

At the time of the IE, the relationship between the types and amounts of marine litter in the environment and the degree of harm caused to marine habitats, communities or populations was not fully understood and an assessment of current status of the pressure could not be undertaken

1.2.3 Main results of the MSFD Initial evaluation from Açores (Portugal)

Descriptor 1

The IE document prepared by Açores included a comprehensive list of benthic habitats, including the deep-sea. For the deep-sea habitats, seven biotopes were characterized: 4 coral gardens, 2 sponge aggregations and another including a mixture of different biotopes. Very comprehensive and detailed information on the deep-sea benthic habitats identified is included in the IE document, but it was not possible to conduct an evaluation for benthic habitats.

An evaluation for GES for benthic habitats was not possible due to the lack of quantitative information to address the indicators for D1.

Descriptor 3

Azores fisheries are multispecific, hence it is difficult to analyse data at the level of "stock" (they are scarce for the Azores). Further, the management units for stocks are not defined and in many cases, stocks are distributed in different habitats and outside the Azores EEZ. Furthermore, the interaction between Azores fisheries and international fisheries is unknown. Considering the temporal dimension, some data series are available, but only for short periods and provided from research cruises whose methods are not suitable to calculate abundances. The limited data availability and liability of the existing data, and also the lack of details given by the EC (whether to approach the combination of different indicators in the evaluation per stock or for the pool of the species) made it difficult to assess GES at the level expected by the EC. To assess GES, the most important commercial species were selected, of which 7 are demersal (or bentho-pelagic in some cases) species that also inhabit deep areas: *Pagellus bogaraveo, Polyprion americanus, Conger conger, Helicolenus dactylopterus, Phycis phycis, Beryx decadactylus, Pagrus pagrus, Beryx splendens*. For the period analysed, each species is considered to be in GES.

The quantity and liability of the existing data and the lack of details given by the EC in how to approach the combination of different indicators in the evaluation per stock or for the pool of the species made it difficult to assess GES at the level expected by the EC

Descriptor 6

The Azores IE highlighted the difficulties in evaluating this descriptor due to the large diversity of benthic habitats and the limitations on available mapping as well as on the characterization of substrate type and associated biotopes. Further difficulties in evaluating the assessment of the current impacts have been also stressed in the report. This also highlighted that the descriptions included in the IE on the benthic biotopes are based on studies in specific areas and most of these have been performed only in the last two decades (the report is dated 2014). Further, no mapping is available for the distribution of these habitats. Habitats below 800 meters are considered pristine in Azores. To evaluate GES in the seafloor requires time series (not currently available) on the composition and structure of the benthic communities, mapping of the habitats as well as information on the functionality and vulnerability of the structuring species in front of the anthropogenic activities. Consequently, due to the lack of available information, the decision was taken to focus the IE on the habitats identified by OSPAR as endangered or in decline. Criteria 6.1 (indicators 1 ad 2) and 6.2 were addressed (indicator 1). From the deep benthic habitats, cold-water corals (CWCs) and hydrothermal vents were evaluated.

For CWC, the evaluation shows that GES can be considered as achieved, considering the current available information as well as the overlapping the distribution maps of CWC reefs and coral gardens (see **figure 2**).
For the hydrothermal vents, the evaluation shows that GES can be considered as achieved, considering the current available information as well as the overlapping the distribution maps of

these ecosystems and the scientific activity (which seems to be the single one affecting these ecosystems).

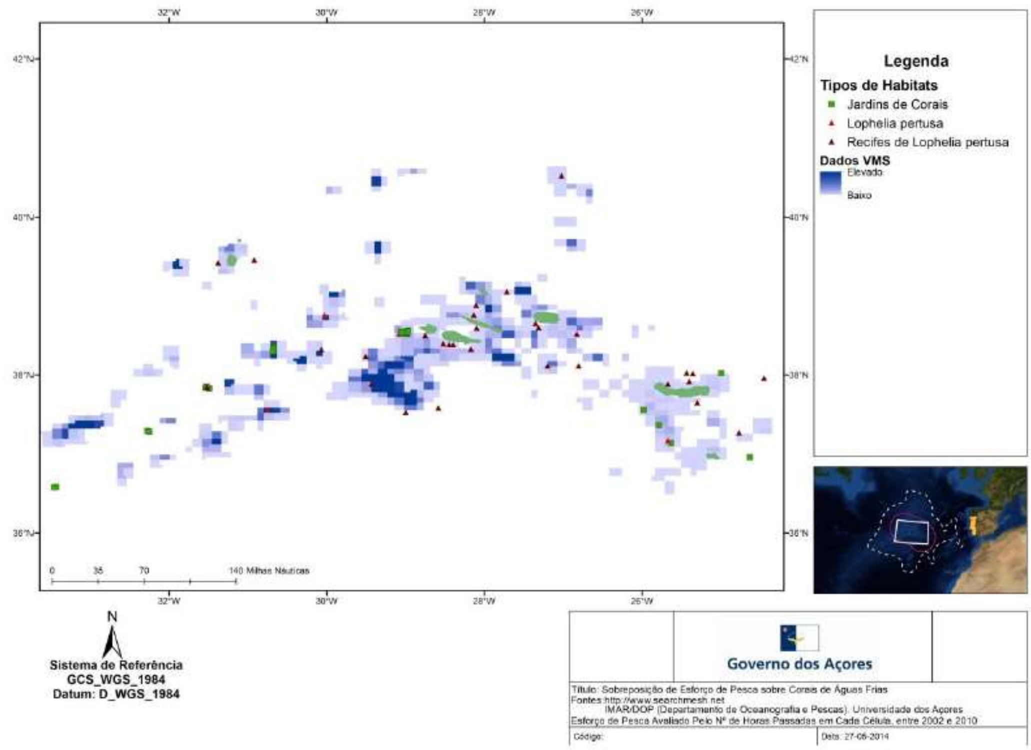

Fig. 2 *overlapping of coral gardens and Lophelia pertusa reefs and VMS data for the Azores (source report Initial Evaluation Açores).*

Due to the lack of data for most benthic habitats in Azores, the IE focused on the coral gardens and CWC reefs as well as hydrothermal vents. In both cases GES was considered to be achieved.

Descriptor 10

To evaluate GES for D10 in the IE, the following criteria were selected: 1) Litter characteristics and 2) litter impact in marine life. For litter characteristics: indicators on (1) quantity, composition, spatial distribution and whenever possible origin were considered and a specific indicator for microparticles (mostly microplastics) was selected. For litter impact, the selected indicator was litter ingested by organisms. However, at the time when the IE was presented, evaluation was not possible due to the lack of information on those indicators.

For the IE, indicators to address D10 were selected, however the lack of information on these prevented evaluation of GES for this descriptor.

1.2.4 Main results of the MSFD initial evaluation from Gibraltar Strait-Alborán Sea and Gulf of Cádiz (Spain)

These two areas (Gibraltar Strait-Alborán Sea and Gulf of Cádiz) were evaluated separately as they belong to different demarcations. Therefore, results of the IE are presented for each demarcation, 1.2.4.1 and 1.2.4.2 respectively for Gibraltar Strait-Alborán Sea and Gulf of Cádiz.

1.2.4.1 Gibraltar Strait and Alborán Sea

Descriptor 1

At species level there was relevant information available for some groups from (for instance) long-term data series, whereas from other groups the information was more scattered and unequal through time or space. For this reason, in general the GES approach was more qualitative even if for some specific cases it was possible to quantify some aspects.
At the habitat level, for most habitats there was no information available on distribution, extension and status. The degree of knowledge of these habitats in past times was even more limited. Consequently it was not possible to establish any reference value to compare with the current situation. A reference level could be established for well-preserved areas (with low anthropogenic influence/impact). However this information was not available for all habitats and it is representative only for some locations but never for the whole demarcation[4]. Therefore, the spatial and temporal handicaps as well as methodological constraints did not allow definition of GES for the Strait of Gibraltar-Alborán zone in a quantitative way. Consequently the definition of GES cannot refer to a baseline established, but to a positive/negative/stable tendency with respect to a "reference level", since in most cases it is impossible to reach the reference level due for instance to an irreversible loss of habitat, high costs, large temporal scale to reach recovering processes etc.. Moreover, the concept of GES should take into account the sustainable use of marine resources at a level where human activities are compatible with the conservation of marine ecosystems (including species and habitats) in agreement with the ecosystem approach. Therefore, GES is not synonymous with "reference level" (in the cases where it was possible to fix it) and must take other factors into account .

Species level[5]

Demersal fish and elasmobranchs and mobile invertebrates (crustaceans and cephalopods)
For this group of echotypes there was more data availability and long-term data series. GES was assessed in a quantitative way. However the GES definitions for the different groups can be modified in the future considering: (1) a potential increase in knowledge of the studies species, 2) advances in the study and definition of the reference levels conducted by international groups (OSPAR, EU), 3) a deeper knowledge on the relations pressures-state and their interaction with the human activities.
The necessary conditions to reach GES in this initial evaluation were:
At community level, and for the three cases mentioned above, a percentage of species, based in the binomial distribution, should fulfil this individual criterion to ensure that the results obtained are not due to natural variability. Further, the 95% percentile for fish size distribution (estimate of indicator 1.3.1, Table 1 in **Annex I**) is maintained or increased with respect to the values detected in the initial evaluation.

Habitat level

[4] Demarcation is the spatial unit used in the IE for the MSFD in Spain. These units are smaller than the sub-regions defined by the MSFD and they have been determined in the Spanish legislation related to the MSFD (Ley 41/2010, de 29 de diciembre, de protección del medio marino).
[5] Species level is considered here as in the IE from Spain commercial species have been also included in D1, not only in D3.

Considering the habitat level, the distribution (criteria 1.4 Table 1 in **Annex I**) and extension (criteria 1.5, Table 1 in **Annex I**) of protected habitats is maintained or increased. The dominant habitats present distribution and extension values that guarantee their conservation.

- The status of the habitats, evaluated considering the status of the species and typical communities is maintained within the values that guarantee their perpetuation, functioning, maintenance of characteristic and key species
- Regarding the descriptors of habitat condition for rocky habitats, GES is defined as the situation where the values for the different descriptors/indicators of condition or status of the rocky habitat analysed did not significantly deviate from the values in similar rocky habitats unaffected by any anthropogenic influence. The GES determination and capacity to reach this status mean that studies to establish the reference levels for each descriptor and in each area of the demarcation (sub region) for each typology need to be carried out.

Ecosystem level

At ecosystem level it is considered that GES is achieved when:

- The marine ecosystems maintain a structure and functionality in agreement with the physiographic, geographic and climate situation of the area, in which the species and habitat diversity is maintained, as well as the complexity of the trophic relations. Human pressures do not condition the ecosystems maintenance, and its continuity is guaranteed through the sustainable use of goods and services.
- The value of the "maximal average size" for the more relevant demersal fish and invertebrates, as an indicator of the status of the demersal ecosystems, is maintained or increased according to the values detected in this initial evaluation.
- The indicator "conservation status of fish" (CSFa), as an integrative tool of the analyses of the conservation stage of the ecosystems, is maintained or decreased according to the values detected in the initial evaluation and is always under "1". In the same way, the indicator "fish conservation status" (CSFb) stayed stable or increased which implies that the proportion of large individuals of the species vulnerable to fishing activities remains stable or is even recovering.

Lack of data for many areas of the demarcation as well as lack of long-term data series for most species/habitats/ecosystems did not allow GES for the Strait of Gibraltar-Alborán zone to be defined quantitatively. Therefore the definition of GES should not be the reference level established, but a positive tendency to a "reference level" or stability, as in most cases it is impossible to reach the reference level due to e.g. the irreversible loss of habitat or large temporal scale for recovering processes.

Descriptor 3

Data to measure main and secondary indicators were available only for 15 species from which data for main indicators were available only for 7 species. Here we present a very short summary of the results of the IE. Data were evaluated for "Level of pressure of fishing activity" as well as "Reproductive capacity of the population" and "Population age and size distribution" (Criteria 3.1, 3.2 and 3.3, Table 1 in **Annex I**). The demersal species evaluated from which data were available were the fish species *Merluccius merluccius* and *Mullus barbatus*, and the red shrimp *Aristeus antennatus*. For those species, considering the values of the historical series the values for D3 are relatively low, hence it is considered that these species are not in GES.

The analyses carried out for 15 commercial species (fish and crustaceans) revealed that GES was not achieved.

Descriptor 6

For most of the habitats there is currently not enough information on the habitat extension and/or status. The spatial and temporal constraints do not allow a quantitative approach to GES of the habitats in the IE. Therefore the definition of GES should not be the reference level established in the evaluation of the status, but a positive tendency to this level or stability, as in many cases it is impossible to reach the "reference level" (e.g. due to irreversible habitat loss, high social costs, long term recovery of ecosystems etc.). Further, GES should be also related to the sustainable use of the marine resources to a level where the human activities and maintenance of marine ecosystem conservation are compatible, in agreement with the ecosystem approach. Therefore, GES is not equivalent to the reference level and must take into account other factors. This can be summarized in the following:

- The distribution area of biogenic habitats and/or protected habitats maintaining positive or stable tendencies that guarantee their conservation (6.1.1, table 1 in **Annex I**)
- The adverse effects derived from human activities do not reach a spatial extension or intensity that compromise the maintenance of the benthic habitats
- The status of the benthic communities, evaluated in terms of biomass of the structuring species/s, richness/diversity or other related indicators, is maintained within the values that guarantee its survival and functionality as well as the maintenance of the associated key species (criteria 6.2, Table 1 in **Annex I**)

Lack of data for many areas of the demarcation as well as lack of long-term data series for most habitats/ecosystems did not allow definition of GES for the Strait of Gibraltar-Alborán zone quantitatively. Therefore the definition of GES should not be the reference level established, but a positive tendency to a "reference level" or stability, as in most cases it is impossible to reach the reference level due to e.g. the irreversible loss of habitat or large temporal scale for recovering processes.

Descriptor 10

In this initial evaluation it was suggested that GES be defined as the status where the quantity of marine litter (including its degradation products) in the coastal zones and in the marine environment decreases with time and is at levels which do not harm the marine and coastal environment. This GES definition for D10 is based in the discussions conducted within the OSPAR working group to coordinate the DMEDM (ICG-MSFD). The fact that it was not possible to define GES in a more specific way, stressed the need to investigate this descriptor more deeply. Specifically, in future it will be necessary to determine what quantities of litter produce harmful effects in the marine environment.

GES has been defined as the status where the quantity of marine litter (including its degradation products) in the coastal zones and in the marine environment decreases with time and is at levels which do not harm the marine and coastal environment.

1.2.4.2 Gulf of Cádiz (South Atlantic)

Descriptor 1

At species level there is relevant information available from, for instance, long-term data series whereas from other groups the information is more scattered and unequal through time or spatial extension. For this reason, in general the GES approach is more qualitative, even if for some specific cases it was possible to quantify some aspects. To define GES at species level, (see footnote page 18) a species classification has been performed, (following expert criteria) depending on the tendency showed by the specific resource (increasing or decreasing tendency), hence based on the evolution of the species in the historical series of data. Following this first classification, the following GES scenarios have been defined:

- Opportunistic species or r strategists with any pattern (increasing or decreasing) of biomass or abundance. For the abundances biomass/number, the Z value of the series should range from -1 to +1.
- Species potentially vulnerable, or k strategists (+age/-reproduction/+size)
- Decreasing tendency: for the estimation of abundance, Z should be ≥+0.5
- Stable or increasing in years immediately prior to the initial evaluation: biomass/abundance should be maintained stable or increase. Natural variability implies Z ≥-0.5

For the three cases mentioned above, a percentage of species, based in the binomial distribution, should fulfil these individual criteria to ensure that the results obtained are not due to natural variability.

Species level

Demersal fish and elasmobranchs and mobile invertebrates (crustaceans and cephalopods)

Please see Species level paragraphs in the previous section (1.2.4.1).

Habitat level

Please see Habitat level paragraphs in the previous section (1.2.4.1).

Ecosystem level

Please see Ecosystem level paragraphs in the previous section (1.2.4.1).

Lack of data for many areas of the demarcation as well as lack of long-term data series for most species/habitats/ecosystems did not permit definition of GES for the Strait of Gibraltar-Alborán zone in a quantitative way. Therefore the definition of GES should not be the reference level established, but a positive tendency to a "reference level" or stability, as in most cases it is impossible to reach the reference level due to e.g. the irreversible loss of habitat or large temporal scale for recovering processes

Descriptor 3

To assess GES for this descriptor, criteria and indicators have been aggregated. Numerical values for the status at the time of the initial evaluation were calculated for criteria 3.1 (level of pressure of the fisheries activity) and criteria 3.2 (reproductive capacity of the population). After these values a calculation for D3 in a scale of 0-1 was performed considering both criteria. Four different methodologies have been used to calculate this value, considering different elements: for the GES indicative values, the values of the last year were in all cases higher than the values considering as the current status (initial evaluation time) the average of the last three years. The value of the current status (time of the IE) as 0.67 (in a scale of 0-1), independently of the weight assigned to the criteria 3.1 and 3.2. The current state with the lower value (0.33) was observed when only the criterion 3.1 was considered and the current state as the average of the last three years. The current status (time of the IE) of D3 after the evaluated values from the historical series ranged (after calculation methodologies had been applied) between a minimum of 0.90 detected for the last year and weights of 0.67 and 0.33 for both criteria and the maximum (1.00) found in several cases. For these two calculation methods it was observed that an increase in the weight of criterion 2 yielded a lower value of the current status. Considering the uncertainty associated with the estimation of the reference values for Maximum Sustainable Yield (MSY) and the fact that most of the exploited fisheries in the Spanish South Atlantic sub-region have a multispecific nature, it was concluded appropriate to adopt the GES definition suggested in the initial evaluation document from Spain for this sub-region as it allows some flexibility around the cited reference values, considering those more as "target values" than as "limit/boundary values". On the other hand, it was considered that due to analytical reasons, the mortality due to fisheries is a more reliable indicator of the current status and a weight of 0.75 was assigned in front of the 0.25 assigned to the reproductive capacity of the population.

Following these considerations, the current status/value (time of the initial evaluation) of D3 in the Spanish South Atlantic sub-region regarding GES is 0.67, decreasing to 0.42 if referring to the current status (the 3 most recent years at the time of the initial evaluation). This seems to point towards a recovery of the pool of the analysed stocks with the main indicators in the last year. Nevertheless these relatively "optimistic" results should be treated with caution for the following reasons: (1) these results have been calculated based on a low number of stocks, some with scarce representation in the area, and (2) the estimation of the main indicators available for the area have been provided at "stock level" and it is not known if values of global estimations are different or not, compared with the values that can be reached at local or regional levels. The analysis of the tendencies of the historical series is not indicative of GES and they only suggest (for a larger number of species than the one considered under the GES concept) that the current and recent status of stocks and species are (considered as a pool) close to values of the average of the historical data series (values close to 1.00).

The status/value of D3 at the time of the IE in the Spanish South Atlantic sub-region was considered to be an "improving" situation regarding GES, pointing towards recovery of the pool of the stocks analysed. These results should be treated with caution due to the low number of stocks evaluated.

Descriptor 6

See results for this descriptor in the previous section (1.2.4.1).

Lack of data for many areas of the demarcation as well as lack of long-term data series for most habitats/ecosystems did not allow definition of GES for the Strait of Gibraltar-Alborán zone quantitatively. Therefore the definition of GES should not be the reference level established, but a positive tendency to a "reference level" or stability, as in most cases it is impossible to reach the reference level due to e.g. the irreversible loss of habitat or large temporal scale for recovering processes.

Descriptor 10

See results for this descriptor in the previous section (1.2.4.1).

GES has been defined as the status where the quantity of marine litter (including its degradation products) in the coastal zones and in the marine environment decreases with time and is at levels that do not harm the marine and coastal environment.

1.2.5. Main results of the MSFD Initial evaluation from United Kingdom

The UK characteristics of GES have been developed by policy makers in consultation with experts and key stakeholders. They provide a high-level, qualitative description of what the UK marine environment will look like when GES is achieved and cover all 11 Descriptors of GES included within the Directive.

UK targets and indicators of GES have been developed on the basis of scientific advice provided by Cefas, the JNCC and a large range of other experts, including those involved in the UK Marine Monitoring and Assessment Strategy. The GES targets and indicators build on the high-level characteristics described above, providing a more detailed and, where possible, quantitative assessment framework for measuring progress towards GES.

Descriptor 1, 4 and 6

Fish. All parts of the marine fish community have been impacted by human activities and improvements in key status indicators for fish communities on or close to the seabed and fish communities in estuaries need to be viewed in this context. Improvements have predominantly been in response to reductions in fishing pressure, but there is some way to go before the majority of commercial fish stocks are at safe levels. There are particular concerns over the status of threatened and vulnerable species such as sharks, skates and rays and deep-sea species, which are especially vulnerable to fishing pressure, as well as for diadromous fish species, that move between fresh water and salt water during their life cycle. There is a need for improved information on the causes of declines in diadromous fish species and highly migratory fish, such as oceanic sharks.

Seabed habitats. Impacts on seabed habitats are widespread and the composition of seabed habitats has been altered over large areas. In general, sediment habitats are more extensively degraded than rocky habitats. Subtidal habitats close to shore are generally impacted by a greater variety of pressures than habitats further offshore. The areas impacted by the greatest number of human activities, and associated pressures, are the Southern North Sea, the Western Channel/Celtic Sea and the Irish Sea. For most activities the intensity of pressures has been relatively stable over the past ten years; however, the distribution of some pressures may have changed.

D1, D3 All parts of the marine fish community have been impacted by human activities. There are particular concerns regarding sharks, skates, rays and diadromous fish species.

D 6 Impacts on seabed habitats are widespread and the composition of seabed habitats has been altered over large areas. Overall sedimentary habitats are more extensively degraded than rocky habitats.

The UK characteristics of GES for D1 are as follows: At the scale of the MSFD sub-regions, and in line with prevailing conditions, the loss of biodiversity has been halted and where practicable, restoration is underway. The abundance, distribution, extent and condition of species and habitats in UK waters are in line with prevailing environmental conditions as defined by specific targets for species and habitats. Marine ecosystems and their constituent species and habitats are not significantly impacted by human activities such that the specific structures and functions for their long-term maintenance exist for the foreseeable future. Habitats and species identified as requiring protection under existing national or international agreements are conserved effectively through appropriate national or regional mechanisms.

The UK characteristics of GES for D6 are as follows: Sea-floor habitats (physically and structurally) are both productive and sufficiently extensive at the level of the MSFD sub-regions, to carry out natural functionality, including the necessary ecological processes which underpin ecosystem goods and services, and are capable of supporting a healthy and sustainable ecosystem for the long term.

Approach to setting GES targets – habitats

The IE identifies significant problems for a number of seafloor habitats, particularly shallow and shelf subtidal sediments. GES targets and indicators have been developed for pelagic, sediment and rock & biogenic reef habitats covering D1, D4, and D6. These include targets and indicators for habitat distribution, habitat extent and habitat condition, as well as physical damage (to the seabed), and condition of the benthic community.

Seafloor habitats:

For rock and biogenic reef habitats the targets are all based on existing targets for these habitats under the Habitats Directive (HD). The aim here has been to ensure consistency with the requirements of the HD, which already provides protection for these the vast majority of rock and biogenic reef habitats. The targets require the distribution and extent of rock and biogenic reef habitats to be stable or increasing, using Favourable Reference Area under the HD as a baseline. They also require these habitats to be in good condition – not significantly impacted by human activities. For listed sediment habitats (i.e. those habitats covered by existing legislation) the targets are also based on existing requirements under the HD and the Water Framework Directive (WFD). However, a large proportion of sediment habitats are not protected by existing legislation. These are known as predominant sediment habitats and new targets have been developed to cover these habitats. The targets for these habitats have been particularly hard to develop because there is a significant lack of evidence and understanding on both current and desired state, meaning that it is not possible to set ecologically meaningful GES target thresholds. For this reason the targets for the condition of predominant sediment habitats are trend-based, pressure targets, requiring a reduction in damaging human impacts on these habitats. At the time of the IE, it was not possible to define the necessary level of reduction in impacts in quantitative terms, but further research will be carried out with the aim of setting specific, quantified targets for predominant sediment habitats as soon as possible in the future.

Implications of the targets – habitats

Seafloor habitats: For those rock & biogenic reef and sediment habitats that are covered by the HD it has been assumed that measures taken under that Directive will be sufficient to achieve GES, particularly through the implementation of the UK's network of Marine Protected Areas (MPAs). For those seafloor habitats not covered by the HD (primarily sediment habitats, but also some rock habitats), the UK's network of MPAs will play a key role in achieving the proposed targets, however additional measures may be needed to further reduce the key human pressures on these habitats. Fisheries impacts remain the most significant pressure on sediment habitats and where unacceptable impacts are identified it is likely that more significant fisheries management measures will be needed under the reformed CFP or national inshore measures in order to reduce these (e.g. additional controls on the use of mobile demersal gear, modification of gear which is most damaging to the seabed). MSFD monitoring for seafloor habitats will be closely linked to information requirements under the HD and evidence associated with commitments on MPAs.

Descriptor 3

There has been a substantial increase in the number of fish stocks that are harvested sustainably over the period 2000-2011. However, a significant proportion of indicator stocks (> 60%) continue to be harvested at rates that are unsustainable and/or have reduced reproductive capacity. Further reductions in fishing pressure on around half of stocks in UK waters would be needed to ensure levels expected to provide the highest long term yield. There is a lack of consistent and quality data for most shellfish species which means that robust stock assessment is not available at regional level.

The number of fish stocks that are harvested sustainably has substantial increase over the period 2000-2011. However, a significant proportion of indicator stocks (> 60%) continue to be harvested at rates that are unsustainable and/or have reduced reproductive capacity. Lack of quantitative data for shellfish species avoid to assess GES

GES targets for fish:

For fish, there are few targets in existing legislation which are suitable as indicators of fish biodiversity. For this reason most of the GES targets developed for fish are new. Targets have been developed in relation to fish abundance and distribution, and also in relation to the overall health of the fish community.

Targets for fish abundance and distribution: The species to be included in the assessment for these targets are chosen by identifying the 33 % most sensitive species caught in existing research surveys and then excluding any for which data is too poor to allow robust statistical analysis. Baselines will be set as the average value for each species throughout the entire time period.
Setting the targets in this way means that the rarest species (e.g. angel shark) will be excluded from the assessment of GES, but it is not considered possible to set appropriate, technically defined indicators and targets for these species due to the lack of survey data.
It is also acknowledged that these targets will not cover coastal, deep-sea or pelagic fish species due to the currently limited data availability. Data sets have been identified that cover deep water and coastal fish species, but they still do not provide comprehensive coverage of all areas and further work is needed to consider how these could be used for the purposes of MSFD assessment.

Targets for fish community length: These targets and associated indicators aim to assess the overall health of the fish community and are based on indicators developed within OSPAR for the North Sea. The targets look at the size structure of the fish community as a whole and measure the relative proportion (by weight) of large fish to small fish observed in a survey. The assessment covers most fish species caught by bottom-trawl research surveys, including both commercial and non-commercial species.
The baselines for these targets vary depending on the area being assessed and represent a time when the exploitation of the fish communities in that region was generally deemed to be at sustainable levels. No data are available to allow the development of baselines equivalent to periods when human activity was minimal.

Although, there has been a substantial increase in the number of fish stocks that are harvested sustainably over the period 2000 -2010, a significant proportion of indicator stocks (> 60%) continue to be harvested at rates that are unsustainable and/or have reduced reproductive capacity. Further reductions in fishing pressure on approximately half of stocks in UK waters would be needed to ensure levels expected to provide the highest long-term yield.

Descriptor 10

Levels of marine litter are considered problematic in all areas where there are systematic surveys of beached litter density. There has only been limited surveying of litter on the seabed and in the water column, which has demonstrated that litter tends to accumulate in certain areas as a result of wind and currents.

There has only been limited surveying of litter on the seabed.

Approach to setting GES targets for marine litter

Due to the limited understanding of the current levels, properties, and impacts of marine litter experts have been unable to propose quantitative targets indicating the point at which GES would be achieved i.e. a litter threshold. Instead, a trend-based target for litter on coastlines has been developed which requires an absolute reduction in visible litter items on coastlines within specific categories (e.g. plastics, fishing litter). The Commission Decision on GES covers a number of other aspects of litter, including litter on the seafloor and in the water column, microparticles, and the impacts of litter on marine life (through indicators of the amounts of litter ingested by key marine species). For these aspects of litter it is not considered possible to set specific targets at the time of the IE both due to uncertainties surrounding impacts and a current lack of data to set suitable baselines. For levels of litter items on the seafloor a surveillance indicator will be adopted in this initial MSFD management cycle. However, due to the persistent nature of most types of litter, this indicator is only likely to change very slowly in response to management measures. With regard to microparticles, expert opinion has indicated that our understanding of the nature of microparticles in the marine environment and their propensity to cause harm is too underdeveloped to establish a meaningful target or indicator at this point in time.

1.3 Some comments on the results of the IE by EU countries, aggregation of indicators and lack of harmonization

After the results of the IE were published, some scientific papers have been published comparing the different results of the IE among countries. One of these works, authored by Cavallo et al. (2016) concluded that, in general, the use of existing data, methodologies and targets from related environmental policies corresponds to the higher levels of coherence among countries while a limited use of such policies produces less coherence. This suggests that the European Commission, Regional Seas Conventions and Member States should work together to identify the connection between the MSFD and other existing policies to make a proper use of existing data and approaches and to harmonise different policy objectives. Cavallo et al. (2016) also mention as a weakness in the implementation of the MSFD that in some cases the work conducted by OSPAR and Common Implementation Strategy (CIS) Working Groups came too late (OSPAR published advice documents on descriptors of GES in 2012, while the GES Working Group prepared a document with a clearer indication on how to implement the three articles -8, 9 and 10- at the end of 2011). Cavallo et al. (2016) argued that these guidance documents may contribute to a more coordinated implementation of the MSFD during the second cycle, starting in 2018; as well as gaining coherence in the identification of a common list of marine species and habitats that have (sub)regional distribution (e.g. for highly mobile species). This could be a more extensive use of the work already carried out in the context of other directives, conventions and policies. Cavallo et al. (2016) suggested that Member States together with the Regional Seas Convention should identify those policies that better fit with each of the Descriptors and phases to harmonise results and avoid duplication as well as to identify if more research is needed to fill knowledge gaps. Some years later Cavallo et al. (2018) also examines the difficulties in assessing GES at subregional level, analysing the results of the IE from a specific region, which is under the jurisdiction of three different European countries: the Bay of Biscay and Iberian coast sub-region. The authors selected this specific area as it exhibited the lowest levels of coherence during the first phase of the implementation of the MSFD, according to the EC assessment. The results from Cavallo et al. (2018) show the differences among the programmes from the three countries. Although most of the measures developed in the sub-region address marine biodiversity, this occurred across a wide range of actions, covering different pressures and different species and/or habitats. The authors concluded that it is a better use of the regional and European coordination structures is needed to fill gaps in knowledge and to exchange good practices. A third work worthy of reference here, is the paper by Probst and Lynam (2016) who analysed some aspects regarding the results of the IE by the different EU countries and who summarized some of the existing proposals to aggregate indicators and harmonize aggregation methods. Already during the first stage of implementation of the MSFD there was likely a consensus that aggregation should occur in three steps (**Fig. 3**) across indicators within criteria, across criteria within descriptors and across descriptors (Cardoso et al. 2010, Claussen et al. 2011). Later, in 2017, a new commission decision was published (Comission Decision (EU) 2017/848) where the need to reduce the number of criteria that member states need to monitor and assess was included (in order to facilitate future updates of the initial assessment of member states's marine waters and their determination of GES). Further, in the same decision the need to apply a risk-based approach was mentioned, focusing the efforts on the man anthropogenic pressures affecting their waters. Criteria and their application should be specified providing also threshold values or the setting thereof to allow measure GES across the European Union's marine waters. At the European level, the adoption of the MSFD aims to promote coordination among countries and an integrated management of the marine environment. The MSFD requires each country to propose and adopt a programme of measures to achieve GES of the regional seas.

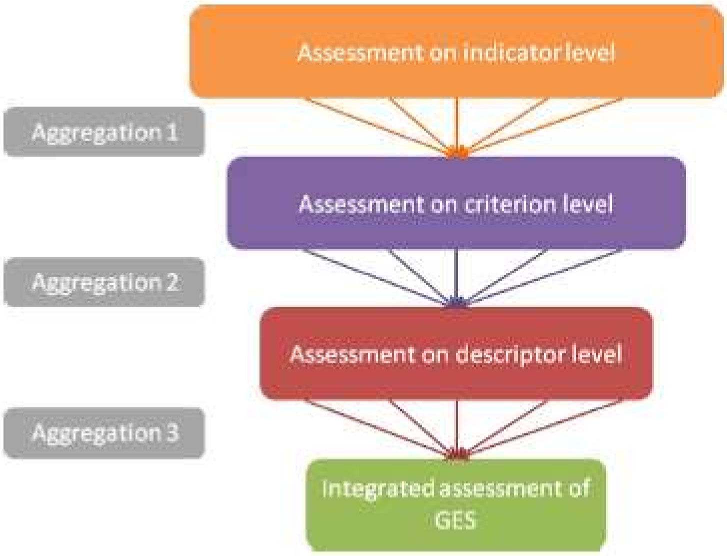

***Fig. 3** Proposed aggregation levels after Claussen et al. 2011 (source Probst et al. 2016).*

2 Assessing GES in benthic ecosystems

In the coming sections an overview on GES assessment, the existing approaches, main documents and reports from ICES and OSPAR as well as scientific papers is presented, as we consider this important background information for this deliverable. **It is worth considering that most of these documents do not specifically refer to the deep sea but to benthic habitats.** This section focuses on the four Descriptors treated within ATLAS (D1, D3, D6 and D 10).

2.1 Work on GES conducted by ICES and JRC

In the next paragraphs a summary on the work developed by the International Council for the Exploration of the Sea (ICES) and the Joint Research Centre (JRC) within the frame of the MSFD regarding the descriptors consider in ATLAS is presented. It is worth highlighting a recent paper by Ballesteros et al. (2018) where the authors discussed the role of ICES advising the MSFD. Indeed, concerning the EU, ICES occupies a central role by providing scientific advice primarily to the Common Fisheries Policy (CFP) through the Commission/DG MARE, which has the power to initiate fisheries policies, propose new legislation to be considered by decision-makers, implement decisions, oversee member states' (MS) implementation, etc. In addition, ICES provides advice to DG-ENV and EU MS regarding the MSFD.

The ICES scientific community and associated partners have worked towards providing scientific guidance to define GES indicators and standards. ICES and the JRC have established Task Groups for each of the qualitative Descriptors with the aim of developing criteria and methodological standards for each. A Management Group has been established to provide information on a number of issues that are common to all of the Descriptors (cf. Cardoso et al. 2010). More recently, ICES suggested some revisions to the MSFD to consider humans impacts on the functioning of ecosystems (ICES

2015). The OSPAR Commission has also worked on developing methodologies and guidelines relevant to determining GES (see next section), in particularly for the descriptors D1, D4, D5, D7, D10 and D11 and more recently D6.

Here we summarised main out comes from the ICES working groups for D1, D6, D3 and D10. Whenever possible the summary here presented will be focused in benthic habitats (including the demersal commercial and non-commercial species). Beside these groups specifically dealing with the above-mentioned descriptors, the ICES WG in Deep-water ecosystems included in 2017 a Term of Reference (ToR) on how to assess GES in the Deep-Sea. As this ToR has been included as part of the work of ATLAS, the discussion on this issue will be presented in section 3.1 of this document. Information is presented for each descriptor.

Descriptor 1

Marine Strategy Framework Directive. Task Group 1 Report. Descriptor 1, Biological Diversity. Cochrane et al. (2010)

The report from Cochrane et al. (2010) redefine GES for D1 as following: "GES for D 1 will be achieved given no further loss of the diversity of genes, species and habitats/communities at ecologically relevant scales and when deteriorated components, where intrinsic environmental conditions allow, are restored to target levels".

The issue on temporal and spatial scales for GES assessment has been addressed by Cochrane et al. (2010). Following the MSFD, GES is assessed at the scale of Region (for the Baltic Sea and Black Sea) or the Subregions defined for the Atlantic and Mediterranean Seas.

Following Cochrane et al. (2010) a suitable set of ecological assessment areas should be defined, which can adequately reflect both the ecological scales exhibited by the biodiversity components in each region/subregion and link to areas which are effective for management measures. GES shall be assessed every six years. Further, they recommend:

- Evidence used for the six-yearly GES assessments is updated before conducting these
- Periodicity of evidence collection is determined according to changing conditions
- Sufficient periodicity of evidence collection to distinguish anthropogenic impacts from natural/climatic variability, and to determine progress against the Programme of Measures
- Targets for GES take into account natural and climatic variability in biodiversity

Considering the levels of ecological organization for assessment, Cochrane et al. (2010) recommended:

- Species state (including intra-specific variation, where appropriate)
- Habitat/community state
- Landscape state
- Ecosystem state

Considering the biodiversity components, Cochrane et al. (2010) recommends appropriate treatment of the biodiversity components:

- The predominant seabed and water column types

- Special habitat types (under Community legislation or international conventions)
- Habitats in particular areas (e.g. in pressured or protected areas)
- Biological communities associated with the predominant seabed and water column habitats
- Fish, marine mammals, reptiles, birds
- Other species (under Community legislation or international conventions)
- Non-indigenous, exotic species and genetically distinct forms of native species

A pragmatic, risk-based selection of biodiversity components is recommended. This could use surrogates or proxies to assess the state of biodiversity of the region/sub region for:

- The predominant habitat/community types
- The ecotypes of the groups of mobile species
- The species and habitats listed under Community legislation and international conventions

Considering the predominant habitats types, based on the EUNIS habitat classification system, Cochrane et al. (2010) suggest that the following broad ecological zones, where relevant to the region/sub region, have to be considered:

- Seabed habitats in intertidal, coastal, shelf and deep-sea zones
- Water-column habitats in coastal, shelf and open sea zones
- Sea-ice habitats

Regarding deep-sea (including shelf areas, only benthic habitats related to the ATLAS case studies/deep sea are included here), the predominant habitat types listed by Cochrane et al. (2010) are:

- Seabed habitats
- Shelf sublittoral rock and biogenic reef
- Shelf sublittoral sediment
- Bathyal rock and biogenic reef
- Bathyal sediment
- Abyssal rock and biogenic reef
- Abyssal sediment
- Ice habitats Ice-associated habitats

In addition to species closely associated with specific habitat types (see above), some species of fish, are wide-ranging and associated with several habitats during their life cycle. These are provisionally listed as:

- Demersal fish
- Elasmobranchs
- Deep-sea fish
- Ice-associated fish

Several criteria to assess the relevant attributes and components of biological diversity have been suggested by Cochrane et al. (2010) (see Table 4 in Cochrane et al. 2010).

Cochrane et al. (2010) argued that because the different elements of biological diversity may not respond to pressures in a similar manner, or at similar rates, the results of assessments for individual biodiversity components cannot be integrated into a single assessment for D 1. Each shall be assessed on its own merit relative to GES (GES or sub-GES conditions). Where sub-GES conditions are recorded for one or more indicators, the likely causes should be identified, and appropriate remedial actions identified and implemented within the Programme of Measures.

In the Cochrane et al. (2010) report, monitoring and research needs are also highlighted. Among those for the development of an assessment and monitoring programme, a pragmatic risk-based and synergistic approach is recommended and the following main questions are proposed:

- What is the current state of biological diversity?
- What is the deviation between observed and target conditions?
- What is the direction of deviation from target conditions, and the speed of change?
- What are the causes of observed changes in biological diversity?

Descriptor 3

Report of the Workshop on guidance for the review of MSFD decision Descriptor 3, Commercial fish and shellfish II (WKGMSFDD3-II) 2015[6]

The ICES report WKGMSFDD3-II from 2015 was an important addition to revisit D3. GES for D3 – Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock. The assessment of the GES status for D3 is based on three criteria: (3.1) exploited sustainably consistent with high long-term yields, (3.2) have full reproductive capacity and (3.3) exhibit a population age and size distribution that is indicative of a healthy stock.

WKGMSFDD3-II focuses on the clarification of scientific challenges for D3 to make the revision of the Decision process more understandable. The text for the criterion 3.2 “reproductive capacity” was consolidated and the criterion 3.3 “Healthy age and size structure” was revised and a roadmap for further development of this criterion was designed.

The consolidation of the 3.2 criteria was based in the current interpretation based on the GES for D3 definition (above) and the aim of the Common Fisheries Policy (CFP) to ’restore and maintain populations of harvested species above levels which can produce maximum sustainable yield’. In order to fulfil the GES criterion 3.2 for stocks for which ICES advice is used as the basis for the assessment of GES, the recommendation is that Spawning Stock Biomass (SSB) I higher than Maximum Sustainable Yield (SSB≥MSY $B_{trigger}$) where MSY $B_{trigger}$ marks the lowest boundary associated with SSB MSY.

Updated estimates of both reference levels for criteria 3.1 and 3.2 put forward by the regional authoritative scientific institutions will be periodically adopted for the assessment against GES.

---

[6] There are two previous ICES reports from 2014 revising D3 (“Report of the Workshop to draft recommendations for the assessment of Descriptor 3 (WKD3R) 2014a and b”)

For criterion 3.3 a suite of candidate indicators that include three relevant properties representing the state and pressure process have been identified following the suggestion from the cross-cutting issues workshop outcomes: (1) Size distribution of the species (state), (2) selectivity pattern of the fishery exploiting the species (pressure) and (3) genetic effects of exploitation on the species (state). The roadmap proposed for the further development of criterion 3.3 involves two separate steps:

1) Indicator evaluation and selection against ICES criteria and across stocks from different functional groups and areas with the aim of selecting one validated indicator per property.

2) Assessment against GES. Primary indicators will be processed similar to those in criteria 3.1 and 3.2 where the knowledge of the characteristics of the indicator and its reference level at the single-species level should allow the identification of the requirements for GES. Similarly, secondary indicators will be processed involving some trend analysis where current state is compared to historic conditions.

Only those indicators that passed the previous step can be considered for assessment against GES where we distinguish between the primary and secondary indicators.

The DG ENV cross-cutting workshop outcomes suggest distinguishing between state-based descriptors and pressure-based descriptors. D3 represents both these aspects. Criterion 3.1 clearly represents pressure while criterion 3.2 and criterion 3.3 as it was initially defined representing state. As the criterion 3.3. is currently developing, the D3 will represent both state and pressure more comprehensively in that two aspects of pressure are described, i.e. fishing mortality and the size-selectivity of the exploitation, and two aspects of state, i.e. biomass and the age- and size distribution.

EU request on revisions to Marine Strategy Framework Directive manuals for Descriptors 3, 4, and 6

In March 2015 a special request from the EC was published regarding D3, D4 and D6, asking for a revision of the previous ICES documents and reports on these descriptors. As a result, several issues regarding those descriptors have been highlighted by ICES considering gaps and needs in the assessment of those indicators.

EU request to provide guidance on the practical methodology for delivering an MSFD GES assessment on D3 for an MSFD region/subregion

In May 2016 a further special request from the EC was published regarding D3 and the Northeast Atlantic ecoregion: "*Guidance on the practical methodology for delivering an MSFD GES assessment on D3 for an MSFD region/subregion, including what should be considered a commercial fish and shellfish, how to treat wide ranging stocks, how to account for multiple stocks in one area?"*
In this advice, the steps to assess GES for stocks (see **figure 4**), as well as for regions and subregions (see **figure 5**) is given. ICES advises that GES is assessed at the unit of stock rather than species in a region. The rationale is that the assessment unit is the stock. Stocks can be combined as spatial components if necessary.

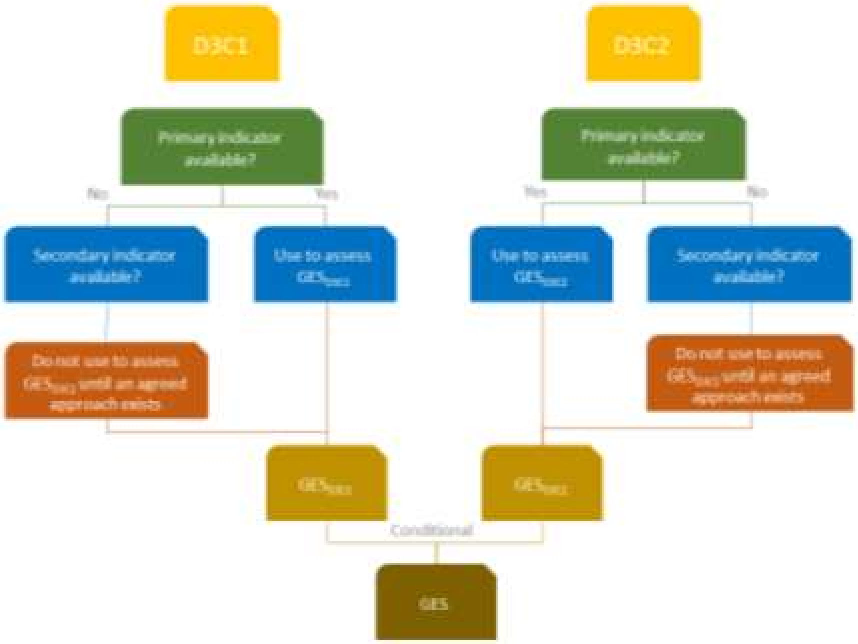

***Fig. 4** Flowchart showing the use of indicators (currently MSY indicators) to assess GES for stocks. ICES considers that no secondary indicators can currently be used to assess GES (source: EU Guidance on MSFD D3 assessment, 2016)*

Stock	D3C1 Primary indicators	D3C2 Primary indicators	GES_{stock}
1	G	R	R
2	G	G	G
3	G	-	?
4	-	-	?
5	R	-	R
6	G	-	?
7	G	G	G
8	-	-	?
9	-	-	?
10	-	-	?
Proportion of stocks at GES	5 out of 6	2 out of 3	2 out of 4
Proportion of agreed limits for GES	Policy to determine	Policy to determine	
Proportion of landings	X out of xxx tonnes	Y out of xxx tonnes	
Unknown	4 out of 10	7 out of 10	

***Fig. 5** Example of a regional GES assessment for D3. (source: EU Guidance on MSFD D3 assessment, 2016)*

Descriptor 6

Marine strategy Framework Directive. Task Group 6 report. Descriptor 6, Seafloor integrity Rice et al. (2010)

The report by Rice et al. (2010) is a consensus document of all task group members. Inputs from the Task Group observers, particularly from OSPAR and HELCOM, was also taken into consideration and often led to improvements in clarity and linkages to work of existing agencies active in European seas.

Some of the main conclusions of this report are the difficulties regarding sampling and measurement, as well as the high scientific uncertainty about aspects of benthic ecology and tolerances of benthic ecosystems to perturbations. These technical/methodological difficulties and the knowledge gaps make the GES assessment challenging.
The authors of the report conclude that a sound assessment of GES is possible, but there is a need to integrate results from local scales where both natural benthic ecosystems and pressures may be very patchy to much larger regional and sub-regional scales.
In Rice et al. (2010) it was also highlighted that ahead of the impacts to the seafloor and benthic communities produced by the many uses of the sea, there should assurances that anthropogenic pressures do not hinder ecosystem components in retaining their natural diversity, productivity and dynamic ecological processes. Many benthic areas do not meet these standards and management must improve status.
Another topic discussed in this task group was the scale for assessing GES. This is a challenging issue for different reasons: (1) benthic ecosystem features are patchy on many scales, (2) a wide range of human activities cause pressures on the sea floor, operating at different spatial scales, (3) although many anthropogenic impacts are local, their direct and indirect ecological consequences may be transported widely by physical and biotic processes, (4) the seafloor monitoring is also patchy and often local. The scale of the impact relative to the availability of the ecosystem properties being impacted is an important consideration.

Rice et al. (2010) conclude that, to deal with the challenge of assessing GES in the seafloor following steps should be followed:

- Identify the **ecological structures and functions** of particular importance
- Identify the **human pressures** known or likely to reach levels that degrade environmental status
- For the **ecosystem components and pressure**s identified as being of greatest importance, use a suite of appropriate **attributes and indicators to assess status relative to pre-identified standards for GES**, along gradients reflecting **meaningful scales** of the seafloor attributes and pressures
- The standards for GES on various indicators must reflect **the different sensitivity and resilience** of the Indicators and their functions in ecosystem processes
- **Risk-based approaches** to monitoring and assessment are proposed to deal with the local-scale patchiness of seafloor Attributes, pressures, and impacts

Report of the workshop to review the 2010 Commission Decision on criteria and methodological standards on good environmental status (GES) of marine waters; Descriptor 6, 2014
The report of 2014 from the ICES WKGMSFDD6 Report 2014, reviewed the 2010 Commission Decision on criteria and methodological standards on GES of marine waters for D6, addressing the main aspects of this D, specifically: (1) Scoping of seafloor integrity attributes; (2) How to ensure seafloor integrity: setting GES boundaries; (3) Indicators for proposed criteria: functionality and recoverability; (4) Relation with other descriptors and (5) Gauging impact: pressure/sensitivity. This document has been fundamental for the proposal of revision of the criteria established by the 2010 Decision of the Commission.

The main conclusions of this workshop were:

1. The need to revise some criteria, specifically 6.1 (*Physical damage, having regard to substrate characteristics)* and 6.2 (*Condition of benthic communities*); instead, considering for 6. 1 *Functionality* and for 6.2 *Recoverability*, both more closely related to resilience and recovery potential of the seafloor.
2. To ensure resilience of the seafloor, the reference points of indicators that are selected should best reflect the possible tipping point, i.e. the level of disturbance at which the decline of the system functionality begins to accelerate. Recoverability needs to be considered in the spatial context within which a disturbed area is located (i.e. connectivity between impacted and non-impacted sites in the region). For both criteria (*Functionality* and *Recoverability*), information on sensitivity and pressures need to be considered together to evaluate overall impact.
3. Pressure indicators alone will result in an incomplete assessment. Natural disturbances occur on the seafloor, and this background needs to be considered in assessments, relative to sensitivity of the seafloor habitat(s) and anthropogenic pressures.
4. The selection of reference points and choices of period for the long-term historic average should be done on a (sub) regional basis by the authoritative scientific institutions

Descriptor 10

Review "Marine litter within the European Marine Strategy Framework Directive " ICES Journal of Marine Science by Galgani et al. (2013)

Coastal and marine human activities generate considerable quantities of waste, which has the potential to contaminate the marine environment. The entanglement of species in marine litter has frequently been described as a serious mortality factor leading to potential losses in biodiversity (e.g. Galgani et al. 2013)

There are few publications on the effects of marine litter in the deep-sea realm, but the decline of deep-water sharks in the North Atlantic has been linked to ghost fishing in the region (Large et al. 2009).

Known impacts of marine litter include alteration, damage and degradation of benthic habitats (Katsanevakis et al. 2007) such as coral reef and soft sediment abrasion from derelict fishing gear or smothering from macro- and microplastics on sandy sediments in the intertidal zones (Katsanevakis et al. 2007). Litter can disrupt the assemblages of organisms living on or in the sediment. But none of these aspects have been directly investigated in the deep sea.

Litter will persist in the sea for years, decades and centuries. Therefore, the assessment of sources alone will not be enough, and long-term monitoring in the marine environment will be required to understand trends. When planning monitoring schemes, consideration should be given to adequate spatial and temporal scales.

In Galgani et al. (2013) (based in Galgani et al. 2010, 2011), a comprehensive table presented a summary of approaches for assessing GES with regards to marine litter, but only two have been included as feasible for monitoring litter in the deep-sea: 1) by trawling which has the advantage of replicability and standardization but it can be conducted only in specific areas where trawling is possible/allowed, or 2) by means of manned submersibles or ROVs which have the potential for use everywhere but covering only small areas and with high costs.

Building upon the MSFD-definition of GES for D10, GES could be regarded as achieved when litter and its degradation products present in and entering EU marine waters (i) do not cause harm to

marine life and habitats; (ii) do not pose direct or indirect risks to human health, and (iii) do not lead to negative socio-economic impacts.
Finally, the aggregation of data for the evaluation at sub regional or even regional scale will be different for the various parameters being considered. For example beached litter surveys can be applied to the European spatial scale while deep-sea floor monitoring, restricted to a few areas, is more relevant at smaller scales and over longer periods.

2.2 Work on GES conducted by OSPAR and HELCOM

2.2.1 OSPAR

There are strong analogies between the MSFD and OSPAR approaches, for instance a connection has been made between "special habitats" (including OSPAR Priority Marine Habitats, PMHs; determined as "threatened and/or declining" under the OSPAR Convention 1992) and the achievement of GES (see Gormley et al. 2015). Previously, other authors already considered when suggesting an integrative approach for GES assessment within the MSFD the inclusion of the experience gained in the WFD implementation, together with that from regional sea conventions, such as OSPAR (North East Atlantic) or HELCOM (Baltic Sea), even if some tools used in those assessment might not be useful or might need to be adapted to approach the MSFD (Borja et al. 2010). The integrative approach of Borja et al. (2010) presents in Table 4 of the manuscript a proposal for an assessment of GES taking into account the ecosystem components, the main pressures, the 11 qualitative Descriptors and some indicators (adapted from the WFD or developed for the MSFD). In the next paragraphs a summary on the OSPAR work on GES is presented.

MSFD Advice Manual and Background Document on Biodiversity (2012)

This document was published as a manual covering the biodiversity-related MSFD Descriptors: D1, D2, D4 and D6, aiming to provide a common ground for coordinated and consistent determination of GES and related identification and establishment of indicators and targets within the OSPAR area. The manual was published in 2012, so many aspects have been revisited several times over the past 6 years, but some others are still valid, most especially the ones related to the deep-sea realm, which are summarised here.

One of the aspects discussed when approaching GES assessment is the setting-up of baselines. In the OSPAR advice manual several "baseline setting methods" are presented. One of those is to use as a baseline existing reference states. This is considered to be a scientifically robust, transparent and comprehensible method, and should be the preferred approach to setting baselines where it is possible to find areas where anthropogenic influences on seabed habitats are negligible. This approach may be more easily applied to the deep sea/offshore areas than to coastal ones. Also, the use of historical reference states has been considered as a potential baseline for some offshore sediment habitat types, for which few historical data sets exist.
The manual also highlights the existing European indicators and state targets for different habitats, considering that for those deep-sea rock and biogenic reef habitats which are subject to few pressures (e.g. some CWC reefs and deep-sea sponge aggregations), the current condition and extent could be used as a baseline (determined through modelling and mapping techniques) and a limit (as opposed to target) could be set at this current condition and extent in line with the HD approach (target-setting method).

At the time of writing this manual, the group agreed that there were still gaps, with no indicators or targets developed, for example: deep sea and coastal species; some functional groups; size based indicators specific for non-commercial species; and genetics.
It was also specifically indicated that D6 has much in common with assessment of habitats under D1. The manual recommends treating the two together, with assessment of 'seabed substrate' types under D6 aligned with the predominant habitat types of D1, and with common assessment of seabed quality and setting of targets, e.g. for reductions in impacts. Whilst the Commission Decision indicators for D6 are more oriented towards functioning of seabed communities, they are compatible with and complementary to those used for D1. As for D1, an overall assessment of the substrate types needs to assess the extent of impact from all pressures affecting the seabed, at the scale of the assessment area.
Regarding the issue of scale, it was highlighted that it is specific for each biodiversity Descriptor, and that there are significant knowledge gaps for many biodiversity components, for both spatial and temporal scales, especially for the deep sea. Regarding D6 assessment scale, although knowledge is less complete offshore and in the deep sea than in coastal areas, many studies suggest that the dominant space and time scales are both greater in these ecosystems.

OSPAR CEMP Guidelines and OSPAR intermediate assessment documents

CEMP Guidelines
Several OSPAR CEMP (Construction of an Environmental Management Plan) guidelines have been developed in OSPAR to implement indicators. Regarding the descriptors treated in this deliverable, there are documents available in the OSPAR webpage for the following OSPAR indicators BH1, BH2, BH3, FC1, FC2, as well as in litter in the seafloor (see **Annex II** for OSPAR indicators).

OSPAR intermediate assessment documents
A summary of the main conclusions extracted in the OSPAR intermediate assessment documents for D1, D3, D6 and D10 is included here.

D1, D6 (2017)
BH2, BH3 OSPAR indicator
Extent of Physical Damage to Predominant and Special Habitats, dealing with the MSFD Descriptors: D1 and D6 (Criteria: 1.6 - Habitat condition; 6.1 - Physical damage). The assessment covers the period 2010–2015 (**Fig. 6**)

The main message of the analyses is that bottom-contacting fishing physically disturbs seafloor habitats. 86% of the areas assessed in the Greater North Sea and the Celtic Seas have physical disturbance, of which 58% showed higher disturbance. 74% of all assessed areas experience consistent pressure year on year. This will very likely affect the ability of habitats to recover.

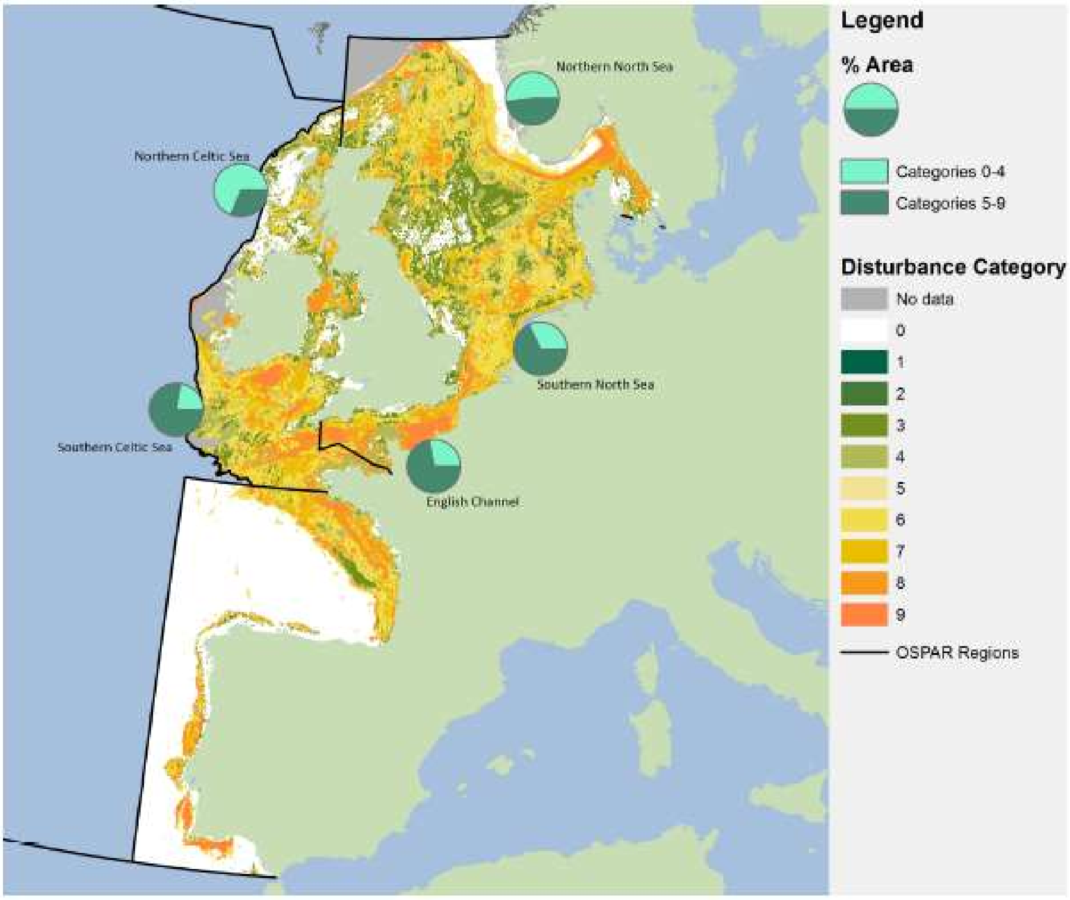

Fig. 6[7] *Spatial distribution of aggregated disturbance using the 2010–2015 data series across OSPAR sub-regions. Disturbance categories 0–9, with 0= no disturbance and 9= highest disturbance. Plots show percentage area of OSPAR sub-regions in disturbance categories 0–4 (none or low disturbance) and 5–9 (high disturbance) across reporting cycle (2010–2015). The percentage was not included for the Bay of Biscay and Iberian Coast due to the lack of complete data (source: report on Extent of Physical Damage to Predominant and Special Habitats, OSPAR 2017).*

D1 (2017)

BH2, BH3 OSPAR indicator

Recovery in the Population Abundance of Sensitive Fish Species, dealing with the MSFD Descriptor: D1 (Criterion: 1.2 -Population size). The assessment covers the period 2010–2016. (**Fig. 7**)

The main message of the analyses is that the decline in abundance of sensitive fish species has been halted in the Celtic Seas and Greater North Sea. However, significant recovery of populations is only apparent in the Celtic Seas.

7 Note included in the OSPAR report regarding the information displayed in the figure: "*This is the first OSPAR-wide assessment of physical damage to benthic habitats. As such, confidence in the methodology is low / moderate. Confidence in the data availability is low (but moderate to high in well surveyed areas).*"

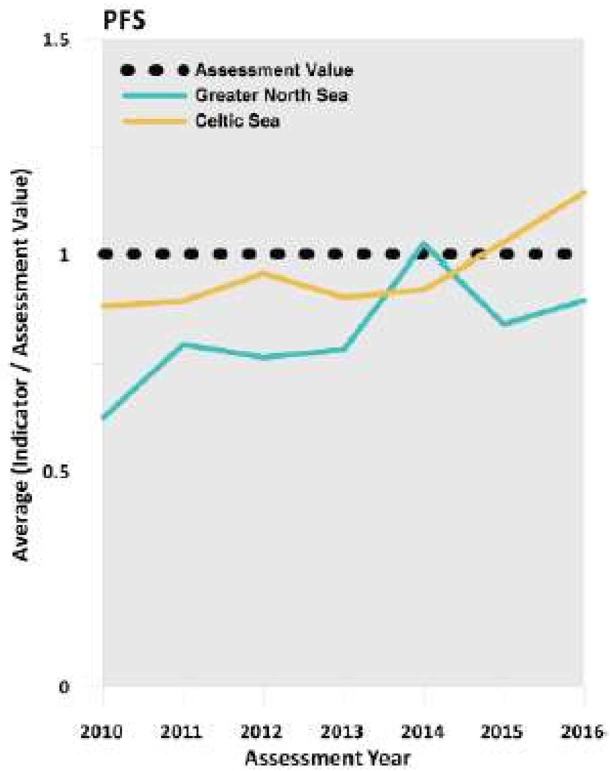

Fig. 7[8] *Integrated assessment outcomes for population abundance recovery (where a value above 1 means the assessment value is being met or exceeded) derived using an averaging integration approach (source: report on Recovery in the Population Abundance of Sensitive Fish Species, OSPAR 2017)*

D1 (2017)

BH2, OSPAR indicator

Condition of Benthic Habitat Communities: The Common Conceptual Approach, dealing with the MSFD Descriptor: D1, D5, D6 (Criteria: 1.6 - Habitat condition; 5.3 - Indirect effects of nutrient enrichment; 6.2 - Condition of benthic habitat community).

The main message of the assessment is that benthic habitats are essential for marine life. Assessing their condition against all pressure types is a huge new challenge for science and management. Initial assessment results are available for two pressure types. Further development of this common approach will integrate assessment results and include additional habitat types and pressures.

It is worth highlighting that the broad habitat types regarding the deep sea (**Table 1**) in most cases have been identified but not yet assessed.

[8] Note included in the OSPAR report regarding the information displayed in the figure: "*For this assessment the confidence in the methodology is moderate and the confidence in the data is high.*"

Broad Habitat Type	Physical damage	Removal of species	Hydrological changes	Eutrophication (nutrients or organic matter)	Non-indigenous species	Contaminants	Litter	Energy, including underwater noise
Littoral rock and biogenic reef				A				
Littoral sediment				A				
Infralittoral rock and biogenic reef				A				
Infralittoral sediment	P			A				
Circalittoral rock and biogenic reef				A				
Circalittoral sediment	P			A				
Offshore circalittoral rock and biogenic reef								
Offshore circalittoral sediment	P			P		P		
Upper bathyal rock and biogenic reef								
Upper bathyal sediment								
Lower bathyal rock and biogenic reef								
Lower bathyal sediment								
Abyssal								

Key

A	Assessed and reported under the European Union Water Framework Directive (WFD)
	Considered under the European Union Marine Strategy Framework Directive (MSFD)
P	Partially assessed in the Intermediate Assessment 2017
	Main risks (potentially widespread across the OSPAR Maritime Area)
	Relationship identified but not currently assessed

Table 1 *Relationships between habitat and pressure types, and how/if the relationships are currently assessed or considered. Relationships based on the revised MSFD - COMMISSION DECISION (EU) 2017/848) and OSPAR/MSFD pressure categories (source: Report on Condition of Benthic Habitat Communities: The Common Conceptual Approach, 2017*)

D1 (2017)

FW3, OSPAR indicator

Pilot Assessment of Mean Maximum Length of Fish, dealing with the MSFD Descriptor: D1 (Criterion: 1.7 Ecosystem structure)

The OSPAR pilot assessment measures the change in species composition as determined by the mean maximum length of each species, which is assumed to represent their vulnerability to additional (often fishing-related) mortality. There is no consistent pattern across the assessed regions but there are often distinct changes over time within regions. (Fig. 8)

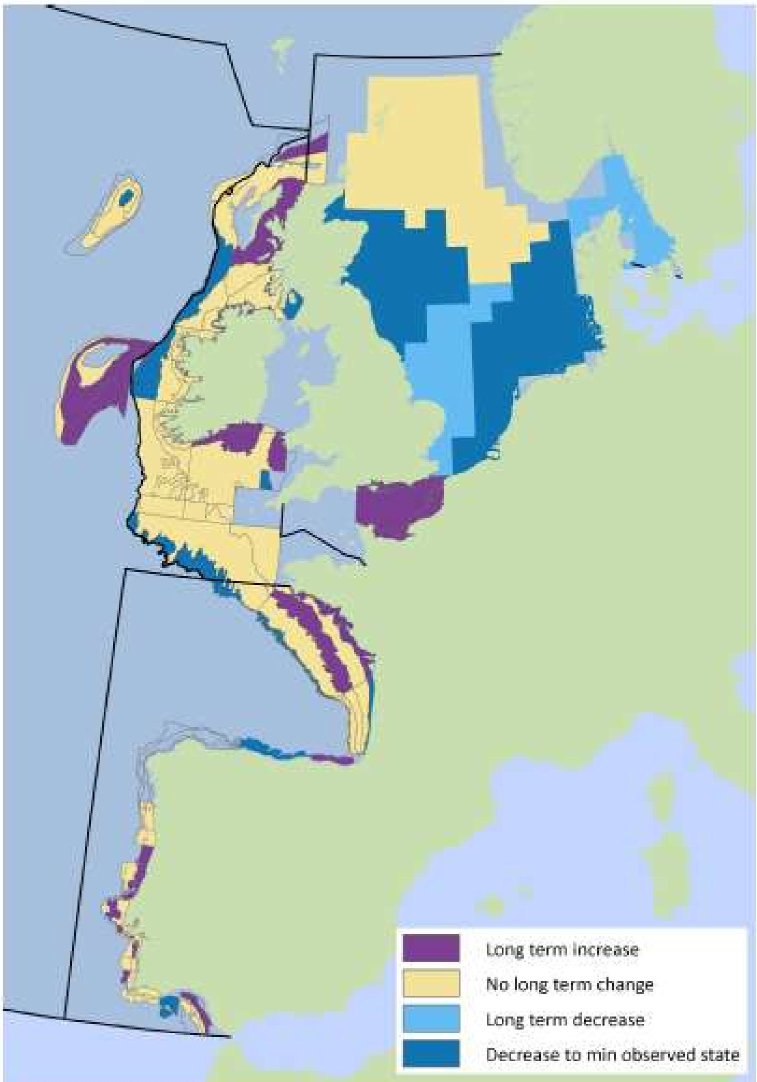

Fig. 8[9] *Spatial patterns in mean maximum length per sub-division for demersal fish assemblages (source: Pilot Assessment of Mean Maximum Length of Fish, OSPAR 2017)*

2.2.2 HELCOM

The HELCOM Baltic Sea Action Plan was adopted in 2007. The Initial Holistic Assessment is also a regional contribution to the initial assessment according to the MSFD for those HELCOM Contracting Parties that are also EU Member States. The HELCOM approach is unquestionably useful as it includes a holistic approach where the current status, causes, solutions, costs and benefits as well as future perspectives are clearly presented following comprehensive evaluation. The HELCOM approach also address several MSFD descriptors. However the HELCOM approach is more focused in shallow waters, with special emphasis in the pelagic realm, sea mammals and seabirds as well as in other aspects such as water contamination. No specific indicators for benthic habitats are addressed and the D3 and D6 were not considered for these reasons, so it was decided not to include the results of the HELCOM action plan in this deliverable. However, see section 2.1.3 where the scientific literature has been reviewed; in the specific section on multimetric indexes, the BEAT tool generated within HELCOM is commented on.

[9] Note included in the OSPAR report regarding the information displayed in the figure: "*For this assessment the confidence in the methodology is moderate and the confidence in the data is high.*"

2.3 Good Environmental Status in the Scientific Literature

A revision of more than 70 scientific and technical papers and reports has been conducted. In the next paragraphs a summary of the most relevant aspects regarding GES evaluation and evaluation approaches is presented. Whenever possible the extraction of information is focused on the specific ATLAS issue: how to evaluate GES in the deep sea, but as the literature specifically focused on the deep sea is very scarce most of the works highlighted here deal with benthic ecosystems. Further at the time of preparing this deliverable, within the ATLAS project work conducted in the work packages on Marine Spatial Planning (WP6) and Biodiversity (WP3) started to merge and work together. For instance, to properly evaluate the results of the GES assessment conducted with the NEAT tool (see section 3) it would be fundamental to know about existing pressures in the evaluated areas in the ATLAS case studies. Additionally, aspects such as defining tipping points to be able to better define resilience for the different ecosystem types will be partially provided from WP2 as result of the aquaria experiments that are being conducted within ATLAS. In the same way, it will be fundamental to take into account connectivity when evaluating the resilience of the ecosystems. Further, WP4 results will also contribute to enlarging our knowledge on the connectivity between deep-sea ecosystems. Hence, we assume that at the end of the ATLAS project more information will be available helping to assess GES in the deep-sea realm in the North Atlantic.

2.3.1 GES in a changing environment

Already in 2013, shortly after the IE of the MSFD was concluded by the European countries, Borja et al. (2013) published work dealing with the concept of GES analysing the complexity that the concept involves. One of the main conclusions of the Borja et al. paper is that the means of implementing the MSFD should be based as much as possible on the work of the Regional Seas Conventions (e.g. OSPAR, HELCOM) and also whenever possible should be based on existing data sets. Borja et al. (2013) also attempted to define GES, taking into account that this definition should encompass all Descriptors and criteria, but also highlighting the importance of taking into account which data and information are required to ensure that the definition is met (for detail information see Table 4 in Borja et al. 2013). The paper stresses that whereas some data are available covering the regional seas, the data on pressures correspond to small areas, making it necessary to combine these different scales of information. This implies the challenge of assessing GES at regional level via a broad approach but at the same time ignoring or giving less weight to the specific problems, or the other way around, highlighting the point-of-source problems to indicate the quality status of the whole area.

One of the aspects to take into account beside defining what GES means, is the challenge of having enough methods and ways to measure GES. It is clear that while for some parameters there are enough agreed targets and or limits (the authors specifically mention contaminants), for many other these boundary values have not been defined, this is true for ecosystem services, for example. In any case, it is clear that more efforts are still required to produce more comprehensive data sets but also to concentrate on processes and cause and effect and to improve the science of monitoring. The question on having reference conditions is also an important issue and difficult to address as even if some approaches have been used (i.e. comparisons with areas considered as pristine or predictive models), in the first instance reliance on expert judgement will be needed (Borja et al. 2013 and references therein). An expert system that can capture expert judgement in a robust and defensible manner, as demonstrated across different continents (Teixeira et al. 2010), may be required, and this has been indeed used recently (Elliot et al. 2018).

The concept of GES has been also discussed in the framework of the pelagic habitats. Even if the ATLAS approach is mostly focused on benthic ecosystems, some of the thoughts and ideas developed to assess GES in the pelagic realm are useful and applicable to the benthic realm. Dickey-Collas et al. (2017) concluded that to be in GES but at the same time able to provide goods and services, three conditions should be met: 1) all species present under the current environmental conditions should be able to find the habitats essential to close their life cycles, 2) biogeochemical regulation is maintained at normal levels and 3) critical physical dynamics and movements of biota and water masses at multiple scales are not obstructed. Dickey-Collas and co-workers also consider the need to discuss the reference points with knowledge brokers, managers and stakeholders. Considering the features of this changing pelagic realm, the authors discussed the need to integrate multidisciplinary empirical data sets with spatial and temporal models to assess and monitor progress towards GES, as well as to evaluate the potential GES changes in the pelagic habitat. In this sense it has been also discussed in the scientific literature that GES cannot be approached as a “static” concept, not only because of the extremely changeable pelagic environment, but also because of the need to take into account changes that take place in the ocean as a whole. In some cases those changes can be a result of the anthropogenic activities and their management in a specific area (e.g. drilling, fisheries), and in other cases due to anthropogenic impacts that are not managed (e.g. climate change). These aspects are discussed by Elliot et al. (2015) who consider the need to accommodate the shifting baselines originated by climate change when monitoring and assessing GES, as well as when establishing management measures. The authors suggest in their paper that climate change can prevent GES from being achieved.

2.3.2 Approaches to assess GES, conceptual approaches, models and multimetric indexes

Beside the use of predictive habitat models, since the publication of the MSFD and especially after the IE has been published by the European countries, several works have been published exploring the development of multimetric index and models useful in integrating different descriptors for GES assessment. Shortly after the publication of the IE, several working groups were constituted with the aim of improving the approaches and ways to assess GES (see previous section on ICES work 2.1.1). For instance, the work published by Rice et al. (2012) was one of the first attempts to explore GES for D6. The paper summarizes the main conclusions of an international expert group established to review the scientific basis for making the GES concept for D6 operational (see also Rice et al. 2010, previous section 2.1.1).

Experts concluded that consideration of 8 attributes of the seabed system would provide adequate information to meet requirements of the MSFD:

(1) substrate, (2) bioengineers, (3) oxygen concentration, (4) contaminants and hazardous substances, (5) species composition, (6) size distribution, (7) trophodynamics and (8) energy flow and life history traits.

The experts further concluded that GES cannot be defined exclusively as “pristine environmental status”, but rather status when impacts of all uses were sustainable. Uses were considered sustainable if:

(1) the pressures associated with those uses do not hinder the ecosystem components to retain their natural diversity, productivity and dynamic ecological processes and 2) recovery from perturbations such that the attributes lie within their range of historical natural variation must be rapid and secure.

An important and interesting output highlighted in Rice et al. (2012) was that some suggestions were proposed for a specific set of indicators. The reasons this was argued were that (1) no single set of indicators will meet the needs of all EU countries in all regional seas, and (2) according to the MSFD indicator, selection is the prerogative of individual states. However, in the summary of this report the need for consistency in assessing GES across European countries was also highlighted.
A selection of indicators for seafloor integrity was proposed in Rice et al. (2012) based on the 8 attributes of the seabed:

(1) type, abundance, biomass and areal extent of relevant biogenic substrate; (2) extent of the seabed significantly affected by human activities for the different substrate types; (3) presence of particularly sensitive and/or tolerant species; (4) multi-metric indices assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species; (5) proportion of biomass or number of individuals in the macrobenthos above some specified length/size; and (6) parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community.

One aspect to be taken into account is that in this work, as with most of the revised scientific papers, the specific case of the deep sea has not been addressed nor have the intrinsic difficulties in obtaining information to inform these indicators.

Models and multimetric indexes

Models

Since the MSFD was published, and especially after the publication of the results of the IE, several attempts have been made to asses GES in an integrative manner (e.g. Borja et al. 2011, Halpern et al. 2012, Tett et al. 2013, among others). However there are still many gaps in our understanding of marine ecosystems and also in their responses to human pressures (Borja et al. 2013, Katsanevakiset al. 2014). Ecological models can be part of the solution in filling these gaps, and indeed they have been recognized as powerful tools for the evaluation of marine ecosystems ecology (structure and function) and for the prediction of anthropogenic impacts (e.g Fulton and Smith 2004, Shin et al. 2004, Christensen and Walters 2005, Plagányi 2007, Fulton 2010) and climate change (Tomczak et al. 2013, Chust et al. 2014). In this sense, Piroddi et al. (2015) provide an inventory of models in EU regional seas that could assess MSFD indicators associated with biodiversity, non-indigenous species, food webs and seafloor integrity. This model catalogue was part of the outputs of the DEVOTES FP7 Project (http://www.devotes-project.eu/), with the aim of showing the potential of model-derived indicators (see **figure 9**) that can be associated with MSFD descriptors. It also aims to provide a complete assessment of their relevance and degree of “operationality”. The special characteristics of the deep sea (especially the scarce data set) mean that models are potentially important instruments for the assessment of GES. Beside ecological models, other modelling tools have been developed within the MSDF to assess GES, taking into account the need to justify the program of measures proposed to achieve GES, on economic bases. In this context, Kontogianni et al. (2015) present a first attempt to improve the current marine policy making process regarding the way to prioritize and select measures and policies for the management of marine resources. The authors present an expert judgment-based weighting framework named 'MeTaLi'. The tool provides a cost-effectiveness ranking algorithm of alternative measures (e.g. command-and-control, economic, etc.) within the framework of MSFD applying fuzzy and stochastic analysis. However, as this is a new tool, several aspects need to be refined. For instance, even if some measures may be considered to be cost-effective, they may fail to achieve environmental goals or may not be feasible from a social point of view (e.g.in cases where the cost of the measure exceeds the monetized social benefits). Kontogianni et al. (2015) argued that the MeTaLi tool could be a good instrument providing a quantitative cost-effectiveness method to help to address the fundamental question of how to prioritize measures in the context of the MSFD when scientific evidence is lacking. It could be useful to Member States that need to justify and defend their marine policy decisions on economic grounds.

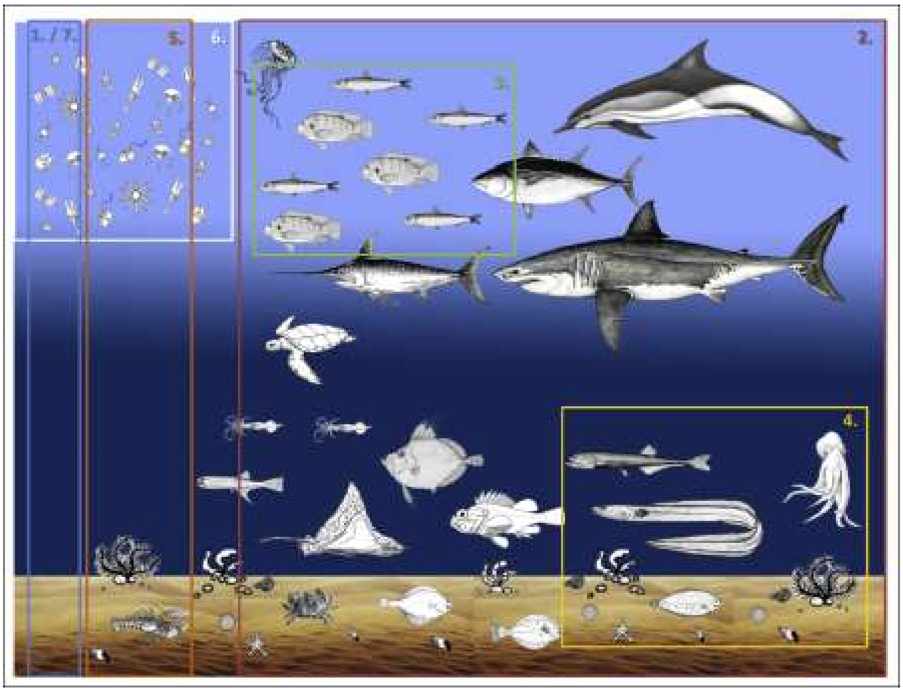

Fig. 9 *Illustration of the model's capacity to describe the ecosystem, from specific processes integrating biological compartments and the associated abiotic environment to the entire ecosystem including, or not, human components or climate impacts. 1 and 7 refer to biogeochemical and coupled physical–biogeochemical models; 2 and 3 refer to multispecies models (either at species or at food web level); 4 refers to species distribution/Habitat Suitability; 5 to meta-community models and 6 to bio-opticalmodels (source: text slightly modified from legend in figure 1 in Piroddi et al. 2015. Image also from Piroddi et al. 2015).*

Multimetric indexes

Beside the use of models, the member states of the European Union use multi-metric macrobenthos indicators to monitor the ecological status of their marine waters in relation to the Water Framework Directive (WFD) and MSFD. The indicators translate the general descriptors of ecological quality in the directives into a single value of ecological status by combining indices of species diversity, species sensitivity and density. In the coming paragraphs a short summary is presented in recent literature where different type of index to evaluate GES within the MSFD has been developed.

Andersen et al. (2014) presented in their paper the BEAT tool (HELCOM Biodiversity Assessment Tool: BEAT). The BEAT tool aims to assess the status of marine biodiversity in an integrated manner. This is complicated mostly due to the fact that monitoring of marine habitats, communities and species is expensive, and often collects data in an incorrect spatial scale and/or is poorly integrated with existing marine environmental monitoring efforts. BEAT integrates interim biodiversity indicators by themes: broad-scale habitats, communities, and species as well as supporting non-biodiversity indicators.

The description of what benthic attributes are important to consider when assessing seafloor integrity in marine areas is described in the Comission decision (EC 2008), as well as in papers produced after a comprehensive analyses of the descriptor (Rice et al. 2012). The European Commission put considerable emphasis on using multi-metric indices also in open waters (EC 2010). In this sense, Villnäs et al. (2015) analyses the performance and usefulness of two multi-metric indices when assessing seafloor integrity across broad environmental gradients. The authors compared the Benthic Quality Index (BQI) and the Brackish water Benthic Index (BBI) between three sub-basins in the Baltic Sea. The results obtained revealed a "context dependency" which points to the need for increased transparency of the importance of the different predictors for directing index values for coherent classifications over broad environmental gradients. The authors suggest that the use of a weight of evidence table to combine multiple indicators would preserve transparency and be more likely to provide a robust assessment method that would detect seafloor degradation at an early stage.

Other works analysed the response of some multimetric indexes to bottom trawling. This is the case of the work by Gislason et al. (2017) where the authors used a linear mixed effects models to analyze how bottom trawling intensity affects the indicators used in the Danish (Danish Quality Index, DKI) and Swedish (Benthic Quality Index, BQI) environmental monitoring programs in the Kattegat. Gilason and co-workers used year and station as random variables and trawling intensity, habitat type, salinity and depth as fixed variables and they found a significant negative relationship between the BQI indicator and bottom trawling, while the DKI is related significantly to salinity, but not to trawling intensity. The results of the analyses revealed that without accounting for the effect of density (individuals per sample) on species density, indicators based on species density will be affected by temporal and spatial variations in density linked for instance to variable recruitment success. When this variation is accounted by random year and station effects, Gilason et al. (2017) found that log trawling intensity explains more of the variation in log density than in the indicators currently used to monitor GES in the Kattegat. Disregarding random effects and the relationship between density and species density, the impacts of bottom trawling are likely to be lost in the translation of ecological quality into macrobenthos indicators. These results show the importance of taking into account the inclusion of environmental drivers as well as random year and station effects in the analyses, in order to make anthropogenic impacts identifiable on a background of substantial natural variation. Gislason et al. (2017) further commented on a new generation of indicators which are now being developed for monitoring macrobenthos status in relation to bottom trawling and MSFD requirements. Some of these indicators are based on changes in species or trait compositions (e.g. longevity) (Hiddink et al. 2006, Eigaard et al. 2016), but they may also be subjected to the same sampling problems as the classical species density and diversity based indicators used to assess Good Ecological Status within the WFD. The authors argued that mixed effect models provide a possibility for dealing with some of these problems and allow a more precise translation of the qualitative descriptors of the directives into quantitative measurable goals. Using linear mixed-effect models of density solves the problem of standardization across different sources of variation by allowing incorporation of random effects of e.g. space (station) and time (month, year), generated by station specific differences in environmental conditions and by inter-annual differences in recruitment success, as well as fixed effects generated by quantified variables such as salinity, depth, bottom habitat and trawling intensity. Incorporation of environmental covariates and random effects allows changes in density to be mechanistically linked to differences in anthropogenic and natural pressures. Direct effects of fisheries generated mortality on macrobenthos communities can potentially be separated from indirect effects by examining how e.g. growth or reproduction is affected by trawling intensity, providing a possibility for defining limit reference points of relative densities below which offspring production can no longer secure replacement.

A further step in the GES assessment is presented in the work by Uusitalo et al. (2016) were the Nested Environmental status Assessment Tool (NEAT), developed for the integrated assessment of the status of marine waters within the EU FP7 project DEVOTES, was applied to 10 marine ecosystems to test its applicability and compare biodiversity assessments across the four European regional seas. One of the main general conclusions of this work is that the analysis shows that the assessment design (which includes the selected indicators, their target values, as well as the geographical resolution and habitats to be assessed), has potentially a high impact on the result, and the assessment structure needs to be understood in order to make an informed assessment.

Further use of the NEAT tool has been done by other authors after the work by Uusitalo et al. (2016). Nemati et al. published two papers (Nemati et al. 2017, 2018) using NEAT outside the European waters, specifically in the Caspian Sea. In both papers, the authors aimed to assess environmental status in bathing waters, to differentiate areas impacted and non-impacted by bathing activities. In the work from 2017, the authors combined multiple indicators from different ecosystem components (8 physico-chemical, 4 bacteria, 2 plankton, and 1 benthos indicators). In the work from 2018, the authors work with the indicators using two different methods: (1) the 15 indicators were grouped into four groups (physicochemical, bacteria, plankton, and benthos) and each group was investigated separately (one-way sensitivity analysis), calculating NEAT values after omitting each group independently; and (2) indicators were selected randomly, using 1000 Monte Carlo iterations, and removing from 1 to 14 indicators at each iteration. The results revealed that the abundance of Pontogammarus (a species of amphipod) was the single indicator that made the difference in assessing the status among locations, differentiating bathing and non-bathing areas. Hence, this indicator was regarded as a monitoring element detecting the impacts produced by a management measure (beach nourishment) taken by the authorities to maintain the bathing activity.

Another application of the NEAT tool has been done in a recently published paper (Pavlidou et al. 2019) where the assessment was conducted in the Saronikos Gulf, in the Eastern Mediterranean. In this case the authors used different spatial and a 10 years' time series data covering 9 biological and chemical ecosystem components (covering pelagic and benthic realm), 24 indicators and 8 descriptors of the MSFD. The NEAT results were evaluated considering the anthropogenic pressures affecting the study area and the existing management measures. The results were compared to previous ones. The study concluded that using NEAT it was possible to integrate data from different sources, spatial and temporal scales allowing this integration to undertake a real ecosystem assessment. The integration of information at different spatial and temporal scales does not imply any loss of information, and the tool allowed tracking of the problems and cases in poor status that should be addressed at lower levels (e.g. species or species groups). Further, the results were related to the pressures identified and the comparison with previous analyses demonstrates the recovery of the system and the time needed for recovery. The work by Pavlidou et al. (2019) highlighted the utility of this tool for managers, policy makers and scientists when deciding the method to use in assessing the environmental status under the MSFD.

A remarkable contribution in the context of the development of indexes is the MAES index (Mesophotic Assemblages Ecological Status). The index has been created by Cánovas Molina et al. (2016) to evaluate the status of hard bottom Mediterranean mesophotic communities using photography and video footage from Remotely Operated Vehicle (ROV) surveys. The MAES index considers three parameters: (1) the community structure (number of megabenthic taxa, percent biotic cover in the basal layer, density of erect species), (2) the condition of the dominant erect species (average height, percent of colonies with epibiosis/necrosis) and (3) the visible human impact (density of marine litter, including lost fishing gear). The test of the index revealed that sensitivity of MAES index was correlated with the putative human pressure acting upon the site (semi-quantitatively assessed considering fishing effort and coastal urbanization). The authors proposed a standard working protocol related to the evaluation of the MAES index intending to create an effective monitoring tool for the assessment of the ecological status of mesophotic assemblages on a large scale, as required by the MSFD. The use of imagery data to apply this index could be especially useful for the assessment of GES in the deep-sea and more specifically in VMEs.

2.3.3 Measuring indicators uncertainty

As a final aspect to consider in this section regarding models and indexes and their application to address indicators, we consider it valuable to refer to the recent work of Carstensen and Lindegarth (2016) who analyse the importance of uncertainty when estimating and indicator. Indeed the authors stress that indicator uncertainty is rarely estimated, even though frameworks such as the MSFD highlight the importance of quantifying the confidence of an assessment. The paper analyses the different sources of uncertainty that can take place in the methodology used in the sampling process, as well as in the time and space sampling scales or in the people involved in the measures that can also introduce additional uncertainty. Carstensen and Lindegarth (2016) made an attempt to outline different sources of variation, however the authors realise that in most cases it is not possible to estimate all relevant sources of uncertainty from a single ecosystem, and those uncertainty components that can be quantified will not be well determined due to the lack of replication at different levels of the random variations. The authors offered a very clear example highlighting that for example, spatial variations cannot be determined from data sets with just one station. The authors suggest that random variations should be estimated from a large data set, by pooling observations from multiple ecosystems with similar characteristics. Further they recommend considering predictable patterns in time and space using parametric approaches, to reduce the magnitude of the unpredictable random components and potential bias introduced by heterogeneous monitoring. Partitioning the random variation onto multiple uncertainty components is important to obtain correct estimates of the ecological indicator variance, and the magnitude of the different components provide useful information for improving methods applied and design of monitoring programs.

2.3.4 Application of underwater technologies to respond to the assessment of GES within the MSFD

Mapping the seafloor is clearly one of the basic tasks necessary to comply with European directives such as the WFD and the MSFD and to implement legislation to ensure their conservation. There are several methodologies that have been and are currently used to characterize the seafloor. These include scuba diving for shallow areas, or grabs, underwater cameras, remotely operated vehicles (ROV) and manned submersibles for deeper locations. All these methods are useful but time consuming and in some cases expensive providing local information, especially in front of requirements as the ones from the MSFD. Side-scan sonar (SSS) is recognized as one of the most effective tool for underwater mapping. In the study by Pergent et al. (2017) the possibility of coupling a camera with a SSS and acquiring underwater videos in a continuous way has been tested. The association between acoustic data and underwater videos has proved to be a non-destructive and cost-effective method for ground-truthing in marine habitats mapping. This kind of tool can be especially useful for the deep-sea realm as it has the potential to cover large areas in a more effective manner than aforementioned methods.

2.3.5 Assessing D1, D3, D6 and D 10 in the scientific literature. Approaches and proposed indicators. Discussion of results of the MSFD initial evaluation and ways to improve GES assessments

After the initial evaluation of the MSFD, several works have been published aiming to present new approaches to assess the MSFD descriptors as well as discussing the results of the IE and proposing ways to improve the approaches. In the next paragraphs we present the works published on the indicators included in ATLAS.

Descriptor 1. Biological Diversity was assessed

Hummel et al. (2015) assessed the degree of development and operability of the indicators for the MSFD using D1. The authors offered in the paper an overview of the relevance and degree of operability of the underlying parameters across 20 European countries. Hummel et al. (2015) analysed national directives, legislation, regulations, and public available reports. The work revealed that there were marked differences between countries in the degree of ecological relevance and of implementation and operability of the parameters chosen to assess D1. Different scores have been assigned by countries and no country achieved maximum scores for the implementation of D1. The parameters chosen for D1 indicators were generally identified as being an ecologically relevant reflection of biological diversity, but less than half of the chosen parameters were operational. After this evaluation the authors concluded that a harmonized approach to describe and assess marine biological diversity does not exist.

Descriptor 3. Commercial species

The situation of this descriptor in European waters is an important issue, as most European fish stocks are threatened by overfishing and/or by degraded environmental conditions. There is a general concern as to whether commercial fish stocks will achieve GES in 2020 as expected in the MSFD. In order to explore the situation of the fish stocks using a different approach, Jayasinghe et al. (2017) evaluated the status of fish stocks in the subareas of FAO fishing area 27, using mean trophic levels (MTL) in fish landings and spawning stock biomass (SSB). In addition, the authors estimated the harvest rate (HR) of the fish stocks before and after 2008. The results for MTL and SSB display different scenarios for different subareas ranging from fisheries that appear to be sustainable in some sectors to clearly overfished areas and others where fish stocks seem to recover. The results from the HR analyses revealed that most of the fish stocks have lower HR after 2008, indicating that the status has improved, perhaps due to improvements in the implementation of CFP. However, some fish stocks showed high HR even after 2008. In the work by Jayasinghe et al. (2017), the authors also discussed the influence of other factors such as eutrophication, seafloor disturbances, marine pollution, invasive species etc., in SSB and should also be incorporated in the management criteria. Most of these environmental pressures are of high priority in the MSFD, and therefore the authors conclude that their findings will be useful for both CFP and MSFD. The MTL is not included as an indicator in the MSFD, however, the European Environmental Agency suggested it as an appropriate indicator to be used with the implementation of MSFD (EEA 2010).

After the review performed by the EU Comission in 2015 to re-visit the structure of the criteria and indicators of the MSFD, Probst et al. (2016) review some weakness of the current structure of D3 addressing D3, and suggest a more operational structure for this descriptor. The adaptations to the structure of D3 proposed by Probst et al. (2016) try to clarify the purpose of each indicator and its role within the MSFD in order to assess the complex causes and impacts of marine ecosystem alterations. The authors recommended that indicators and criteria of D3 be reorganized within two Pressure-State Response (PSR) frameworks associated with two new criteria. These two criteria are aligned to “stock size” and “size structure within the stock”, and are suggested to replace the current three criteria of D3. Both new criteria together reconcile the assessment of fishing intensity and selectivity, which has been originally suggested by fisheries scientist in the mid-1900s. The first criterion builds on existing indicators used within the CFP and is thereby mostly operational. For the second criterion the authors considered that more research, indicator development and validation is necessary. EU Commission Decision of 2017 defined three primary criteria: D3·C1 Fishing mortality, D3 C2 Spawning stock biomass and D3 c3 age and size distribution of individuals as indicative of healthy populations.

Modica et al. (2016) also suggested the use of an alternative fish-populations spatial indicator. They analyzed populations of three deep-sea (“slope type”) fish species: *Helicolenus dactylopterus, Merluccius merluccius* and *Lophius budegassa*. The authors tested the efficiency of the indicators: “the presence/absence of the population in sampling squares“ and “geographical spread”, which is an indicator proposed by the authors as a new monitoring tool. The results demonstrate that neither indicator was sufficient alone to describe the population spatial pattern or its evolution. Althp To set-up threshold values is challenging, however, directional targets could be proposed, based on the results of both indicators. The analysis could be extended to other “slow type” populations within the fish community and also to different ecoregions. Modica et al. (2016) suggest an approach that includes the estimation of these two indicators interpreting them together to generate a more complete picture of the spatial patterns of the analysed fish populations. This approach helps to summarise fish spatial behaviour and improves information from the indicators applied alone. The combination of both indicators should be used to give a joint interpretation of the spatial structure of the population and its evolution in time. The authors concluded that the two indicators together could be good alternative for fisheries managers.

The work by Utizi et al. (2018) investigates the ability of selected measures (extracted from the provisions of Regulation (EU) No 508/2014 concerning the sustainable development of fisheries and of aquaculture, and which contained measures that could involve a direct impact on the marine environment), envisaged by the CFP reform through the European Maritime and Fisheries Fund (EMFF), to sustain and attain the objectives of the MSFD, which aims to achieve GES in marine waters according to an ecosystem-based approach. The analysis uses an expert judgment-based approach and a specially devised questionnaire, where fisheries science and management experts were asked to assess the impact and interaction of selected EMFF measures on GES achievement as defined for the Italian seas. Their responses are discussed and compared with information from an extensive literature review. The results of the analysis highlight a general agreement between EMFF actions and GES objectives but also identify some potential conflicts.

Descriptor 6. Seafloor integrity

Hard-bottom habitats with complex topography and fragile epibenthic communities are still not adequately considered in benthic monitoring programs, despite their potential ecological importance. While indicators of ecosystem health are defined by major EU directives, methods commonly used to measure them are deficient in quantification of biota on hard surfaces. Beisigel et al. (2017) address the suitability of seafloor imaging for monitoring activities. The authors compared the ability of high-resolution imagery and physical sampling methods (grab, dredge, scubadiving) to detect taxonomic and functional components of epibenthos. Results reveal that (1) with minimal habitat disturbance on large spatial scales, imagery provides valuable, cost-effective assessment of rocky reef habitat features and community structure, (2) despite poor taxonomic resolution, image-derived data for habitat forming taxa might be sufficient to infer richness of small sessile and mobile fauna, (3) physical collections are necessary to develop a robust record of species richness, including species-level taxonomic identifications, and to establish a baseline. Even if this publication presents data from shallow waters, the results obtained are applicable to monitoring with ROVs and other visual methods in deep-sea areas. According to MSFD, environmental status should be evaluated based not only on the abundance and diversity of species but also on the condition, distribution and diversity of habitats (Borja et al. 2013). In the study by Beisigel et al. (2017) the authors demonstrated that benthic imagery allows for the swift assessment of data on large spatial scales without disturbing the habitat, especially the presence of large, dominant epibenthic families and phyla. The MSFD criteria ‘extent of habitat,’ ‘extent of habitat loss,’ and specific indicators developed for the criterion ‘habitat condition’ as well as the corresponding assessment parameters under the Habitat Directive can be evaluated using benthic imagery.

Descriptor 10. Marine Litter

The French initial assessment of the MSFD highlighted the lack of reliable data concerning offshore areas. During the planning of the monitoring programmes, the scientists proposed partially covering this gap by using existing fisheries research vessel surveys deployed for the purposes of the CFP. Baudrier et al. (2018) describe ways of improving the effectiveness of these surveys and making them better suited to delivering the information needed for the MSFD. Marine litter was one of descriptors considered in this work, addressing also 10.1 (trends of amount of litter deposited on the sea floor) and specific examples are given with data on litter which will be used to assess the environmental status of French marine waters. The paper also identifies certain limitations regarding this approach. This French experiment enabled more efficient and effective use of current data collection efforts, while optimising vessel time and implementing an ecosystem approach in collecting data for fisheries management. Baudrier et al. (2018) highlighted that trawl surveys provide adequate means to achieve both criteria 10DC1 (composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed) and 10DC2 (same with micro-litter), with standardized protocols at Regional Sea Conventions (RSC) levels, enabling assessment of sea floor litter, floating debris and microplastics. The use of nets in most surveys gives satisfactory results in terms of sampling, but they probably underestimate the quantities. On the other side, they provide consistent results in terms of trend assessment, location of litter accumulation as well as litter composition (**Fig. 10**). This example illustrates the use of "operational" indicators, which have well understood relationships between natural state and specified anthropogenic pressures, necessary to define environmental targets and decide on management measures.

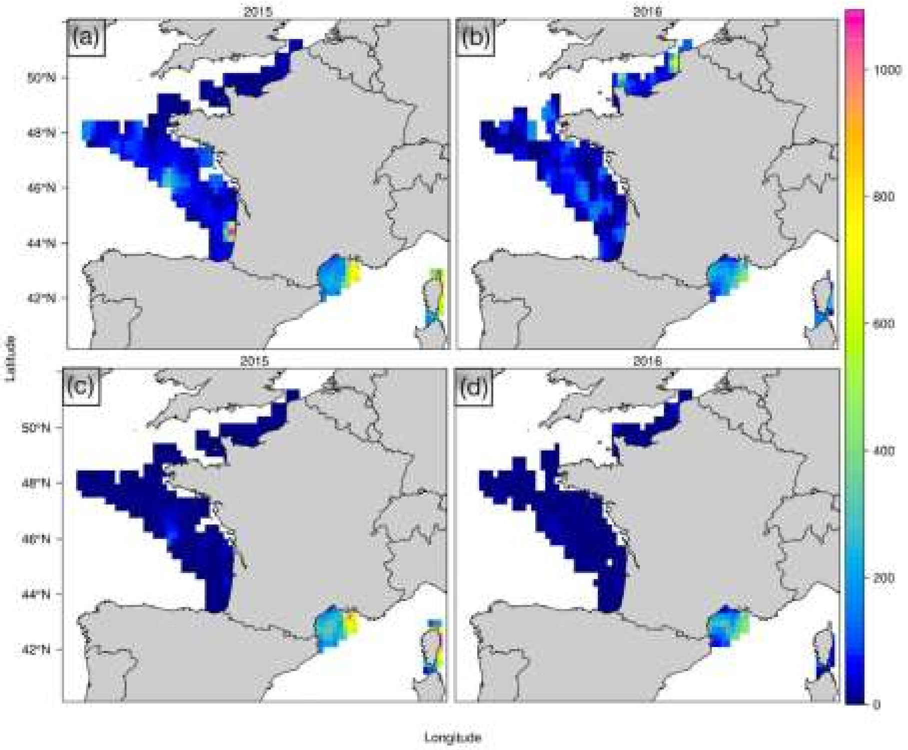

***Fig. 10** Gridded maps of average densities of bottom (a-b) total litter and (c-d) plastic sheets and bags collected in 2015 and 2016 during the MSFD optimised French fisheries surveys (source: Baudrier et al. 2018).*

Another work recently published (Consoli et al. 2018) deals with the quantification of marine litter on the seabed, from shallow to deep areas. Consoli et al. (2018) analyse ROV video footage at depths ranging between 20 and 220 m on the rocky banks of the Straits of Sicily which are included in an Ecologically or Biologically Significant Area (EBSA). The observed average density was higher (5.2 items/100m^2) at depths > 100m than at shallower depths (< 100m, 0.71 items/100m^2) with lost or abandoned fishing lines constituting 98.07% of the overall litter density, thus representing the dominant source of marine debris. Litter interactions with fauna were frequently observed, with 30%

of litter causing “entanglement/coverage” and 15% causing damage to sessile fauna. A total of 16 species showed interaction (entanglement/coverage or damage) with litter items and 12 of these are species of conservation concern according to international directives and agreements (CITES, Berne Convention, Habitat Directive, SPA/BD Protocol, IUCN Red List). The assignation of Specially Protected Areas of Mediterranean Importance (SPAMI) in the investigated area could represent a good management action for the protection of this hotspot of biodiversity and towards achieving GES by 2020, under the MSFD. The study detected a very high rate of entanglement hence the authors suggested a strategy of assessing this kind of impact using ROV as a monitoring device.

2.3.6 Monitoring GES

Monitoring is fundamental within the MSFD as it is the way to evaluate changes in GES. Barrio Froján et al. (2016) review the UK-case study, analyzing the different monitoring approaches from industry, private companies and the government, to highlight whether synergies between them could be developed into an integrated approach to marine benthic monitoring. An integrated approach would have ecological benefits, as greater consistency in sampling and analytical protocols would reduce uncertainty in the predictions of impact, and facilitate the assessment of GES within the MSFD. The same approach would also be of benefit, as spatial-temporal duplication in sampling would be reduced, and the value of acquired data would be maximised, resulting in a more efficient and cost-effective approach. In this paper, the authors highlight one step towards the integration of monitoring as already being achieved, since the industry has agreed to make available the data from its long-term benthic monitoring stations to help government in wider assessments of GES. An enlargement of this approach to include more sectors of industry would be desirable, always with Government leading the monitoring, as this is important to avoid any biased assessment of the marine environment. It is conceivable that the adoption of such an approach in the UK across all sectors of offshore industry and government may garner international interest, as other EU member states also have to meet their monitoring obligations under the EU MSFD, and other Directives.

2.3.7 Harmonising MSFD and MSPD

To harmonise the MSFD and the Marine Spatial Planning Directive (MSPD) is a challenging issue. However, Söderstrom and Kern (2017) discussed in their work the connections between marine spatial planning (MSP) as a part of the EU ‘blue growth’ strategy and MSFD and also that in previous works other authors considered these connections as ambiguous (Brennan et al. 2013). The authors argued that MSP can be seen as a tool of implementing MSFD and assisting its environmental objectives, and on the other hand it can be regarded as being based on the “three pillars” of sustainable development (social, environmental, economic), while MSFD only targets the environmental pillar. Indeed, MSP and MSFD could be seen as complementary policies. In this vein, the recent work of Elliot et al. (2018) deals with the need to explore approaches to meet the challenges that European countries face considering the need to harmonise the requirements of the MSFD (to achieve GES) and to have a coherent and integrated pattern of sea use as required by the MSP directive for all maritime states including, for Europe, the joint adoption of these two directives. Elliot and co-authors proposed in their work an approach based on a hypothetical example and a Best Expert Judgement (BEJ) methodology. The approach combines the expertise of main actors on a hypothetical marine scenario that allows the severity of the activity’s effects on GES to be determined (based on the 11 MSFD Descriptors), weighing the severity of the impacts according to the area of the footprint of each activity. The approach also permits the calculation of GES of marine regions, indicating whether the adoption of quality assessment and spatial planning can be mutually beneficial, or conversely if it might be antagonistic in meeting environmental targets. The work by Elliot et al. (2018) discussed this approach with the aim of maximising the use of a marine area but minimising environmental degradation due to new activities. This novel approach shows the role of BEJ in cases where marine adaptive management is still required, despite the frequent paucity of information or data on which to base management decisions.

Considering this need to harmonise MSPD and MSFD, and in the specific case of the vastness of the deep sea, predictive habitat models can be a useful instrument to better characterize the deep sea and also to establish monitoring programs following the predictions from the models. In this vein, Fernandes et al. (2018) developed a new approach for selection of high priority areas for conservation using Marxan software and cumulative impacts decision support tools. The study has been conducted in shallow areas. However, it is worth mentioning in the context of the deep sea as outputs from this study show the valuable contribution of these type of studies supporting the planning process when developing management alternatives. The work by Fernandes et al. (2018) illustrates how ecological goals can be better included to contribute to the Maritime Planning process and to highlight the usefulness of systematic planning that can be applied to support the connection between MSFD and MSPD.

2.3.8 The MSFD and marine goods and services in benthic ecosystems

In the context of the MSFD the preservation of the marine resources and ecosystems is a fundamental aspect, as are goods and services provided by the oceans to human beings. Indeed the GES definition included in the MSFD implies that ecosystem services and societal benefits should be taken into consideration when measuring GES. However, Borja et al. (2013) pointed out that these aspects are not mentioned in either the Descriptors or associated criteria. Several works deal with the goods and services provided by benthic ecosystems in European waters. However, the deep sea, and in particular benthic habitats, is mostly lacking in ecosystem services assessments (Armstrong et al. 2012, Thurber et al. 2013).

Galparsoro et al. (2014) assess and map the ecosystem services provided by benthic habitats in the European North Atlantic Ocean, in the context of the MSFD. The European North Atlantic Ocean (EEZ only) covers more than 4.5 million km^2, of which 26% corresponds to continental shelf (up to 200m depth), and 74% to deeper areas. At the time of publication of the work by Galparsoro et al. (2014), 88% of the continental shelf and 18% of the deeper areas had been mapped, accounting for 38.9% of the total EEZ area of the European North Atlantic Ocean. The results of the study by Galparsoro et al. (2014) provided a first assessment of the benthic ecosystem services at the Atlantic-European scale, displaying also ecosystem services maps and their general spatial distribution patterns. The authors make 2 conclusions. Firstly, benthic habitats provide a diverse set of ecosystem services, being the food provision, with biodiversity maintenance services more extensively represented. (Results indicated that more than 9% of the mapped area provides biodiversity maintenance and food provision services; meanwhile, grounds providing reproduction and nursery services are limited to half of the mapped area). Secondly, ecosystem services assessment categories are significantly related to the distance to the coast and to depth. (These are higher near the coast and in shallow waters - this gradient is likely to be explained by difficult access (i.e., remoteness and depth) and lack of scientific knowledge for most of the services provided by distant benthic habitats). However, as exploration of the deep sea improves with recent technological advances, access to such habitats

(Ramirez-Llodra et al. 2011) will become less difficult, increasing the ecosystem services that they provide in the near future (Thurber et al. 2013).

The work by Broszeit et al. (2017) analyses whether a selection of GES indicators related to biological descriptors, D1, D2, D4 and D6, may provide information relevant to ecosystem services, potentially allowing use of collected environmental data for more than one purpose. The authors selected 7 marine ecosystem services from the published lists of indicators, comparing them to 296 biodiversity-related indicators included within the DEVOTOOL catalogue (http://www.devotes-project.eu/devotool/), established for screening marine biodiversity indicators for the MSFD. After several analyses conducted (see Broszeit et al. 2017) the authors concluded that 247 biodiversity indicators were identified as potentially useful ecosystem service indicators. By highlighting the comparability between ecosystem service and biodiversity indicators it is hoped that future monitoring efforts can be used not only to ensure that GES is attained, but also that ecosystem service provision is maximised. It is recommended that these indicators should be tested across EU regional seas to see if they are useful in practice, and if ecosystem service assessments are comparable across regional seas.

A recent work authored by Norton and Hynes (2018), estimates the value of non-market benefits associated with the achievement of GES. The authors combine contingent valuation method (CVM) and value transfer (VT). The first method is based on questionnaires carried out with individuals given a hypothetical situation, valuation of willingness to pay (WTP) or willingness to accept (WTA) a change to the goods or service being valued by the respondents. As CVM can be costly and time-consuming, VT can be an alternative approach (this approach includes spatial elements such as distance decay and population density). Norton and Hynes (2018) explores impact of distance decay on welfare estimates as well as the impact from the modifiable area unit problem (MAUP) when population density is included as an explanatory variable. These issues can have a large effect on a VT estimate. In the study, the overall value for achieving GES for Atlantic member states varied between € 2.37 billion and € 3.64 billion.

2.4 Assessing GES in the Deep-sea

Since publication of the MSFD and further subsequent decisions of the commission, as well as the work on the IE conducted by European countries, many institutions and scientific teams have been working to refine the definition of GES. Further advances have been made in trying to improve and adapt the indicators to different countries and regions and also to develop indexes and tools to assess GES. Further, much work has been done in evaluating the scales for assessing GES and more generally towards ways to approach GES assessment. Considering all this work, it is remarkable that none has specifically addressed the GES concept and assessment in the deep sea. The deep-sea realm was considered in some of the IE from some countries (see previous chapter), but mostly this focused on specific habitats or ecosystems. In all cases the lack of information for the deep-sea realm has been highlighted, and in most cases the impossibility of GES assessment has also been noted. For instance, Teixeira et al. (2016) noted that the number of indicators decreased noticeably from shallow to deep waters, due among other factors to the lack of sampling.

Main gaps in the assessment of GES in the deep sea that have been mentioned in the literature and also in the ATLAS kick-off meeting (Edinburgh 2016) are:

- **Lack of data** for most regions. Existing data correspond to small areas and the information is scattered
- Information in **pressures and impacts is also scattered** and refers to specific zones
- **Lack of baseline and reference status** to refer to assessment of GES
- **Difficulties in setting boundary values**

Next we include some of the results presented in the scientific literature regarding the assessment of the environmental status of deep-sea areas. The literature research we performed revealed that the published works focus from one side on the assessment of the impacts caused in the deep-sea by bottom-trawling activities and from the other on the importance of GES assessment in the context of MSP. A short subsection is included presenting briefly IDEM, a European project aiming to assess GES in the Mediterranean deep sea.

The fact that the lack of data from the deep sea is an important handicap when assessing GES, has been stressed by Crise et al. (2015) in their paper, in which the European project PERSEUS aimed to identify the most relevant pressures exerted on the ecosystems of the Southern European Seas. Several scientific papers, which include also deep-sea areas, analyse the effect of bottom trawling on benthic communities using Biological Traits Analysis (BTAs) (e.g. Tillin et al. 2006, de Juan et al. 2007, de Juan and Demestre 2012, van Denderen et al. 2015). Indeed it is well known that among the anthropogenic impacts affecting the sea floor, bottom trawling is the most widespread physical human disturbance in the seabed and produces a wide range of direct and indirect impacts on benthic ecosystems. In this line, Korpinen et al. (2013) presented a method to assess the quantity and distribution of anthropogenic impacts on benthic habitats in the Baltic Sea by using spatial data of human pressures and benthic habitats. The interesting aspect of this paper in the deep-sea context is that they performed this study including shallow and deep-sea areas. The authors concluded that over the entire sea area, deep-sea habitats were more impacted than shallower infralittoral and circalittoral habitats. Indeed they found that almost no deep-sea habitat was undisturbed (< 1%) and the widest impacts were estimated for sand and coarse-sediment habitats (68% and 75%, respectively). The authors also made an attempt to establish thresholds and evaluate GES, concluding that in the sub-basin scale only one third of the habitat types were in GES. Regarding the evaluation of "physical loss pressure" (PL) within the MSFD frame, mapping of pressures in a standardized and comparable way is an important step to assess the spatial pattern of the impacts caused by human pressures as well as how this pattern changes through the time. In this context, Paganelli et al. (2017) proposed a method to estimate the spatial extent of PL pressure overlaid with the distribution of the seabed habitats to estimate the loss of biogenic substrates. The study is a valuable contribution as it establishes baseline conditions for PL pressure in order to compare the current situation with future conditions and evaluate different possible management scenarios.

In this regard, seabed mapping is increasingly being used to characterise substrate type (see section 2.1.3.4), using tools such as multibeam echosounds (MBES) and MBES-borne backscatter surveys, which are becoming a useful methodology to detect, analyse and quantify changes in the characteristics of the seafloor. The recent work by Montereale-Gavazzi et al. (2018) tests preensemble and post-classification approaches of the seabed features in a specific area of the North Sea; the authors detected that fauna growth was constrained by sand coverage or increased turbidity levels, which could result from anthropogenic activities. In this work, therefore, monitoring of gravel:sand ratio was considered to be a relevant indicator of GES in a 9 years survey program. The results display a fluctuating but on average stable gravel:sand ratio. Further, the two-dimensional morphological analysis, based on the bathymetric data, suggested a loss of profile complexity across the time period of the surveys. The methodology presented by Montereale-Gavazzi et al. (2018) is repeatable and can be applied to broad scale geographical extents if long-term data sets are available.

Within the same topic of analysing the effects of anthropogenic impacts in deep-sea habitats, in a recent paper, González-Irusta et al. (2018) present the index they developed which aims to classify species (using biological traits) according to their sensitivity to bottom trawling: the BEnthos Sensitivity Index to Trawling Operations (BESITO). The index has been applied using 8 biological traits whose selection was based on the general knowledge of trawling impacts on epibenthic communities in previous works using BTAs to determine (see Gónzalez-Irusta et al. 2018 and references therein). In order to assign the weight of the traits in the BESITO formula, the variation in the relative biomass of each trait's level was analyzed. The index successfully classified the species analysed according to their sensitivity to trawling, allowing modelling of the impact of trawling disturbance on sensitive species, without the masking effect of opposed responses. González-Irusta et al. (2018) concluded that the BESITO index has been successfully tested in a broad and complex area and they believe this will help develop a list of species classified according to their sensitivity to trawling. Such a list will be of high relevance for national and international legislation (MSFD, HD). It is however worth considering that in many cases deep-sea ecosystems are VMEs where bottom-trawling surveys do not take place. This makes application of indexes based on biomass values difficult for these ecosystems.

Assessment of GES is fundamental for proper Marine Spatial planning (MSP), which is emerging as a tool for organising uses of the marine environment, while preserving its quality. The work by Gilbert et al. (2015) deals with this issue and the authors argued that there is a clear need for MSP, but at the same much care must be taken with MSP, as the spatial and temporal scales of maritime activities and of GES may be mismatched. Gilbert et al. (2015) identified in this work four principles for careful and explicit consideration to align the requirements of the MSFD and MSPD and enable MSP to support the achievement of GES in Europe's regional seas. Detailed information is given in the paper by Gilbert et al., but due to the importance of this issue and the close relationship between MSFD and MSPD we include here the four principles:
"(1) A given plan will need review and modification if achieving or maintaining GES in the planned area is threatened. To support effective implementation, robust governance and institutional arrangements, supported by an EU directive, are needed, (2) As GES is to be achieved at subregional or regional sea levels (MSFD, Article 3[5], Article 4; EU 2008), MSP needs to be coherent at multiple spatial scales, (3) Maritime activities that are less amenable to review, and with the potential to adversely affect place-specific descriptors, i.e., D7, D11, and D6, require explicit and careful examination during the preparation of the EIA as required under the Directive on Strategic Environmental Assessment (Directive 2001/42/EC; EU 2001) and (4) MSP's environmental objective means that it needs to address cumulative effects and make trade-offs between pressures and

environmental effects. Frameworks to assess effects, together with a stakeholder process, are needed for effective resolution of conflicts between maritime uses and the marine environment."

To illustrate these principles, Gilbert et al. (2015) present some case studies in the paper. One of those is located in deep-sea areas, as it deals with the *Lophelia pertusa* reefs, a paramount example of a deep-sea benthic structuring organism for which the destructive effect of fishing has been demonstrated (Hall-Spencer et al. 2002, Davies et al. 2007), implying also a cost to the fishing industry through damage or loss of nets. The case study analyses the sustainability of deep-water fisheries and cold-water biogenic reefs, and the effectiveness of establishing MPAs, to conserve *Lophelia pertusa* (Hall- Spencer et al. 2009). Beside the protective effect that could have direct effects in achieving GES, the designation of such areas also has an MSP meaning. In this specific case study several GES descriptors interact with the MPA planning of this study (D1, D3, D4, D6 and D10). Of the descriptors specifically considered in ATLAS, for D1, planning for a "no-take" MPA could prevent further destruction of reefs and preserve habitat/nursery areas for associated species; for D3, requiring healthy stocks of commercially exploited species, good MSP would result for instance in more fish moving in and out of the MPA, which would in turnresult in restored stocks in the MPA, a positive result for MSP; and finally, the end of trawling activities should lead to the recovery of benthic communities within the MPA (Hiddink et al. 2006), contributing to D6. The decrease in remains of fishing nets contributes also to a reduction in marine litter, D10. This case study demonstrates the potential of MSP to benefit maritime activities and the marine environment. This positive outcome is affected by three factors that create a win–win situation. Firstly, *Lophelia pertusa* is a stationary species supporting reef communities found at specific locations, although the species being fished are mobile. The benefits of MPA protection given to specific sites extend beyond the sites. Secondly, fishermen wish to avoid reefs to protect their gear and so may tolerate exclusion zones. Thirdly, the environmental effects of both maritime activities are on-site and spatially contained, and so can be planned. This case study exemplifies the connection between different MSFD descriptors as well as the importance of assessing GES in the MSP context.

2.4.1 The project IDEM (Implementation of the MSFD to the DEep Mediterranean Sea)

The aim of the IDEM project (funded under the European Union's Directorate General Environment) is to support the implementation of the MSFD in the Mediterranean deep sea through: a) the determination and assessment of GES and b) the configuration of environmental targets. In addition, the IDEM project will advance understanding of the distribution and impact of anthropogenic activities as well as the availability of data regarding the MSFD indicators in the Mediterranean deep sea.

The IDEM project is comprised of 9 partners (Università Politecnia delle Marche-Italy; Consiglio Nazionale delle Ricerche-Italy; Agencia Estatal Consejo Superior de Investigaciones Cientificas-Spain; Department of Fisheries and Marine Research - Ministry of Agriculture, Rural Development and Environment-Cyprus; Agenzia Nazionale Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile-Italy; Institut Français de Research pour l'Exploitation de la Mer – France; Tel Aviv University-Israel, Universitat de Barcelona-Spain; University of Malta - Malta); more information about the aims and objectives of IDEM project can be found in the project's website: http://www.msfd-idem.eu/.

3 The ATLAS approach

3.1 The challenge of ATLAS. Assessing GES is the North Atlantic deep sea

The ATLAS project is focused on North Atlantic deep-sea ecosystems. At the ATLAS kick-off meeting in Edinburgh in June 2016, a working group was assembled to identify the specific challenges of addressing GES in the deep sea. Challenges identified were inherently related to the characteristics of this realm, which can be summarized as:

- The **remoteness** of the deep-sea realm and the inherent difficulties in conducting sampling (e.g. for biodiversity assessment)
- The **high costs** associated with deep-sea research
- The **relatively short history** of deep-sea research and hence still scarce data available
- The nature of the deep-sea gathered data which is not only **scarce,** with frequently **isolated records**, but also **very scattered**
- The **lack of long-term series** and difficulty in establishing any **monitoring programs**
- The **lack of a baseline (e.g. pristine conditions of CWC reefs, deep-sea sponge grounds)**
- Many deep-sea ecosystems are included with the Vulnerable Marine Ecosystems (VMEs) where the most appropriated methods of sampling are **non-invasive** (mostly image methods) which have limitations for studies of biodiversity and for general taxonomical identification
- Many deep-sea species are **low resilient**, displaying **slow growth rates** and **late maturity** traits
- The selection of relevant **SMART[10] indicators and targets** for the deep sea is challenging.

After this first workshop within the ATLAS kick-off meeting, in subsequent annual general assemblies (2017 and 2018) specific sessions have been organised to address the GES work within the project.

The working group also considered:

1) the results from the first evaluation of the GES in the different countries;
2) the Commission Decisions from 2010 and especially from 2017; and
3) the special characteristics of the deep-sea mentioned above.

The approach in defining "what constitutes GES" in the deep sea could include the following aspects:

Due to the specific biological and ecological known characteristics of the majority of the studied deep-sea species, recovery rates after impacts can be very low or nonexistent; hence the application of the precautionary principle is fundamental in any assessment of GES in the deep sea. Also, considering the increasing (global warming, ocean acidification) and future threats (mining), addressing GES in any regional assessment including the deep sea needs to take into account these future scenarios.

3.2 The approach of the ICES WG DEC to assess GES in the deep sea

[10] SMART (Specific, Measurable, Attainable, Relevant, Time-bound)

The annual meeting of the ICES group WGDEC conducted in 2017, included as one of the ToR: "Begin to explore how to best define Good Environmental Status (GES) for deep-sea habitats; in particular, commence a review on progress with indicator development for the deep sea – ToR [b]". This work has been conducted in the light of the ATLAS project work that started at that time to approach the issue of GES and the deep-sea realm.

In the following paragraphs, a summary of the work conducted within this ToR is presented. The full contents of ToR b are included in **Annex I**, as attached document to this deliverable.

As already highlighted in section 2.1.1 of this deliverable, the ICES scientific community and associated partners have worked towards providing scientific guidance to define GES indicators and standards. The OSPAR Commission has also worked on developing methodologies and guidelines relevant to determining GES, in particularly for the descriptors addressing biodiversity, food webs, eutrophication, contaminants, litter and noise, and recently also seafloor integrity (see section 2.1.2 of this deliverable).
To further facilitate implementation, the European Union 7th Framework Programme (FP) project DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status) has built a catalogue of models and their derived indicators to assess which models provide information about indicators outlined in the MSFD, particularly for the biodiversity, food web, non indigenous species and seabed integrity descriptors (Piroddi et al. 2015). Another important output from DEVOTES is the software package NEAT (The Nested Environmental status Assessment Tool), which has been developed to support the integrated assessment of the status of marine waters (e.g. Uusitalo et al. 2016). To explore how best to define GES for deep-sea habitats, WGDEC 2017 undertook a review of progress with indicator development for the deep sea.

Road map to assess GES in the deep sea
Since evaluating GES for the deep sea has not been discussed in detail, it was agreed at WGDEC to start developing a road map to outline the process and explore the concepts necessary (**Figure 11**). As described in Prins et al. (2014), the first question that needs to be addressed is "What is the appropriate ecosystem component level (species, habitat and ecosystem) and spatial scales for the assessment of GES in the deep sea?" **During the ATLAS kick-off meeting (June 2016, Edinburgh), it was agreed that addressing GES for habitat and ecosystems (rather than species) would be more appropriate to the deep sea, due to sampling and taxonomic constraints**.

To appropriately address GES in the deep sea, a review of the work done previously on the development of indicators should be performed. A number of EU and national projects have been developing indicators to address GES in different ecosystems (e.g. DEVOTES, Options for Delivering Ecosystem-Based Marine Management (ODEMM) and MarLIN4) together with work done in ICES Working Groups (e.g. Working Group on Marine Habitat Mapping (WGMHM)). As most indicators have been developed for coastal and shallow-water ecosystems, it is necessary to review existing information and evaluate which indicators can be applied to assessing GES in the deep sea. The descriptors considered useful to start the evaluation process of GES in the deep sea are:

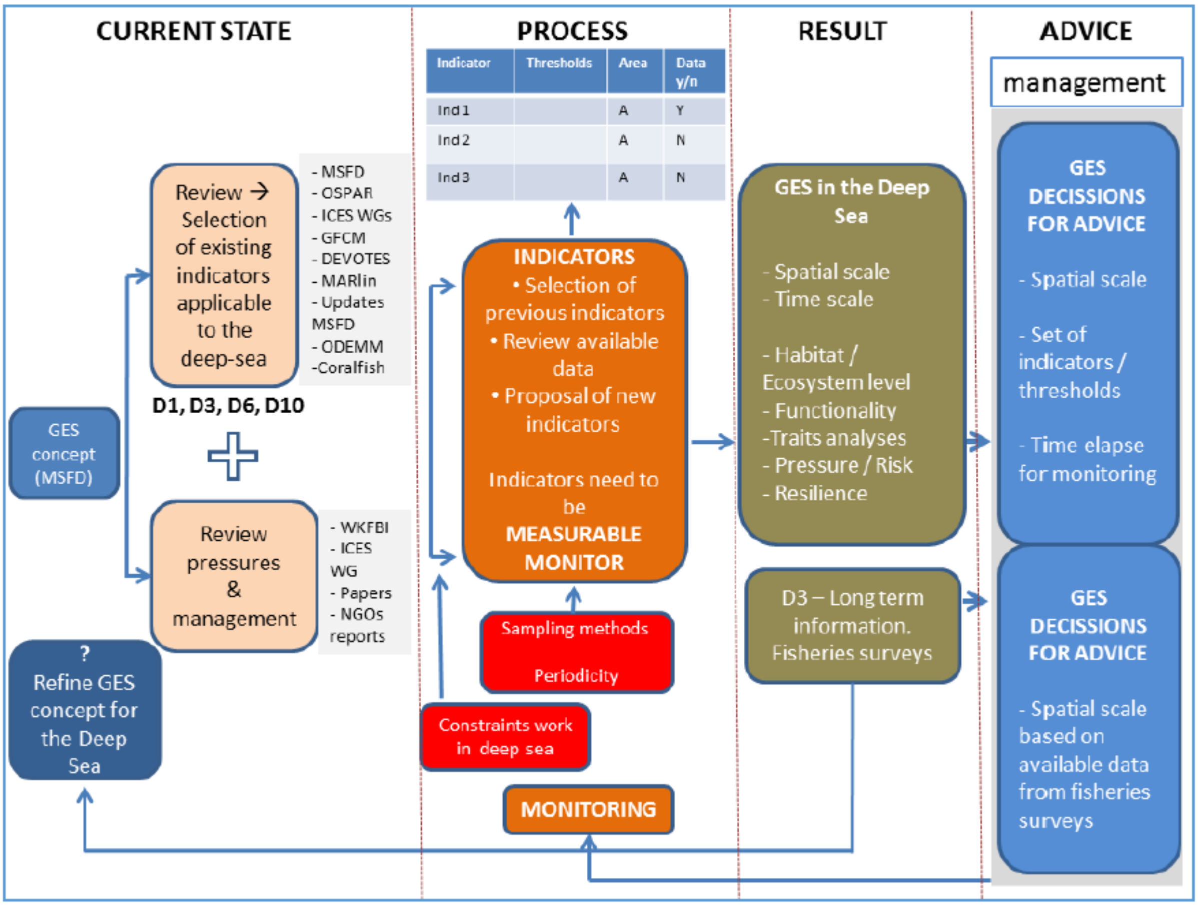

Fig. 11 *Preliminary concepts and road map to best address GES in the deep sea (source: WGDEC report 2017)*

D 1 Biodiversity

Criteria used to evaluate D1 should work on different ecosystem components (species, habitat and ecosystem) and at spatial scales. Due to the lack of information for most parts of the deep sea, evaluation of biological diversity indicators will likely remain at a habitat and ecosystem level and at a broad scale.

D 3 Commercial fish and shellfish

Criteria for evaluating Descriptor 3 should be developed in collaboration with existing ICES working groups such as WGDEEP and may consider the level of pressure of the fishing activity, the life history of the considered species and the population structure of the fishing stocks.

D 6 Seabed integrity

Criteria to evaluate Descriptor 6 should also be developed in collaboration with existing ICES working groups (e.g. WG Marine Habitat Mapping), workshops such the WKFBI (workshop on guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats) or the WKBENTH (workshop to evaluate regional benthic pressure and impact indicator(s) from bottom fishing). D6 may address both the level of physical damage to the seabed as well as the status, focusing mostly on the functionality of the benthic community.

D 10 Litter
A number of peer-reviewed papers have begun to address litter in the deep sea (e.g. Ramirez-Llodra et al. 2011, Pham et al. 2014, van den Beld et al. 2016).

Additionally, a further review of past, current and future pressures in the deep sea is needed, in addition to management measures. Previous work on this subject should be included in the revision (e.g. reports from ICES WGs).

Process of developing indicators
After a careful and comprehensive review of the existing information, a selection of existing indicators should be conducted. Furthermore, a review of the available data to apply these indicators has to be performed. New indicators may also need to be proposed considering the specific constraints of working in the deep sea (e.g. remoteness, difficulties conducting scientific surveys and sampling in deep-sea areas, lack of baseline data) and the main characteristics of these ecosystems. The selection of indicators should ensure they are SMART (Specific, (Re-) Measurable, Attainable, Realistic and Timely). Furthermore, the selection of indicators for the deep sea needs to take into account:

- The sampling methods used in deep-sea scientific surveys (e.g. towed cameras, ROVs);
- The often low periodicity of the surveys (impacting opportunities for monitoring).

Once the indicator list exists, WGDEC suggest developing a matrix (see Table 4.1 in **Annex I**), for the different indicators, indicating applicable habitat type and area, thresholds indicating degraded habitat (whenever possible) and whether data are available or has to be collected. Indicators for D 3 may be straightforward to define as the information gathered from the fisheries surveys is standardised.

Results of the application of GES deep-sea (DS) indicators
As a result of the selection and development of indicators, a set of GES-DS indicators will be applied to delineated areas, remembering that not all indicators will be applicable to all areas. Considering the spatial scale on which GES should be assessed is an important consideration in the deep sea. In Europe, the MSFD provides a means of setting boundaries for spatially managed areas. The FP7 project “Monitoring and Evaluation of Spatially Managed Areas” (MESMA) has developed a generic framework to facilitate marine spatial plans. The MESMA framework comprises a series of steps that can be completed, to a greater or lesser extent, to evaluate/propose an existing or new management plan for a given spatially managed area (see Figure 4.2 in **Annex I**).

Knowledge of the impact footprint of human activities operating in the deep sea will inform the extent of areas required to manage these activities. This will subsequently inform over what spatial scale GES should be evaluated. The ATLAS project will apply the MESMA framework to develop marine plans to support Blue Growth scenarios in 12 case studies located in different jurisdictions across the Atlantic.

Time-scale is another important issue, especially regarding monitoring. Ten years may be an appropriate time-scale, and also realistic, taking into account the probability that a scientific survey will revisit a specific site. This does not apply to D3 as fisheries surveys take place at a higher frequency and hence more regular monitoring is expected.

Beside spatial and time-scales, some other aspects were identified during discussions by ATLAS partners and during this meeting of WGDEC. These include:

• Biodiversity (D1) will generally be addressed at biotope/habitat/ecosystem except where species determinations are unambiguous, e.g. *Lophelia pertusa*.
• The seabed integrity (D6) will focus on ecosystem functionality due to the lack of a baseline for other indicators and the difficulty of obtaining data in the deep sea for commonly used indicators such as abundance/biomass measurements.

Furthermore during this WGDEC meeting it was agreed to consider:

• Trait analyses;
• Pressure/risk assessment;
• Habitat/ecosystem resilience.

The results of the analyses could be displayed in a table similar to **Table 2** below, where the different habitats considered in an area as well as the different indicators would be displayed and the status presented in a general way using a simple traffic light system (red, amber, green). An easy-to-read table would be more useful (even if very simplified) for managers.

Area	Habitat 1	Habitat 2	Habitat 3	Habitat 4
Indicator 1				
Indicator 2				
Indicator 3				
Indicator 4				

***Table 2** Example of a potential way of displaying the environmental status evaluation of an area. Legend: red= good environmental status not achieved; yellow= good environmental status partially achieved; green= good environmental status achieved (source: WGDEC report 2017)*

For D3, the indicators might be similar to the ones already being used in the assessment of GES of assessed stocks in coastal and shelf seas (ICES 2012); e.g. Spawning–Stock Biomass (SSB), Fishing mortality consistent with achieving Maximum Sustainable Yield (FMSY), Spawning–stock biomass (SSB) that results from fishing at FMSY for a long time (BMSY), fishing activity, the life history of target species, and the population structure of the fishing stocks). The spatial scale for D3 assessment might be limited to the existing fishing grounds, from where most fisheries surveys are conducted. However, D3 should also address non-assessed stocks with alternative techniques (e.g. ROV transects) and indicators, and also on non-fishing grounds. It should be noted that trawling impacts seabed integrity (D6) which may require a broader spatial assessment due to downstream effects of resuspended sediments. Time-scales for evaluating assessed stocks may be defined by fisheries survey periodicity. In the specific case of D3 the lack of baseline information (as was the case for the benthic ecosystems) is not an issue for assessed stocks, since long-term data series may be available allowing analysing the GES and trends over time. A potential easy-to-read table for summarizing D3 is shown in **Table 3**. Such a table may be prepared for each spatial area including the different analysed fish stocks and a GES status will be added into the table for each analysed indicator.

Area	Fish stock1	Fish stock2	Fish stock3	Fish stock4
Indicator 1	red	yellow	yellow	green
Indicator 2	yellow	yellow	yellow	yellow
Indicator 3	yellow	yellow	green	green
Indicator 4	red	yellow	red	yellow

Table 3*. Example of a potential way to display the environmental status evaluation of the fish stock in an area. Legend: red= good environmental status not achieved; yellow= good environ-mental status partially achieved; green= good environmental status achieved (source: WGDEC report 2017)*

Combined analyses of multiple GES descriptors in a spatially managed area should help to identify areas where accumulated impacts of overlapping activity footprints have the potential to lead to environmental degradation, such that GES will no longer be achieved. Mitigation actions will then need to be proposed. A better understanding of the factors leading to accumulated impacts will also be important in this regard.

Conclusions WGDEC 2017

The temporal and spatial scale on which GES should be assessed in the deep sea is an important aspect to be considered and which will need further discussion. Due to the data-limited situation and challenges posed for monitoring, it may well be the case that GES will have to be assessed at large spatial and temporal scales when compared to the shallower waters of the European Seas. For similar reasons, the type of indicators to be used may have to be simplified and likely be based on high level analyses related to traits, pressures/risks, and habitat /ecosystem resilience. Ultimately, the results of the combined analyse of GES descriptors may lead to a potential refining or redefinition of the GES concept for the deep sea.

3.3 ATLAS GES definition for the deep-sea realm

The ATLAS GES working team together with the case study leaders of the European case studies agreed the following definition for GES in the deep sea (which has been also presented previously this year, as an ATLAS milestone):

"GES in the deep sea means the extraction of living marine resources is occurring at sustainable levels and the extraction of non-living resources do not produce significant adverse impacts that can cause serious harm in the whole ecosystem, i.e. the levels of extraction ensures the continued delivery of goods and services for future generations. In particular, deep-sea GES is achieved when habitat-forming species are in a 'good' condition, as defined by acting as biodiversity hotspots and ensuring the functionality of the system, including the associated benthic, suprabenthic and demersal components. Areas dominated by soft sediments (e.g. the abyssal plains) maintain biodiversity at a level that ensures persistence of functional groups and thus ecosystem function. Impacts on the seabed and their effects on benthos and fish (commercial and non-commercial

species) do not increase the risk of an altered or lost ecosystem functioning, ensuring the sustainable use of deep-sea resources and the continued resilience of ecosystems in the face of a changing climate.”

3.4 Assessing GES in the deep-sea using the software NEAT

In the IE from the countries presented in the first part of this deliverable, the deep sea was not addressed and only specific habitats have been included in some cases (e.g. the carbonate mounds in Ireland or the CWCs habitats in Azores); overall the lack of information on occurrence and extension of the deep-sea habitats as well as a baseline was highlighted. There is even less information available on functionality of the deep-sea habitats.

Consequently, addressing GES in the deep sea is not an easy task. Within the ATLAS project we aim to measure GES by applying tools such as the one developed by the FP7 DEVOTES project and the ICES HELCOM working group. During the second ATLAS general assembly we counted on Dr. Urraya, one of the DEVOTES members and directly involved in the development of NEAT, a software tool specifically develop within DEVOTES to address GES. At that time the ATLAS community agreed to try to apply NEAT as an evaluation tool to address GES in the deep sea. Obviously there are other tools, multimetric indexes and approaches that can be apply to the specific case of the deep-sea, but given the impossibility of testing all of these, we decided to work with NEAT which we consider has the following advantages:

- NEAT has been developed within a European Project fully dedicated to the MSFD
- It is a software that has been specifically developed to assess GES based in a nested analyses (Borja et al. 2016) and is continuously being updated including new elements to make it more effective and precise
- It is a flexible tool and it is possible to conduct assessments with a low number of indicators (the interpretation of the results needs to be done accordingly with the level on information included in each assessment)
- The software already has a large list of indicators for the different descriptors but also new indicators can be added
- It is easy to handle and assessment outputs are straightforward
- The tool has been widely tested and it has been already used in several assessments and there are publications where GES has been assessed using NEAT (e.g. Uusitalo et al. 2016, Nemati et al. 2017, 2018, Pavlidou et al. 2019)

One of the weaknesses of the method is that it is not possible to incorporate “data uncertainty” - an important problem in the deep sea - where the information is scarce and the set-up of boundaries is in some cases “arbitrary” or based on known values from data series (for which, however, it is difficult to ascertain if they respond to a “worst” or “best case” as with NEAT).

Other aspects regarding the tool have been discussed in the specific case studies and at the end of the document a general discussion has been included.

3.4.1 Using NEAT in ATLAS

Brief presentation of NEAT

NEAT is an acronym for "**Nested Environmental status Assessment Tool**" and the NEAT software is an implementation of Nested Environmental Assessment Tool used for assessing the environmental status (GES) of marine areas according to the MSFD. NEAT itself as an assessment method is not restricted to the MSFD but can be used for various other assessment needs. NEAT was one of the outputs of the FP7 project DEVOTES and in the webpage http://www.devotes-project.eu/neat/, an overview of the principles applied in NEAT is presented as well as explanations on the use of the software and advice on how to best utilize the software for making a solid GES assessment for any MSFD descriptor.

Independently of using NEAT or any other assessment approach one of the first steps in assessing GES is to develop a set of indicators appropriate for the descriptors of the MSFD. In ATLAS, 4 descriptors have been assessed: D1, D 3, D6 and D 10. As in Springer 2017, a new decision of the EU commission has been published, where merging of descriptors took place (as D1 is now embedded mostly in D6) and new criteria has been selected. This has been also taken into consideration when defining the indicators set for each descriptor.

It is important to highlight that we decided to keep D1 as we consider it important to take into consideration non-commercial demersal fish species, which will otherwise disappear from the assessment.

In the next sections the process followed in ATLAS to assess GES is explained in detail.

In **table 4** the chronology of the process and steps followed is included.

3.4.1.1 Agreement on indicators selection from NEAT and development of new ones specific for the deep-sea

The first step followed was the selection of indicators to assess GES in the deep-sea. As the NEAT tool has a comprehensive list of indicators, we analyse this existing list to prepare an initial table with all potential indicators suitable to address D1, D3, D6 and D10. Mostly indicators appropriated for deep-sea benthic ecosystems and demersal species (commercial or not) have been selected. As D10 has been never been addressed by NEAT, new indicators were developed within ATLAS.

In a first stage we show a table where 305 indicators were included as well as the four addressed descriptors and it has been submitted to Case Study (CS) leaders for selection, so that each CS leader can decide which indicators are considered suitable to assess GES after expert opinion and knowledge of the CS areas. Further, some CS leaders suggested new indicators specifically for the deep sea. This table is included in **Annex III**.

Indicators voted by 80% of the CS leaders were then selected for shortlist. The only exception was indicators for D3 where the level of agreement was lower and we decided to reduce the threshold level to 65% to ensure a sufficient list of indicators. As NEAT did not include any indicators for D10, all considered indicators for this descriptor in this analyses are new (some of them inspired in the indicators suggested in the original document of the MSFD). **Table 5** includes the short list of indicators agreed by CS leaders.

3.4.1.2 Creation of a publication database including quantitative values to address indicators (set-up of boundary values)

Once the indicators were selected, each CS leader has been working to explore the available data for each case study as well as the ways to measure some of the selected indicators.
One of the most challenging aspects in the task of evaluating GES is to set up boundary/reference values.
Aiming to help CS leaders in this task, a comprehensive literature review was performed in order to summarise the existing quantitative data for different areas, habitats and species groups. More than 300 scientific papers and reports were screened. The information was organised as follows: excel sheets for the following taxa/groups were prepared: *Lophelia pertusa*, *Madrepora oculata*, *Dendrophyllia cornigera*, gorgonians and black corals, sea pens, other cnidarians, sponges, other benthic organisms, fish, litter and human impact. For the three scleractinian coral species (*Lophelia pertusa*, *Madrepora oculata*, *Dendrophyllia cornigera)* there is quite a lot of information, especially for *Lophelia*, hence these three taxa have been treated separately.
For each excel sheet the information has been organised including the following columns: region, location, setting (this refers to habitat type, e.g. cold-water coral reef), depth, method (this refers to the methodology used to gather the data), species (in the excel sheets containing several species, for instance gorgonians and black corals, if the work refers to a specific species this has been included in this column), parameter analysed (this refers to the type of data gathered, for instance, density or biomass), findings (these are the data), GES indicator that can be tested, protection status (if any), human impact and reference/source of the data. The complete database is included as **Annex IV** of this deliverable.

Table 4 *Chronology of the process of assessing GES within ATLAS. The process started during the second General Assembly in April 2017.*

	2017									2018											
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Agreement of use of NEAT to asses GES	■																				
Selection of NEAT indicators by CS leaders		■	■	■	■	■	■	■	■												
Short table selected indicators to test NEAT in ATLAS									■	■											
Literature review for setting-up boundary values for NEAT analyses										■	■	■									
Agreement of short table of indicators in GA and first feedback from CS leaders on infos available for indicators													■								
Excel template to CS leaders to complete quantitative information available to test GES in each European CS with NEAT														■	■	■					
NEAT evaluation run															■	■	■	■	■	■	
NEAT interpretation results																■	■	■	■	■	
Preparation of D 3.1																■	■	■	■	■	■

__Table 5__ Indicators agreed by CS leaders to asses GES using NEAT

NEAT INDICATORS (> 65% AGREEMENT FOR D1 for non commercial fish species and > 80% AGREEMENT for D3 & D6). We highlight with a pale red background new indicators we added, which are not included in the original list of NEAT indicators			
D1	**D3**	**D6**	**D10**
Distributional range and pattern of selected (sensitive) non commercial demersal fish	Abundance ratio of mature individuals of selected fish species	Abundance of coral colonies alive	Areal extent of litter: Type (e.g. plastic, glass)/abundance/density/weight
Species richness of non commercial fish	Age class structure of commercial fish	Areal extent of biogenic / vulnerable habitats (type, abundance, biomass, condition and areal extent of relevant biogenic substrata)	Density of abandoned fishing gear (e.g. lines, nets, etc.)
Abundance of non-commercial demersal fish and cephalopods	Age-frequency distribution of fish	Areal extent of human affected area	Colonisation on litter
Abundance of non-commercial functional groups of fish	Biomass of demersal fish	Areal extent of protected sea areas	Microplastics / Contaminats in sediments/organisms
Species diversity (Shannon index) of non-commercial fish	Biomass of selected fish species	Density of biogenic reef forming species (type, abundance, biomass and areal extent of relevant biogenic substratum per habitat type)	Number of organisms (e.g. coral colonies) entangled in fishing lines or nets
	Biomass of selected fish species (SSB - spawning stock biomass)	Distribution and condition of habitat forming species	
	Body length distribution of fish	Areal extent of sedimentary seafloor / vulnerable habitats (type, abundance, biomass, condition and areal extent of relevant sedimentary communities)	
	Body length distribution of fish in the community	Abundance and composition of functional groups in selected habitats	
	Fishing Effort	Species richness of corals	
	Large Fish Indicator (added by CS leader)	Ratio of live versus dead/overgrown coral cover	
		VMEs and VME indicator taxa (status, areal extent, size-frequency distribution)	
		Structural complexity	

3.4.1.3 Supply of data by CS leaders

Once the indicators were agreed and with the database with quantitative data ready to be used by CS leaders if needed, a template was created including the information required to assess GES using NEAT. This template was created with the invaluable advice fof Ángel Borja, PI of the DEVOTES projects and very familiar with the NEAT tool.

The template was created as simply as possible in order to facilitate the work to the CS leaders, but including the required information to work with NEAT.

Here we summarised the information required in the template:

- **Dimensions of the Spatial Assessment Unit/s** (SAUs) to be assessed. This could be a single one or several. Cs leaders were also asked to give their opinion on how representative the SAUs were for the surrounding area.
- **Habitat type**. Considering the scarce level of information and following the NEAT nomenclature, only pelagic and benthic were included; within the category "benthic", we only distinguished between sedimentary and rocky.
- **Ecosystem components**. Also considering the scarce level of information a short number of ecosystem components have been included: sediments (e.g. metals, organic matter, C/N, litter, microplastics…), benthic fauna (e.g. corals, sponges, polychaetes,…), benthos (indicators refering to the seafloor but not to alive elements), fish.
- **Data.** The available data for each case study were organised for each SAU, habitat type and ecosystem component. The addressed descriptor was also included as well as the indicator (all indicators agreed have been included in the template), a column where it was indicate of information for the indicators were or not available, and the measured unit (e.g. % of coverage). Then several columns were included to add the observed values ± (standard error) and the boundary values, three were mandatory: worst situation, moderate/good situation, best situation. Between these mandatory values three other categories could be added but they were not mandatory: bad/poor, poor/moderate and good/high.

During this process templates have been discussed among CS leaders and the GES-responsible team in ATLAS in order to refine the information, solve problems and in some cases remove data that were not possible to be analysed by NEAT. For instance in several cases and due to the impossibility in establishing boundaries by CS leaders, some initially added values have been removed, reducing the number of addressed indicators. This handicap will be discussed in the last section of the document.

All files filled by CS leaders are included in the **Annex Va** of this deliverable

3.4.1.4 Use of NEAT software in the assessment of GES

The analysis of data was carried out with software **N**ested **E**nvironmental status **A**ssessment **T**ool (NEAT hereafter), Version 1.3 (Berg et al. 2016).
As previously mentioned, ATLAS CS leaders were asked to designate Spatial Assessment Units (SAUs) in their case studies. SAUs are areas within a larger marine area (the parental one) which can be subdivided into smaller parts. All these parts form a nested hierarchy, so the assessment of GES can be performed for each of these individual SAUs or aggregate all those together for an overall assessment of the parental SAU.
Within each SAU, the CS leaders assigned each indicator to a "habitat" and an "ecosystem component" (**Fig. 12**). The subdivisions that can be created for habitats and ecosystem components depend on the amount of available information. So, if appropriate data are available, it is possible to have "sandy" or "muddy habitat" and not just "benthic habitats". The same principle applies to ecosystem components: If appropriate data are available, then the ecosystem component "fish" can be divided into subcategories like "demersal fish" and "pelagic fish".
For each of the combinations of SAU-habitat-ecosystem component-indicator, the CS leaders set up boundary values for classes of environmental status. In NEAT there are by default six categories of environmental status: worst, poor/boundary, moderate/poor, good/moderate, high/good and best (**Fig. 12**). The number of status classes is adopted from the assessment scheme of the WFD Since

many indicators used in the MSFD have their origin in the WFD, it is easy to use those indicators in NEAT (see Berg et al. 2016 for details).

The setup of boundary values for worst, good/moderate and best are essential in NEAT while for the rest categories of status, is optional. In the setup of the boundary values there is some flexibility since for the same indicator you can have different boundary values for different spatial assessment units, habitats or ecosystem components. Set up of boundary values was accompanied by the incorporation of measured average value and standard error for each of the combinations of SAU-habitat-ecosystem component.

When the setup of 1) the combinations of SAU- habitat-ecosystem component, 2) measured values and standard error, 3) boundary values was completed, the assessment could be carried out.

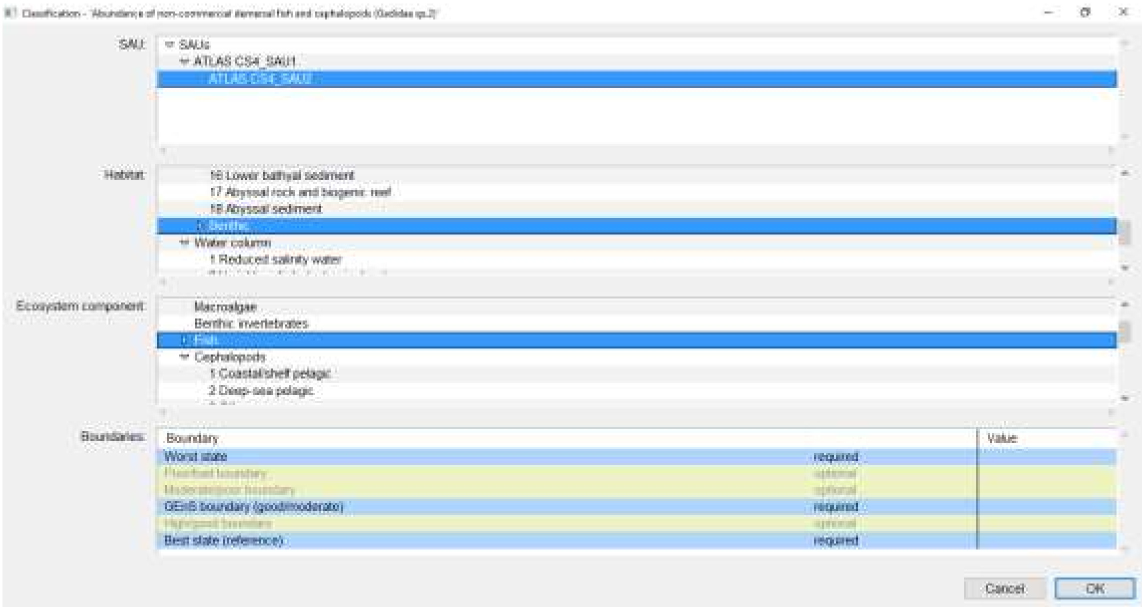

Fig. 12 *NEAT screen to set-up the combining indicators with SAU, habitats and ecosystem components. For each of these combinations measured values and standard error as well as boundary values for the six predefined in NEAT categories of environmental status were set. Setup of boundary values for worst, good/moderate and best status are essential while for other categories, these are optional.*

Calculation of the NEAT value and weighting

Since each indicator has its own measured values and boundary values (**Fig. 13**), all this information must be transformed into a common scale so that the assessment can take place. A common scale is achieved by using the custom boundaries of the indicators and transforming them piecewise (linearly) onto a normalized common scale. This common assessment scale is defined as follows:

0 <= bad < 0.2 <= poor < 0.4 <= moderate < 0.6 <= good < 0.8 <= high <= 1.

On the common assessment scale all five classes are equally broad (0.2 units). The GES boundary on the common assessment scale is the boundary between the moderate and the good status (= 0.6). The normalisation of the boundary values is accompanied by weighting. One of the reasons that weighting takes place is to account for the different spatial scales that may exist in the assessment. For example, a parental spatial assessment unit is divided into spatial assessment unit 1 which has a size of 900 km^2 and spatial assessment 2 which has a size of 100 km^2. This difference in the size between the two spatial assessment units will be taken into account in the assessment of the environmental status of their parental spatial assessment unit. Weighting takes place also to avoid the input of bias in assessments where there are more indicators in one habitat than another (e.g. 5 indicators in the pelagic habitat *vs* one indicator 1 the benthic habitat). In this way the dominance of the assessment by the indicators of one habitat over the other is avoided. In ATLAS case studies, the analysis was run with NEAT's default settings "Weight by SAU Area" (so that the size of each SAU will be taken into account in the assessment of environmental status) and "Do not weight by habitat area" (**Fig.14**).

Following the normalization and weighting mentioned above, the calculation of NEAT values is carried out. The NEAT value is the weighted average of all the indicators of a specific group. This group can be SAU, a habitat and an ecosystem component. NEAT value is expressed between 0 and 1 with these five categories of environmental status in between. In terms of the MSFD, the boundary value for GES would be at 0.6.

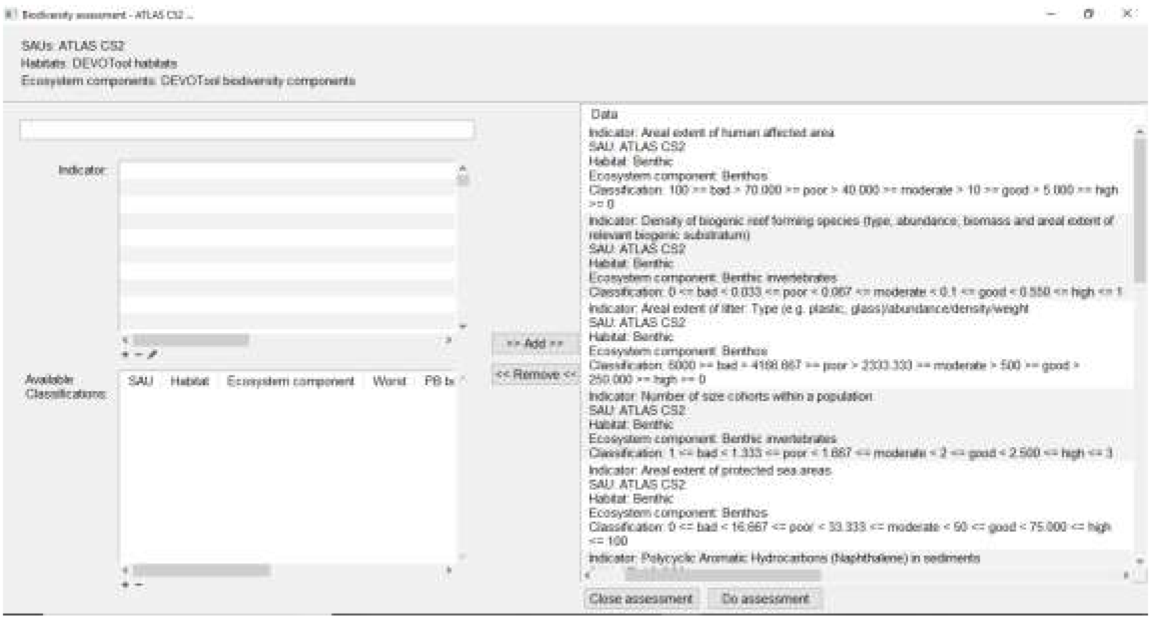

Fig. 13 *NEAT software provides the flexibility so set up different boundary values for each of the combinations of Spatial Assessment Unit (SAU) with habitat, ecosystem component and indicator.*

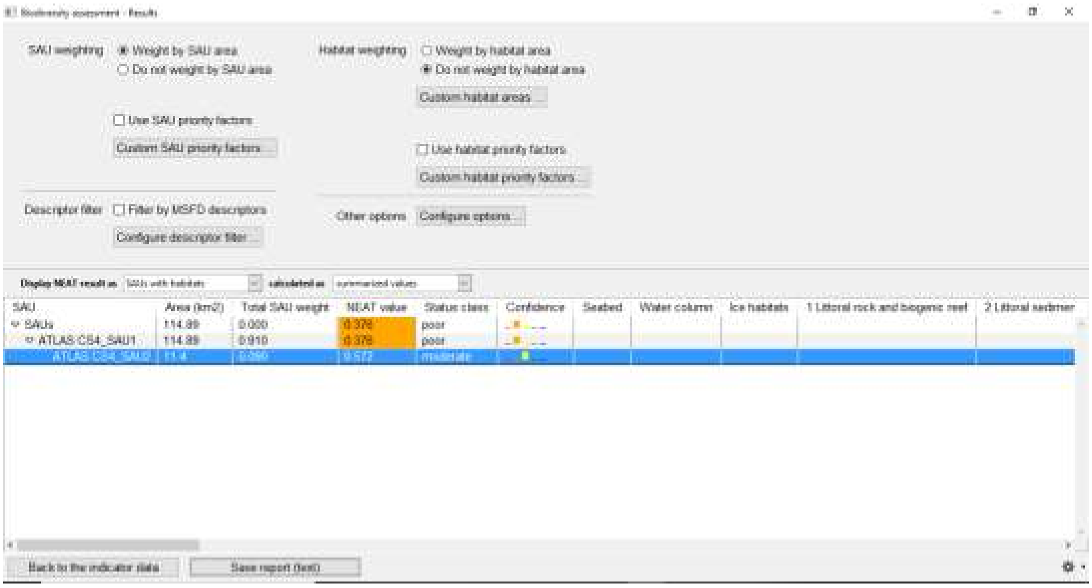

***Fig. 14** Running the analysis in NEAT with the default settings. Results can be presented either as a combination of "SAU with habitats" or "SAU with ecosystem components".*

The analysis of data in NEAT is accompanied by the provision of confidence data for the assessment (see the column "Confidence" in **Fig. 14**). Then height of the bar indicates the confidence in terms of the percentage with which the classification ended up in a particular class when doing simulated assessments based on the indicators' error values and a Monte Carlo simulation. From left to right the bars indicate the bad, poor, moderate, good and high classes (see Berg et al. 2016 for details).

3.4.2 NEAT Results and interpretation from CS leaders for the CS

All NEAT assessments for all case studies have been performed by the GES-team within ATLAS. To help CS leaders to interpret the obtained results another template has been prepared and distributed among case study leaders. The template included the results of the NEAT analyses and some text and guidance for the CS leaders to interpret and discuss results and also to let us know how satisfied they were with the results of the analyses. **Table 6** and **7** summarise the information supplied by CS leader.

In **Annex Vb** we include the template given o each case study leader to interpret and discuss the NEAT results. In the next sections, NEAT results for each case study and interpretation and discussion of the NEAT results from each CS leader are presented.

***Table 6** summary of the information supplied by CS leaders for the corresponding case studies to assess GES using NEAT*

	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
Total extension of case study area (km^2)	5700	5278	40797.804	114.89	35500	20308	38548.81	280	214.071
Extension of SAU consider for the analyses (km^2)	3250	5278	40797.804	114.89	35500	20308	4129.38	280	77.141
Number of habitat type selected	1	1	1	1	4	5	3	1	1
Number of ecosystem components	2	3	3	3	2	2	2	1	2

Number of indicators addressed	5	14	20	20	5	13	11	4	3
MSFD descriptors covered	D6	D3, D6, D8, D10	D3, D6	D1, D3, D6, D10	D6	D6, D10	D3, D6	D3	D1, D6

***Table 7** Summary of all information regarding for the ecosystem components, descriptors and indicators selected as well as the measurement units in each Case Study.*

Ecosystem component	Descriptor	Indicator	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
Fish	**D1**	Species richness of non commercial fish			Species richness per area	mean species richness / km					
Fish	**D1**	Abundance of non-commercial demersal fish and cephalopods			mean N/30 min trawl	# fish/km					
Fish	**D1**	Species diversity (Shannon index) of non-commercial fish			Shannon index						Shannon Index
Fish	**D3**	Body length distribution of fish								Length cm (total or fork depending on the species)	
Fish	**D3**	Biomass of demersal fish		Demersal landings (tonnes) from Scottish waters per ICES statistical rectangle (2012-2016)*							
Fish	**D3**	Biomass of selected fish species			mean biomass (kg) / 30 min trawl					CPUEb (kg fish/1000 hooks)	
Benthos	**D3**	Fishing Effort				VMS data (vessel density per $3km^2$)			Nr hauls per Km^2 per year		
Benthic Fauna	**D6**	Abundance of coral colonies alive	% of sea floor covered					%			
Benthos	**D6**	Areal extent of biogenic / vulnerable habitats (type, abundance, biomass, condition	% of sea floor covered			area covered by live coral, coral rubble (km^2)		%			

		and areal extent of relevant biogenic substrata)									
Benthos	**D6**	Areal extent of rocky seafloor / vulnerable habitats (type, abundance, biomass, condition and areal extent of relevant sedimentary communities)	% of sea floor covered					%			
Benthos	**D6**	Areal extent of human affected area	% of sea floor covered	% of sea floor covered	area (km^2) where surface swept area ratio is > 0.2 (or, one fifth) of the cell	% (open to static gear)		%	% trawled area		%
Benthos	**D6**	Areal extent of protected sea areas	% of sea floor covered		area (km^2)	% (completely closed to all gears)		%	km^2		%
Benthic Fauna	**D6**	Density of biogenic reef forming species (type, abundance, biomass and areal extent of relevant biogenic substratum per habitat type)	% of sea floor covered	ind/m^2		area covered by live coral (km^2)			nr colonies per m^2 (for 5 taxa)		
Benthic Fauna	**D6**	Distribution and condition of habitat forming species				area covered by coral mini-mounds (km^2)					
	D6	Areal extent of sedimentary seafloor / vulnerable habitats (type, abundance, biomass, condition and areal extent of relevant sedimentary communities)				area covered by live coral, coral rubble (km^2)		%			
Benthic Fauna	**D6**	Species richness of corals						coral taxa / image (aprox. 3m^2)			
Benthic Fauna	**D6**	Species richness of benthos			Species richness						

Benthic Fauna	**D6**	Ratio of live versus dead/overgrown coral cover	ratio live/dead coral cover			ratio live/dead coral cover		ratio live/dead coral cover			
Benthic Fauna	**D6**	VMEs and VME indicator taxa (status, areal extent, size-frequency distribution)				#VME indicator taxa per km2					
Benthic Fauna	**D6**	Number of size cohorts within a population		Number of size cohorts							
Benthic Fauna	**D6**	Average swept ratio for habitat					Dimensionless				
Benthic Fauna	**D6**	Weighted Swept VME Area Ratio					Dimensionless				
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Naphthalene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Phenanthrene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Anthracene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Fluoranthene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							

Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Pyrene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Benz[a]anthracence) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Chrysene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Benzo[a]pyrene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Benzo[ghi]perylene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							
Benthos	**D8**	Polycyclic Aromatic Hydrocarbons (Indeno[123-cd]pyrene) in sediments (concentration)		µg kg-1 dw (normalised to 2.5% Total organic carbon)							

Benthos	**D10**	Areal extent of litter: Type (e.g. plastic, glass)/abundance/density/weight		Items/km^2		#records of marine litter (number of items per minute of video tow)		litter per image			
Benthos	**D10**	Density of abandoned fishing gear (e.g. lines, nets, etc.)						fishing gear per image			

* Whenever possible, analyses have been carried out at species level

3.4.2.1 LoVe Observatory (Case Study 1) (Contribution from Dick van Oevelen and Tanja Stratmann)

Located in northern Norway (**Fig. 15**) for the LoVe Observatory Case Study two SAUs have been considered. The The LoVe obervatory is located along cold-water coral reefs in a glacial trough. The specific area studied is small, but representative for 'all' cold-water coral reefs found in this trough and probably for more CWC reefs along the Norwegian shelf. SAU 1 is a glacial trough with the cold-water coral reefs and SAU 2 the adjacent shelf-slope area.

Fig. 15 *Location of LoVe observatory (CS 1). a) location of the observatory, b) location of the two selected SAUs for NEAT analyses.*

For Love Observatory (CS1), the overall result for the analysed SAUs is that GES is achieved. Looking at the ecosystem components (benthic invertebrates and benthos), the first one which responds to the fauna displayed a moderate GES for the two analysed SAUs whereas regarding the affected seafloor the GES is optimal due to an almost complete lack of impacts in the area. However at habitat level, the overall result is that GES is achieved.

The CS leader and co-workers fully agreed with the result obtained from the NEAT assessment, which was consistent with their knowledge of the area and of the human pressures there. However, they were only moderately satisfied with the amount and quality of information they supplied to perform the NEAT analyses.

The data set used to analyse CS 1 (Lofoten – Vesterålen Ocean Observatory, LoVe) is based on a deep-sea observatory that was launched in September 2013. Hence, a five-year time series exists of ocean currents, water temperature, salinity, conductivity, turbidity, pelagic biomass estimates, still photos of the coral reef, and chlorophyll concentrations to assess GES and human pressure on the Hola trough.

***Table 8** results of the NEAT assessment for Case Study 1. LoVe Observatory. Indicators for D6 have been assessed.*

Assessment of ecosystem components & habitats								
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthic invertebrates"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Benthic"**
SAU	3250	0.000	0.616	Good	49.7	0.418	0.814	0.616
SAU_1	350	0.108	0.750	Good	100	0.567	0.933	0.750
SAU_2	2900	0.892	0.600	Good	44.8	0.400	0.800	0.600

The monthly available high-quality data from the observatory in SAU1 are concordant with the confidence of the GES assessment, but assessing the quality of the GES assessment for SAU2 is more difficult. The Hola trough has a very diverse topography, including sand waves (Bøe et al. 2009) and CWC reefs (Bøe et al. 2016). These reefs, however, require hard substrate and the sand waves are therefore not a suitable substrate, independent of human impact. Hence, to assess the NEAT value adequately for habitat "benthic" and in particular for "benthic invertebrates", a habitat suitability model should be developed for the Hola trough prior to the NEAT assessment. This habitat suitability model could give indications of where to expect which type of benthic fauna, especially where we might expect CWC reefs. A comparison of this model output with our actual observations could subsequently feed into the NEAT analysis.

Due to the high habitat variability we are rather hesitant to perform the NEAT analysis, not only for point observations of CWCs at the LoVE observatory (SAU1), but for the entire Hola trough (SAU1+SAU2). Almost all CWCs in the Hola trough occur inside the SAU1, which is a protected SAU1 area (**Fig. 15**). Therefore, performing a NEAT analysis that focuses mainly on cold-water corals gives less information. In order to assess GES of the entire Hola trough we would suggest performing additional analyses for sand waves and glacial lineations that are present inside and outside SAU1 (see **Fig. 16**). However, at present the data coverage at these specific locations is insufficient to perform a (detailed) NEAT analysis.

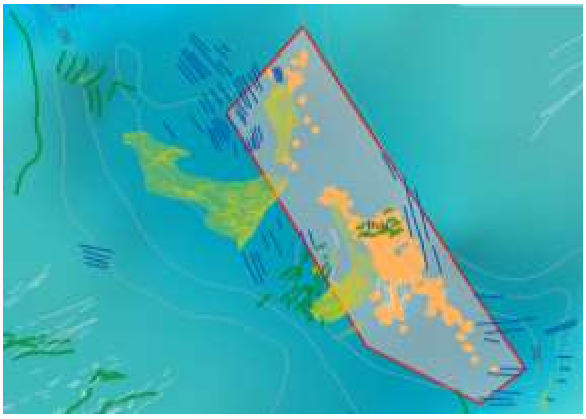

Fig. 16 *Map of the Hola trough. The red polygon shows the borders of SAU1. Orange dots indicate locations of cold-water corals, yellow lines are sand waves, blue lines show glacial lineation, white lines are current channels and dark-green lines present recessional moraines (Source: www.mareano.no)*

3.4.2.2. Faroe-Shetland Channel (Case Study 2) (Contribution from Georgios Kazanidis and Lea-Anne Henry)

The Faroe Shetland Channel is located between the Faroe and the Shetland Archipelagos (**Fig. 17**). The CS is included in the Sponge Belt Nature Conservation Marine Protected Area.

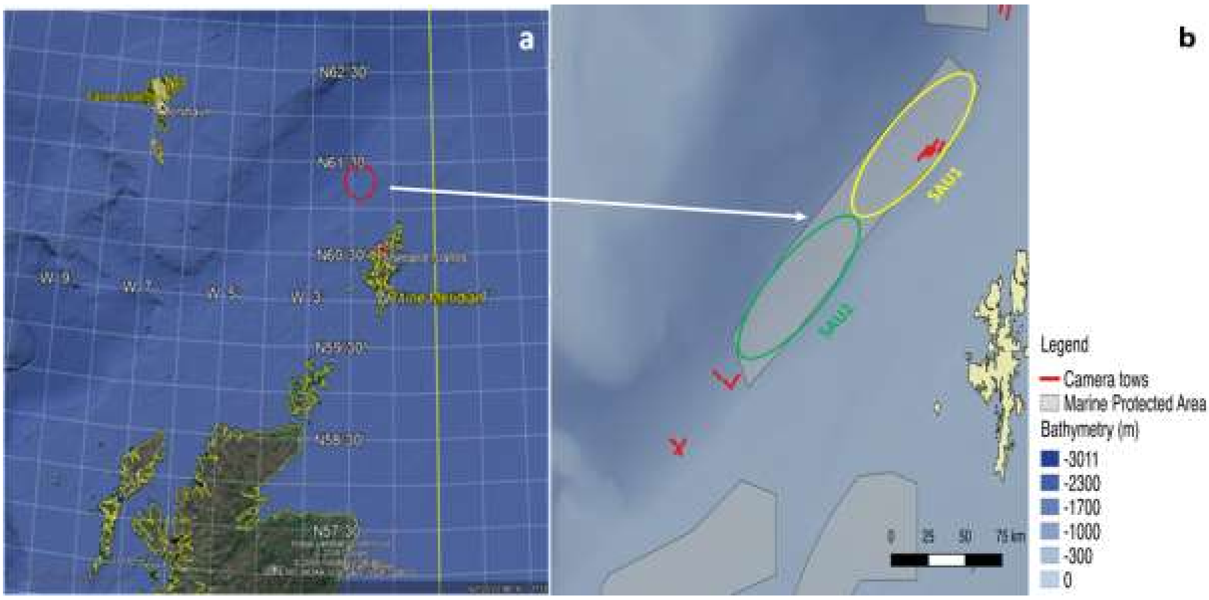

Fig. 17 *Location of the Case Study 2, the Faroe-Shetland Channel. a) general location of the area, b) detail of the location of the analysed SAUs within the Nature Conservation M.*

The CS leader and co-workers were moderately satisfied with the NEAT outcome, mainly because most of the available data cover a very small part of the Faroe Shetland Channel Sponge Belt Nature Conservation Marine Protected Area (NCMPA, hereafter). For example, the surface of the seabed surveyed with a towed-camera was 0.0031 km^2 (out of a total of 5278 km^2 of the whole NCMPA). The data from this video survey were used in the examination of the indicators, namely 1) areal extent of human-affected area; 2) density of biogenic reef forming species; 3) areal extent of litter and 4) number of size cohorts within a population. The data used for the assessment of fisheries cover almost all the Sponge Belt NCMPA (i.e. data come from the ICES rectangles 51E8, 51E7, 50E6). However, our experience with fisheries data is very limited (e.g. in the setup of boundary values) and thus we have assessed these data with caution. It is acknowledged that the ATLAS CS 2 is regarded as a Sponge Belt NCMPA and that in the centre of the NCMPA there is higher confidence about the records of deep-sea sponge aggregations compared to other regions of the Sponge Belt NCMPA (Henry and Roberts 2014). These factors provide a moderate - but not an ideal - level of confidence about how much the outcome of the NEAT analysis represents the status for the sponge aggregations inside the NCMPA. Additional efforts on the mapping of the distribution of the deep-sea sponge aggregations within (and outside) the NCMPA are under way (Kazanidis et al. in preparation; JNCC, personal communication); when this piece of work is completed it will give us the opportunity for a better evaluation of the status of sponge aggregations. In addition, this rather limited information regarding the detailed distribution of the sponge aggregations across the whole Sponge Belt NCMPA, is hampering the detailed assessment of the impact of oil & gas activities taking place inside the NCMPA (e.g. the Laggan oil field). Previous studies by Jones et al. (2006) in the Laggan oil field have recorded lower density of sponges in areas close to the oil installations where there is accumulation of drill cuttings. Specifically, the density of sponges (all morphotypes) was higher in areas of “no disturbance” (i.e. no visible disturbance to seabed; 484.4±720.2 sponge ind ha^{-1}) than areas of partial (disturbance visible on seabed; 266.7±377.4 sponge ind ha^{-1}) and full disturbance (total seabed smothering; 33.7±55.0) (see Table 1 in Jones et al. 2006 for details). The impact from drilling activities was generally seen in areas within 100 m from the installations; however, the impact of these drill cuttings on the physiology and performance of sponges in areas beyond the radius of 100 m is unknown and should be subject of future research activities taking into account the complex hydrography of the area and the type of the discharges (Kutti et al. 2015, Main et al. 2015, McKenna et al. 2016, Vad et al. 2018). At this point it should also be mentioned that the level of confidence about the outcome of NEAT analysis is supported by recent findings within the NCMPA showing that concentrations of polycyclic aromatic hydrocarbons (PAH) in sediments were lower than the OSPAR Background Assessment Concentrations (i.e. see Table 2 in Webster et al. 2018 for details).

Regarding the amount of supplied data, the level of satisfaction is moderate since the towed-camera images analyzed for this assessment of GES (n= 233) cover a small part of the entire NCMPA (see also above). It is expected that more data will be soon available from the northern (and probably from the southern) parts of the Sponge Belt NCMPA and these will support a more coherent assessment of the status of sponge aggregations. The level of satisfaction with the data for the impact of human activities (e.g. fisheries, hydrocarbon contaminants) would be also characterized as moderate (e.g. more data on the effect of oil & gas activities in the sponge communities would be very helpful). Considering the type of data supplied, the level of satisfaction is moderate/good, since work has been varied out on: a) major aspects of population structure like sponge density (i.e. values of sponge specimens/m^2) and b) body size structure (number of individuals per size class). These are important aspects regarding seafloor integrity (D6). In addition, data relevant to human activities that could affect the status of sponge aggregations i.e. oil & gas activities, fisheries, marine litter, have also been used. As regards the quality of the data, the level of satisfaction is good since the data have been produced from well-established methods (see McIntyre et al. 2013, 2016 for the use of towed cameras in studying deep-sea ecosystems; Kazanidis et al. 2010 for the use of the software FISAT for studying body-size distribution in benthos; Webster et al. 2018 for analysis of contaminants in deep-sea sediments and benthos) and reliable sources (fisheries data come from the Marine Scotland MAPS NMPi: National Marine Plan interactive at https://marinescotland.atkinsgeospatial.com/nmpi/). Considering the time frame covered by the data the level of satisfaction is low since they are observations from a particular point in time, for instance: 1) data on areal extent of human-affected area, 2) density of biogenic reef forming species, 3) areal extent of litter and 4) number of size cohorts within a population, were all collected in September 2014. In addition, fisheries data cover a short time series i.e. 2012-2016.

However, it should be mentioned that the absence of long-term time series in the deep sea is an inherent problem in deep-sea science and a fundamental one when assessing GES due to the lack of baseline information and/or long-term data series.
The satisfaction level regarding the boundary values used for the indicators is moderate; specifically: 1) The level of satisfaction for the setup of boundary values on sponge density is moderate. There is limited knowledge about the parameters shaping density of deep-sea sponge aggregations and thus it is challenging to disentangle the extent to which sponge communities are shaped by natural and anthropogenic activities. In the setup of the boundary values in the Faroe Shetland Channel NCMPA, data from sponge grounds in the North Atlantic (e.g. McIntyre et al. 2016) and OSPAR documentation about deep-sea sponge aggregations, have been used. 2) The level of satisfaction for the setup of boundary values on sponge-size distribution is moderate. This is because these boundary values have been exclusively based on the examination of towed-camera images and thus small-size sponges (e.g. 1 cm in diameter) were not detected. Future studies analyzing Box corer/Van

Veen grab samples will shed light on small-size sponges (and thus in recruitment). 3) The level of satisfaction for the setup of boundary values for the human-impact related indicator is moderate. This is especially evident in the case of fisheries data due to the very limited knowledge of the CS leader and co-workers in handling fisheries data. However, the level of satisfaction for the setup of boundary values for the contaminants-related indicators is good since these values have been based on the OSPAR Background Assessment Concentrations and relevant studies in the Faroe Shetland Channel Sponge Belt NCMPA (i.e. see Table 2 in Webster et al. 2018 for details).

Below suggestions are included from CS leader and co-workers for further work in the Faroe Shetland Channel Sponge Belt NCMPA that would enable a better assessment of environmental status in the future:

- Detailed mapping of deep-sea sponge aggregations across the Sponge Belt NCMPA (e.g. in northern and southern regions). This mapping should be accompanied by recording of relevant environmental parameters (temperature, salinity, oxygen concentration, Chl-a, turbidity, type of substrate) in appropriate spatial scales enabling in this way a better understanding about the distribution of the sponge aggregations and the environmental parameters that shape their distribution.
- Collection (e.g. Van Veen Grab, Box corer) and analysis of benthic samples enabling a better assessment of the population structure of sponges (e.g. presence of small-sized sponges that could not be seen in towed-camera images analyzed here).
- Modelling of distribution of drill cuttings. This would enable a better assessment of the impact of oil & gas activities in the sponge aggregations (up to now assessments have focused on the proximity of installations – see Jones et al. 2006).

Table 9 *Results of the NEAT assessment for Case Study 2. Faroe-Shetland Channel. The outcome of the NEAT analysis includes data on indicators from D3, D6, D8 and D10. D8 is not assessed by ATLAS for GES assessment but because the data we found on hydrocarbon concentrations in FSC Sponge Belt Nature Conservation Marine Protected Area sediments are interesting for GES assessment (especially taking into account the oil & gas activities within the MPA), we decided to include them in the analyses.*

Assessment of ecosystem components & habitats									
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthic invertebrates"**	**NEAT value for ecosystem component "Fish"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Benthic"**
SAU	5278	0.000	0.687	Good	100	0.860	0.518	0.882	0.687
SAU-1	2639	0.500	0.844	High	99.6	0.860	0.357	0.882	0.844
SAU-2	2639	0.500	0.529	Moderate	100		0.529		0.529

3.4.2.3 Rockall Bank (Case Study 3) (Contribution from David Stirling)

Rockall Bank is located in the NE Atlantic Ocean 400 km west of the Outer Hebrides (**Fig. 18**). It is part of the larger Rockall Plateau comprising Hatton Bank on the western side of the plateau, Rockall Bank on the eastern side and George Bligh Bank on the northern side. The Rockall Bank itself is approximately 450 km long running NE to SW and 200 km wide at its widest point. It ranges in depth from 0 to 1000 m. The eastern and northeastern edge of the bank falls away very steeply from 250 m descending the Rockall Trough at 1000-1500 m. The western and southern slopes are less steep and descend into the Rockall-Hatton Basin at around 1000 m (information extracted from Howell et al. 2009). The seabed on Rockall Bank is thought to show a gradual transition from rocky outcrops around Rockall itself, through low rock ridges or boulder fields partly covered in coarse carbonate sand, to an almost complete cover of fine carbonate sand (Blacker 1982)

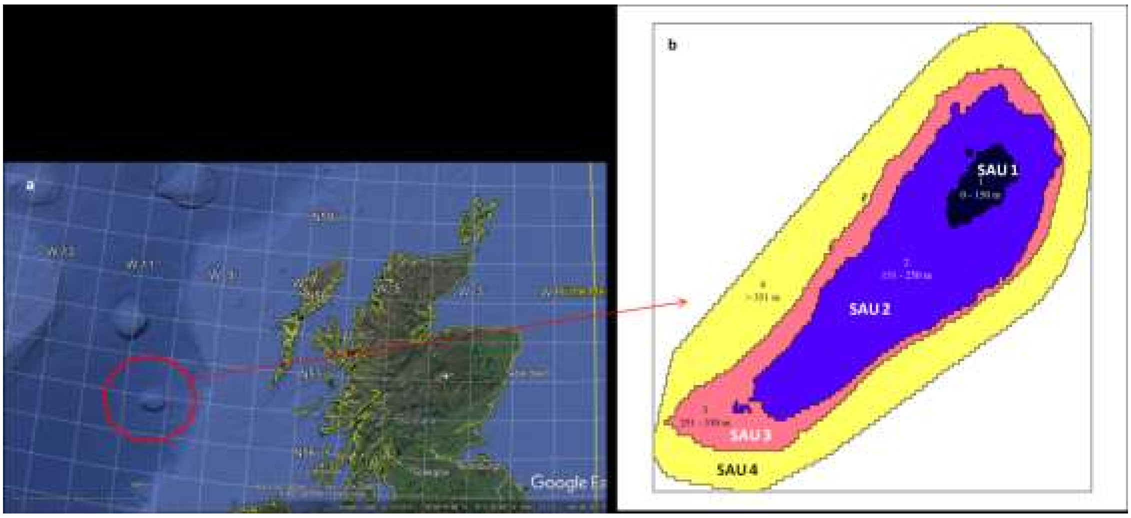

Fig. 18 *Location of the Case Study 3, the Rockall Bank. a) general location of the area, b) detail of the location of the analysed SAU within Rockall Bank.*

The overall result of the NEAT analysis for Rockall Bank suggests it is in *poor* environmental status. To the best of my knowledge this is the first attempt at assessing GES at the broad scale of Rockall Bank. Less formal assessments exist for smaller areas of the bank by the Joint Nature Conservation Committee (JNCC), a statutory adviser to the UK Government and devolved administrations. JNCC view features in the East and North West Rockall Bank Special Areas of Conservation to be in unfavourable condition, principally due to fishing activity (JNCC 2018a, 2018b).
The data set used to inform the fish-based indicators for the current assessment, i.e. the Rockall Haddock survey (years 1985 – 2017), also suggest lower values in 2017 than historical maxima for the majority of species and SAUs (e.g. **Figure 19**). The results of the NEAT analysis for Rockall Bank therefore seem to be aligned with these findings. However, it is also clear from the fish data that there is high variability across time for the fish community on Rockall Bank. This variability has implications for setting realistic targets for GES and hence the meaningfulness of the resulting GES assessment. Indeed, ecosystem variability has been identified as one of the most common critical issues complicating the implementation of MSFD (Alexander *et al.*, 2015), and this is discussed in more detail below.

Two sets of fish species have been considered for this analyses, one included non-commercial species (D1): poor cod (*Trisopterus minutus*), blue skate (*Dipturus flossada*), Raitt's sand eel (*Ammodytes marinus*), boarfish (*Capros aper*), grey gurnard (*Eutrigla gurnardus*) and smooth sand eel (*Gymnammodytes semisquamatus*) and the other set was commercial species (D3): angler (monkfish) (*Lophius piscatorius*), blue-mouth (*Helicolenus dactylopterus*), grey gurnard (*Eutrigla gurnardus*), haddock (*Melanogrammus aeglefinus*), ling (*Molva molva*), long rough dab (*Hippoglossoides platessoides*), megrim (*Lepidorhombus whiffiagonis*), Norway haddock (*Sebastes viviparus*) and witch (*Glyptocephalus cynoglossus*).

Table 10 *Results of the NEAT assessment for Case Study 3. Rockall Bank. The outcome of the NEAT analysis includes data on indicators from D1 (non commercial fish species), D3 and D6.*

Assessment of ecosystem components & habitats									
Spatial Assessm ent Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthic invertebrates"**	**NEAT value for ecosystem component "Fish"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Benthic"**
SAU	40797.804	0.000	0.313	Poor	100	0.600	0.248	0.604	0.313
SAU_1	1274.353	0.031	0.283	Poor	100	0.600	0.281	0.000	0.283
SAU_2	13931.484	0.341	0.394	Poor	74.1	0.600	0.326	0.871	0.394
SAU_3	7501.094	0.184	0.510	Moderate	100	0.600	0.455	0.826	0.510
SAU_4	18090.873	0.443	0.171	Bad	100	0.600	0.091	0.396	0.171

The CS leader considers that the outcome of NEAT analysis is moderately concordant with his knowledge/information for the case study regarding human pressures in the area of study.
NEAT results are discussed below in the light of the existing information and expert opinion from CS leader.
Rockall Bank has supported a fishery for more than 200 years (Newton et al. 2008), with regular (almost yearly) independent fisheries surveys being conducted since 1985 up to the time of writing. Therefore, the time frame and amount of data available to inform the fish-based indicators is generally good. However, due to spatial and temporal coverage of the data, much more data is available for the shallower SAUs (1 & 2) than for the deeper ones (3 & 4) (**Fig. 18, fig. 20**). Moreover, sampling of the deeper SAUs began much more recently (since 2009) than for the shallower ones.
The data informing the indicators related to benthic communities were taken from the ICES VME database and are primarily comprised of incidental recordings of benthic invertebrates, mostly as trawl bycatch. Along with no baseline information, these data are not quantitative and do not easily fall into a time-series.

Threshold setting

One of the major issues with supplying data for the assessment of GES on Rockall Bank was the setting of threshold and target values, with the data sets used for fish or benthic invertebrates presenting different challenges. Although fish-based indicators are informed by a moderately long time series, the setting of meaningful thresholds is hampered by the natural variability observed Rockall Bank. Without clear baseline data and/or data that do not easily present as a time-series, or quantitatively, it is difficult to set targets.

Variability

If the overarching purpose of the MSFD is to achieve sustainable exploitation of ecosystem goods and services, i.e. in the case of Rockall Bank sustainable harvesting of fish stocks, then natural variations in the ecosystem must be taken into account (Alexander et al. 2015). In areas where natural variability is a significant feature, the setting of GES targets should, somehow, be tied to the prevailing oceanographic conditions at the time of the assessment.

Naturally alternating cyclical periods at the scale of the North Atlantic have been hypothesised to play a role in the distribution and abundance of fish. The impact of high frequency (~7 – 25 years) cyclical phenomenon, such as the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), on biological time-series has been well documented in the literature (Southward et al. 1988, Alheit and Hagen 1997, Stenseth et al. 2002). Responses to more slowly alternating phenomena, such as the Atlantic Multidecadal Oscillation (AMO), over longer time periods (>50 years) have also been shown to have significant effects on phytoplankton and fish distributions and abundances, potentially mediated through its influence on oceanic gyres (Hátún et al. 2009b, Edwards et al. 2013). The influence of these oscillations is spatially heterogeneous, with the area to the north-west of the British Isles and South of Iceland, i.e. around the Hatton-Rockall Plateau (HRP), suggested to be amongst the most affected by fluctuations (Edwards et al. 2013).

Rockall Bank is situated at the boundary between two counter rotating gyres; the subtropical and subpolar gyres of the North Atlantic (McGrath et al. 2012). As such, it lies at the interface between two biogeographical provinces, the Atlantic subarctic province and the N. Atlantic drift province. The physical oceanography of this area is dominated by the dynamics of the North Atlantic subpolar gyre (SPG). The SPG is a large cyclonic gyre of relatively cold and low-saline subarctic water in the central northern North Atlantic (Hátún et al. 2009a, Berx and Payne 2017). Changes in the strength and extent of the SPG dictate the marine climate of Rockall Bank because it lies in a region where the position of the subarctic front influences significant change in the characteristics of the water to which it is exposed (Hátún et al. 2009a). How the northwards flowing North Atlantic Current (NAC) is bifurcated around the HRP depends on the strength of the SPG and consequently the position of the subarctic front. During strong SPG conditions the NAC predominantly flows to the east of the plateau exposing it to subarctic water, while during weak SPG conditions it predominantly flows to the west, bathing the HRP in warmer more saline Modified North Atlantic Water. During extended periods of weak SPG conditions the upper water properties (0 – 700 m) of the HRP likely reflect changes in the source properties of the southern water masses (Johnson et al. 2013).

Several recent studies in the NE Atlantic have reported ecosystem changes associated with changes in the strength and extent of the SPG. The spawning distribution of blue whiting, *Micromesistius poutassou*, has been linked to SPG strength where, during strong SPG years and the accompanying spread of cold, fresh water masses over the HRP, spawning is constrained along the European continental slope. Under weak SPG conditions, however, when conditions over the HRP are warmer and more saline, the spawning distribution of blue whiting moves northwards and westward, across RB and the HRP (Hátún et al. 2009b, Payne et al. 2012). Other studies have linked changes in SPG strength to changes across trophically connected levels in the food chain, ranging from phytoplankton to pilot whales (Hátún et al. 2009a). A recent published data set that distils the complex spatio-temporal dynamics of the SPG into a single time series facilitates investigations into the drivers of ecosystem variability (Berx and Payne 2017).

Correlations between fish biomass and SPG strength on Rockall Bank for the period 1993 – 2015, with 14 of the most frequently observed fish species (i.e. those caught during at least 80 % of the years for which SPG-I data were available) show moderate to strong correlations (r = > 0.4, or < -0.4) with the SPG-I (Stirling et al. 2018 *in prep*). Of these species, haddock is the only one to show a positive correlation of biomass with SPG-I, declining as SPG strength has declined. Others, such as the monkfish *Lophius piscatorius*, show strong negative correlations between biomass and SPG strength (-0.729), suggesting an increased abundance with a weaker SPG and consequently warmer conditions on Rockall Bank. Indeed, the black-bellied angler, *Lophius budegassa*, which is a more southerly distributed species has been caught in recent years, but was absent during the 1990s and 2000s (r = -0.756, n = 4). While the mechanisms behind these relationships, such as the effect of recruitment, are currently being explored, the results from the correlative analysis suggest a shift in the Rockall Bank fish assemblage from one more characteristic of subpolar regions during the early 1990s to a more boreal one in recent years, reflecting a decline in the SPG strength during this period.

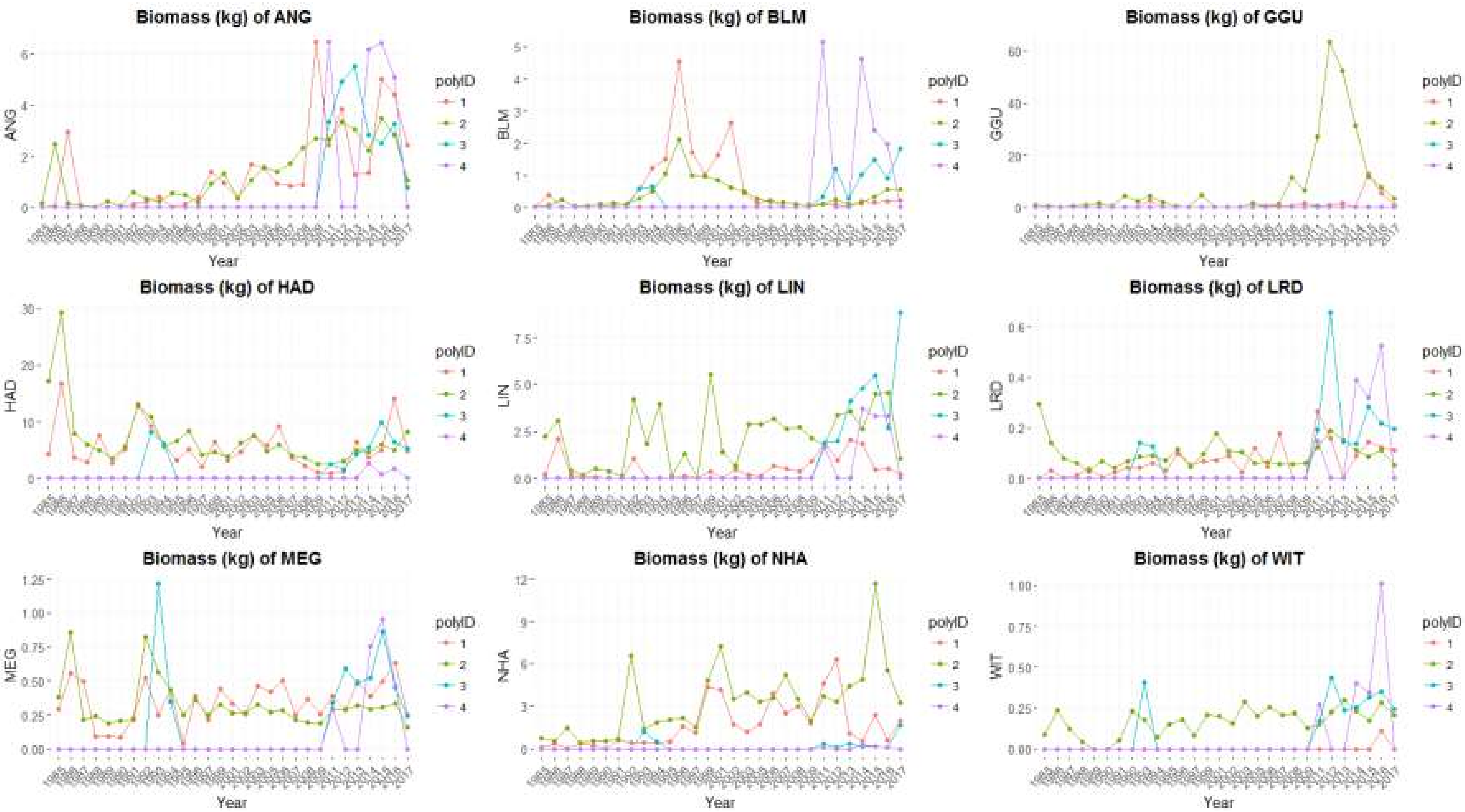

***Fig. 19** Mean biomass (kg) / 30 min trawl for commercial species considered in the assessment (ANG: angler, BLM: blue mouth, GGU: grey gurnard, HAD: haddock, LIN: ling, LRD: long rough dab, MEG: megrim, NHA: Norway haddock, WIT: witch. Each colour line represents data for the different SAUs (SAU 1: red, SAU 2: green, SAU 3: blue, SAU 4: purple).*

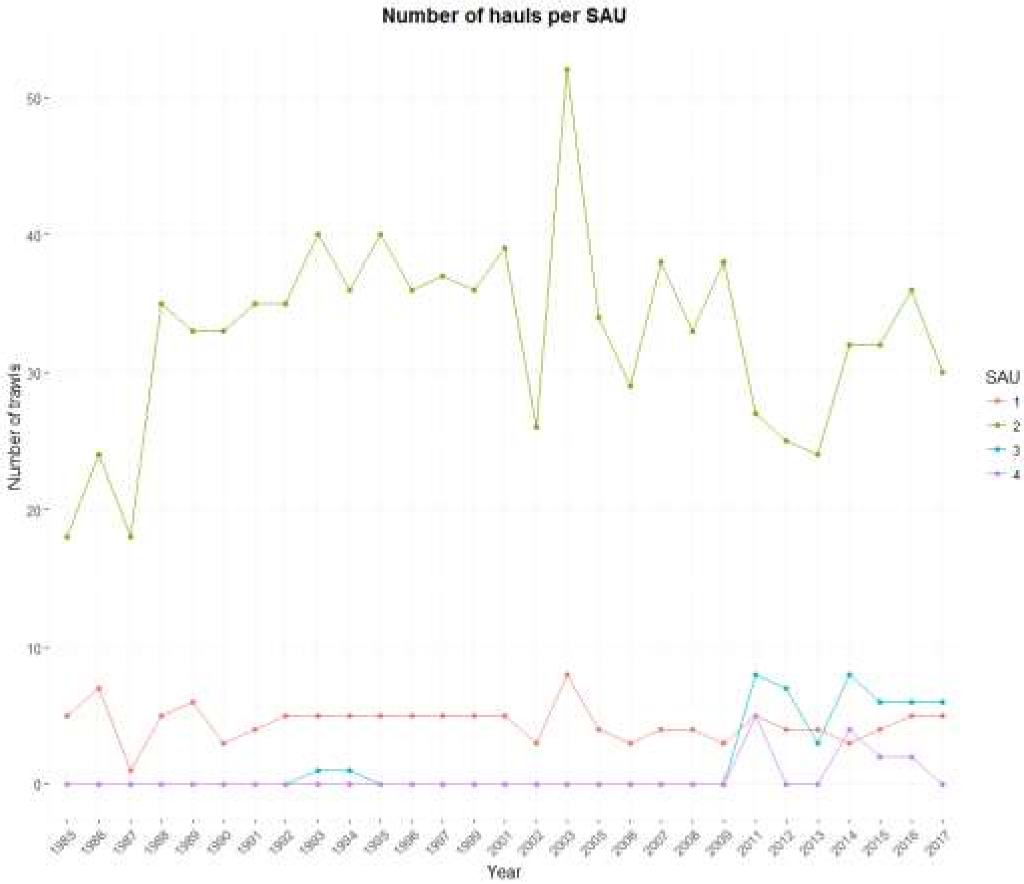

Fig. 20 *Number of hauls per SAU for each year of the Rockall Haddock Survey. Each colour line represents data for the different SAUS (SAU 1: red, SAU 2: green, Sau 3: blue, SAU 4: purple).*

Given the seemingly dynamic nature of the fish assemblage on Rockall Bank in response to oceanographic conditions, it is difficult to decide on meaningful threshold values for fish-based indicators for the assessment of GES. The thresholds used in the current assessment do not take into account oceanographic conditions and should therefore be viewed with caution.

Benthic invertebrate thresholds

The above discussion on fish is also applicable to benthic invertebrates. However, the data for these is some way from this being a serious limiting factor. In the absence of baseline data and the qualitative nature of the ICES VME data set, along with the data not fitting easily into a time series, means setting targets and thresholds for GES was particularly difficult and was achieved rather arbitrarily without any specific information on the levels of species richness that would represent being in GES. The results from this component should therefore also be viewed cautiously.

Improving understanding

Going forward, it is important to disentangle the effect different oceanographic states have on fish assemblage structure on Rockall Bank. While in the short-term, correlative studies may provide some useful information, understanding the mechanisms behind these correlations and how other aspects of population structure, such as recruitment, play a role will be more challenging. For benthic invertebrates, targeted, quantitative surveys/monitoring in a similar way to those conducted for fish, would go some way to addressing the deficits in these data.

Satisfaction with the supplied data: Moderately satisfied

Final conclusions

In summary, the assessment of GES for Rockall Bank has proven an interesting exercise with the final results from the NEAT analysis agreeing with other less formal and more spatially constrained assessments in the area. However, on account of the high variability within the fish time-series data, which seems to be correlated with metrics of oceanographic state, along with the fact that these were not incorporated into the current assessment, the results from this assessment should be viewed with some caution. Likewise, a similar view should be taken for the results based on the benthic invertebrate data due to the necessarily arbitrary setting of threshold and target values. Moreover, on account of the spatially and temporally heterogeneous distribution of the data, it may be more prudent to introduce a weighting scheme for NEAT that accounts for the amount of data available per SAU and not solely based on areal size.

3.4.2.4 Mingulay Reef (Case Study 4) (Contribution from Murray Roberts and Lea-Anne Henry)

The Mingulay Reef is located in the Hebrides Sea (**Fig. 21**) and is a site of community importance as it harbours an important CWC reef.

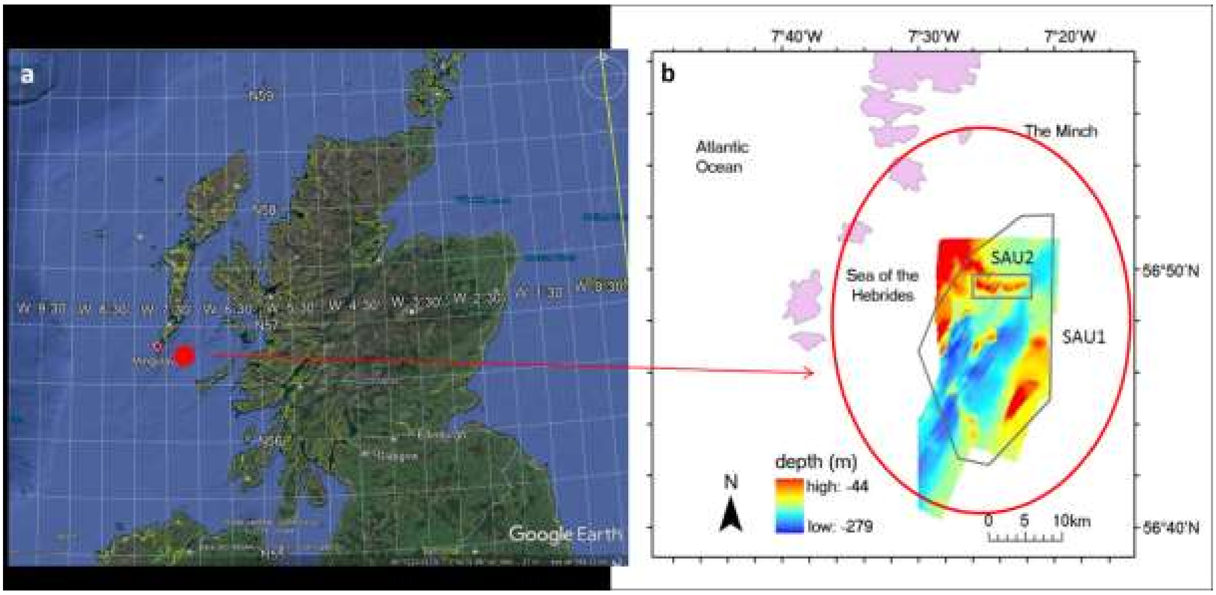

***Fig. 21** a) location of the Mingulay Reef in the Hebrides Sea. b) details of the CS area displaying the two SAUs analysed in the NEAT assessment.*

The overall result of the NEAT analyses for the assessed SAUs was “poor”, however the results for the different ecosystem components are rather different as the benthic invertebrates obtained a NEAT value indicating GES was achieved, whereas the fish compartment indicate a “poor” status and for the benthos component GES was achieved overall, with a moderate value for SAU2 (**Table 11**). The CS leader moderately agreed with the outcome of NEAT analyses, considering the knowledge and information she has available for the case study as well as regarding human pressures in the area of study. The CS leader considered that NEAT's categories of "Fish" and "Benthic habitat" (which depends on "Fish") overly influenced the results. It is the CS leader's expert opinion that although Mingulay was probably in better condition in the geological past, that in the present day, Mingulay is nonetheless in what she would describe as "Good" condition.

The NEAT analyses were overly influenced by the analysis of fish in the spatial assessment units. The only method to evaluate fish at Mingulay is by remotely operated vehicle (ROV), as the CS leader and the team working in the area do not support the use of trawling, which would give good results for fish but would destroy the reef. Many fish species avoid loud, strange man-made moving objects like large ROVs (see Andoloro et al. 2013); as a result, fish diversity in our analyses is lower than what was observed in other CWC reefs where other methods were used, including trawling but also baited traps. Moreover, other studies where ROV surveys have been conducted also obtained higher diversity values for fish, however it should be taken into account that those ROV surveys conducted many more video transects than we did. Notably, the fish community around the perimeter of Mingulay is sampled twice a year by the Scottish Government, and lists dozens of species (see the ICES DATRAS database for the IBTS-Scottish west coast demersal fish surveys). The CS leader and her team also know that the blackmouth catshark *Galeus melastomus* lays its eggs in the Mingulay MPA directly on the corals (Henry et al. 2013), however even *G. melastomus* was not recorded during ROV surveys. Because NEAT includes "Fish" in the "Benthic habitat" category, this effect was then perpetuated to degrade GES assessments of benthic habitat.

Table 11 *Results of the NEAT assessment for Case Study 4. Mingulay Reef Complex. The outcome of the NEAT analysis includes data on indicators from D3 and D6.*

Assessment of ecosystem components & habitats									
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthic invertebrates"**	**NEAT value for ecosystem component "Fish"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Benthic"**
SAU	114.89	0.000	0.376	Poor	83.7	0.637	0.232	0.871	0.376
SAU_1	114.89	0.910	0.376	Poor	83.7	0.637	0.232	0.871	0.376
SAU_2	11.4	0.090	0.572	Moderate	100	0.637		0.507	0.572

In terms of data reliability, the results for Mingulay were affected by the method for surveying fish, which has only been done using ROV, and there were limited ROV dives here. Furthermore, video quality was diminished as the visibility at Mingulay is poor. The conditions here are usually very turbid. Thus, the fish diversity data suffered from amount of data (few ROV dives), the type of data (by ROV), and quality (turbid waters, fish probably avoiding the ROV). To assess fish at Mingulay, wider spatial coverage would be necessary, and this would have to be built into the Regional Assessment. If Mingulay were to be included in future GES assessments for the Regional Assessment, the CS leader would recommend the use of baited or unbaited photolanders to collect time-lapse photography within the SAUs defined here, across all the reefs in the MPA, not just at Mingulay Area 1. As regards the data quality, the CS leader is fairly (but not completely) satisfied with the benthic invertebrate and benthic habitat data quality, type and coverage, but little satisfied with the fish data, in terms of all of the above.

The lack of spatial and temporal coverage of fish species at Mingulay, combined with the biased view that ROV observations can give us about fish, certainly handicapped the NEAT assessment at Mingulay. If these data were be included, then NEAT assessment would have been (we think) much better, so there maybe should have been a point in NEAT to help us evaluate whether our data should be included or not. The CS leader does not have an issue with the SAUs at Mingulay. The CS leader suggests that a future version of the NEAT software should give the users the opportunity to incorporate information on supplied-data uncertainty.

3.4.2.5 Porcupine Seabight (Case Study 5) (Contribution from Anthony Grehan and Oisín Callery)

The Porcupine Seabight SAU 1, encompasses an area between 500 and 3750 m depth on the continental slope. The assessment of MSFD Descriptor 6: Seafloor Integrity is based on swept area ratio as a proxy for fishing impact on both VME and MSFD predominant habitats found in the SAU by depth band, i.e. Upper Slope (200 m to 750 m), Upper (750 to 1500 m) and Lower (1500 to 2700 m) Bathyal. Most VME as represented by the actual or predicted presence of *Lophelia* reef occurs in the Upper Bathyal (Rengstorf et al. 2014). Comparison with fishing swept area ratios shows little overlap with VME and therefore potential impacts are likely to be small – as reflected in the NEAT output.

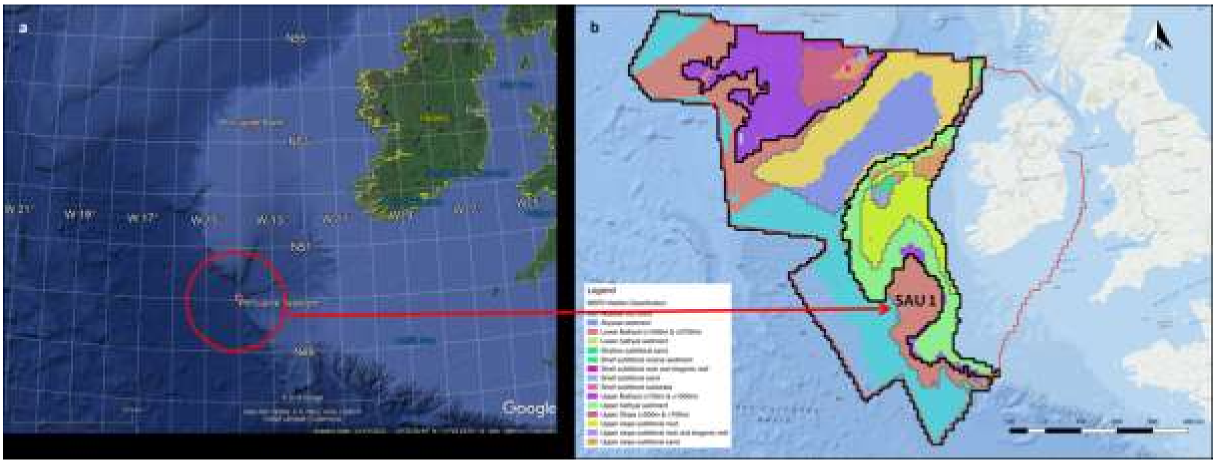

***Fig. 22** a) location of Porcupine Sea Bight in the NE Atlantic, b) details of the CS area displaying the SAU analysed in the NEAT assessment.*

The CS leader and co-workers considered that the outcome of NEAT analysis is concordant with their knowledge/information for the case study regarding human pressures in the area of study.

Considering the amount of supplied data, regarding the data for "Ecosystem Component "Benthos", data were available for the selected SAU, based on a predicted habitats data source (2008 MESH model). In areas where neither evidence nor predicted data was available, a depth proxy was created using INFOMAR bathymetry. (When viewing the Predominant Habitat Type habitats layer, the Predominant Habitat Confidence should be also be used as reference as this provides the user with a means to establish the data source underpinning the derived PHT habitat type per polygon). Regarding the data for "Benthic habitat", data were available for the selected SAU and both validated records of *Lophelia* reef and SDM outputs (see above) were used. Data on fishing pressure were also available for the analysed SAU. Fishing pressure has been measured using the swept area ratio collated by ICES (cf. ICES 2016, 2018) and calculated by analysis of Vessel Monitoring System (VMS) data.

In relation to the quality of data supplied, for the ecosystem component "benthos" it was considered moderate as substrate delineation is predicted and likely to be coarse given a lack of systematic ground truthing. For the benthic habitat, data quality has been considered from good to moderate, as it combines known reef records with predicted presence based on model outputs. The latter would require validation. Finally, regarding the fishing pressure data, they have been considered good, with the caveat that VMS position records are notified by fishing vessels only every two hours. This creates the possibility of undetected entry into marine protected areas such as Special Areas of Conservation.
Regarding the time frame covered by the supplied data, for the ecosystem component "benthos" it covers from 2013 to the present (Irish Marine Atlas), for the "benthic" habitat from 2013 to the present time, and for fishing pressure from 2009 to 2017.

Table 12 *Results of the NEAT assessment for Case Study 5. Porcupine Sea Bight. The outcome of the NEAT analysis includes data on indicators from D3 and D6.*

Assessment of ecosystem components & habitats											
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for ecosystem component "Coral Reef"**	**NEAT value for habitat "Lower Bathyal (<1500m & >2700 m)**	**NEAT value for habitat "Upper Bathyal (<750m & >1500 m)**	**NEAT value for habitat "Upper Bathyal Sediment"**	**NEAT value for habitat "Upper Slope"**
SAU_1(Porcupine Seabight)	35500	1.000	0.978	High	100	0.995	0.858	0.926	0.992	1.000	0.994

The analyses presented here covered the ATLAS Porcupine Case Study covering an area of 35,500 km^2. The CS leader and co-workers have, however, analysed the entire Irish deep-water EEZ and offshore banks out to the limit of the claimed extended continental shelf covering an area of 589,600 km^2.
Considering the threshold selection, there is a degree of subjectivity and expert judgement in the selection of thresholds until such time as impacts are sufficiently quantified. CS leader and co-workers were satisfied that the threshold values they have selected were on the side of caution.

CS leader and co-workers considered that more work needs to be done on establishing the link between fishing pressure and impact and in estimating cumulative impacts in general. Further comprehensive habitat mapping is required in deep-waters. Monitoring of fishing activity could be improved by obliging VMS position updates every 30mins rather than every 2 hrs.
Considering the above-mentioned information, the CS leader and co-workers were moderately satisfied with the data they supplied to perform the NEAT analyses.

As a final conclusion regarding the assessment, the CS leaders and co-workers highlight that because the assessment was based on only one SAU and therefore does not utilize the nested assessment capability of NEAT. Using depths zones as habitat proxies is very coarse and much more information is required about substrate that can only be addressed through comprehensive habitat mapping.

3.4.2.6 Bay of Biscay (Case Study 6) (Contribution from Lénaïck Menot)

The Bay of Biscay is a vast bight with waters under the jurisdiction of two countries: Spain and France. The continental margin of the Bay of Biscay is incised by over 80 submarine canyons (Le Suavé et al. 2000). For the purpose of this exercise, the upper continental slope of the Bay of Biscay has been divided into three Spatial Assessment Units (**Figure 23**): the canyons (SAU-3), the interfluves that separate the canyons (SAU-2) and the open slope (SAU-1). These three large geomorphological features are the result of a semi-automated classification based on the bathymetry and its derivatives at a 100 m resolution (Bourillet et al. 2016, De Chambure et al. 2013).

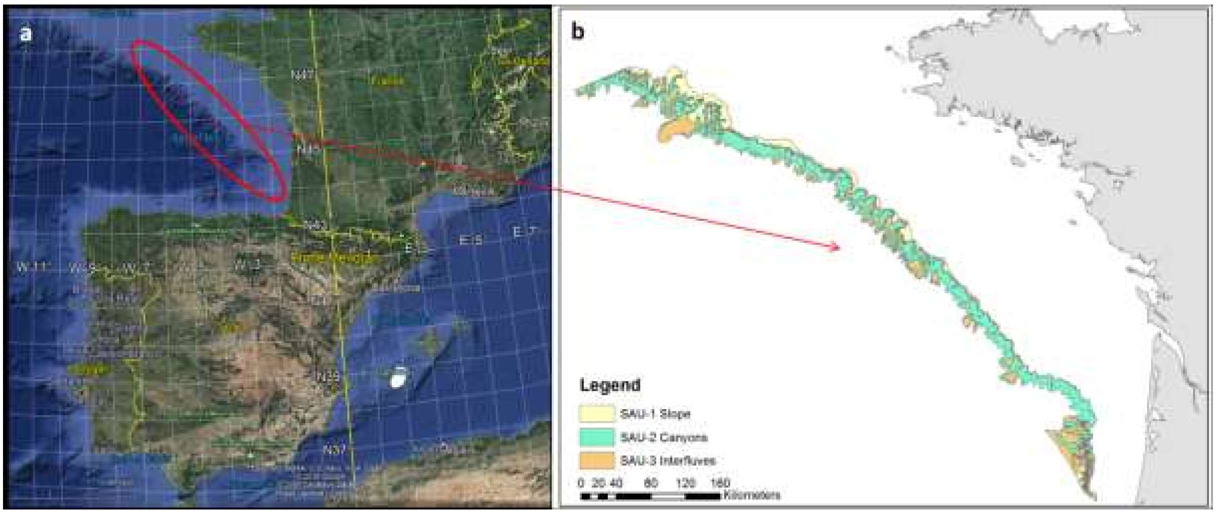

Fig. 23 *a) location of the Bay of Biscay case study area, b) detail on the three SAUs selected to assess GES.*

The open slope is mainly a narrow band in-between the shelf break and the canyon heads. With an area of 4118 km², it represents 20% of the total area of the case study and extends down to 2121 m depth but with a mean depth of 368 m. In contrast, the interfluves and canyons are deeper on average (1100 m and 1194 m, respectively), extending down to 2274 m depth. The canyons represent the largest SAU with 10654 km² (53% of the case study area), followed by interfluves with 5536 km² (27% of the case study area).

Not surprisingly, the shallower open slope has been the most heavily trawled over the last 10 years (Woillez et al. 2018). At first glance, the results of the NEAT analysis, ranging from bad to moderate, might thus seem consistent with the intensity of anthropogenic pressures in this SAU. However, the reliability of this assessment can hardly be assessed due to a lack of sampling and knowledge. Indeed, the slope is the most under-sampled of the three SAU. The status of aggregations of sea pens and alcyonaceans on soft sediments ranks as poor because this habitat has not been observed in the SAU but the absence could equally be a sampling bias or a true evidence of human impact. In addition, although on the slope the environmental status of the aggregations of *Lophelia* and *Madrepora* on soft sediments ranks as moderate, it is unclear whether this SAU lies mostly within or outside the niche of these two reef-building species (van den Beld et al. 2017). The environmental status of this habitat could thus either be due to natural or anthropogenic causes. Finally, as discussed below, in the absence of reference data and lack of stakeholder consultation, the thresholds of all indicators have been somehow arbitrarily defined.
In conclusion, the lack of sampling, knowledge and reference data on the distribution and biology of deep-sea species prevent a reliable assessment of the environmental status of benthic habitats.

The data set used for the assessment comes from annotations of taxa and habitats on images from 50 dives of the ROV Victor 6000 and the towed camera SCAMPI in or near 24 canyons of the Bay of Biscay (van den Beld et al. 2017). The main objective of this exploration endeavour, carried out from 2009 to 2012, was to re-discover and map the CWC reefs once described by Joubin (1922) and Le

Danois (1948). The locations of the dives were thus not random and the data set is not representative of benthic habitats but rather skewed toward CWC habitats.

The length of seafloor explored during the 50 dives totalized 184 km, of which 33 km were annotated as 'aggregations of the two reef-building scleractinian corals *Lophelia pertusa* and *Madrepora oculata* on soft sediments', 8.2 km were annotated as 'aggregations of sea pens and gorgonians on soft sediments', 3.4 km were annotated as 'aggregations of colonial scleractinians on hard substrates' and 3 km were annotated as 'antipatharians and alcyonaceans on hard substrates' (Arnaud-Haond et al.2017, Davies et al. 2017, van den Beld et al. 2017). The area of the seafloor that has been explored could not be quantified due to the absence of lasers and accurate altimeter but assuming a transect width of 3 m on average, a first order approximation would be 0.5 km^2, which is 0.003% of the case study area. In addition, the sampling effort was not homogeneously distributed among the three SAU. The SAU canyons represent 53% of the case study area but concentrate 83% of the sampling effort. The two others SAU were thus vastly under sampled.

The surveys carried out between 2009 and 2012 were in the first place guided by descriptions of coral reefs in the Bay of Biscay given by Joubin (1922) and Le Danois (1948). Diving on the coordinates provided by these two authors proved to be unsuccessful in most instances. Whether the coordinates were not accurate enough or the reefs were no longer present remained unclear. Indeed, Joubin (1922) already reported on trawls bringing back tons of *L. pertusa* corals on deck. The data on which the assessment is based were thus acquired almost a century after the first known anthropogenic pressures began on the slope of the Bay of Biscay. As a consequence, a reference for GES is missing, which impairs the definition of all other thresholds.

Table 13 *Results of the NEAT assessment for Case Study 6. Bay of Biscay. The outcome of the NEAT analysis includes data on indicators from D6.*

Assessment of ecosystem components & habitats												
Spatial Assessment Unit (SAU)	**Area (km^2)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthic invertebrates"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Agg. *Lophelia* & *Madrepora* on soft sediments"**	**NEAT value for habitat "Agg. Sea pens & alcyonaceans on soft sediments"**	**NEAT value for habitat "Agg. *Lophelia* & *Madrepora* on hard substrates"**	**NEAT value for habitat "Agg. Antipatharians and alcyonaceans on hard substrates"**	**NEAT value for habitat "Benthic"**
SAU parental	20308	0.000	0.717	Good	100	0.829	0.641	0.730	0.595	0.861	0.940	0.627
SAU_1 (slope)	4118	0.203	0.358	Poor	99.6		0.358	0.500	0.000			0.575
SAU_2 (canyons)	10654	0.525	0.846	High	99.8	0.907	0.780	0.920	0.875	0.893	0.940	0.601
SAU_3 (interfluves)	5536	0.273	0.736	Good	100	0.667	0.801	0.664	0.754	0.811		0.716

Moreover, we acknowledge the fact that in the framework of blue growth (BG), the thresholds should be defined through discussions among stakeholders (i.e. professional fishermen's associations, environmental organizations, regulatory bodies). Without robust reference data and without stakeholder consultation, the thresholds were arbitrarily defined by the CS leader for the purpose of this exercise. The CS leader mentioned that the performed literature database was not useful for this specific case as the metrics reported in the literature do not match the metrics of the CS data set.
It should be noted that uncertainties due to under-sampling, insufficient knowledge and lack of reference are not taken into account by the confidence level computed through the NEAT analysis. The confidence level is computed from the standard error of the metric used to assess an indicator. However, while any metric can be quantified precisely, it doesn't mean that the estimate is accurate (Andrew and Mapstone 1987). Moreover, replication was not possible for all metrics, meaning that it was not possible to compute a standard error. In those cases, standard error was set to zero, which artificially inflates the confidence level.

Final conclusions
The recent exploration of the deep Bay of Biscay by means of an ROV and a towed camera allowed the mapping of cold water coral habitats in submarine canyons. Alive and dead colonies of the reef-building scleractinians *L. pertusa* and *M. oculata* were found; forming large 3D structures, small patches or fields of rubbles (Arnaud-Haond et al. 2017, van den Beld et al. 2017). However, it is impossible to disentangle the natural and anthropogenic causes that might have contributed to explaining the current environmental status of CWC habitats. Indeed, trawling on the slope of Bay of Biscay began a century ago and the biological data produced by the first oceanographic expeditions in the 19th century are not sufficient to provide a robust reference on which to define GES.

In order to define what is "good", we need to know what is "best". In other words, we need to describe marine habitats that are no longer under the pressure of human activities. The main human activity to have a significant adverse impact on benthic habitats of the Bay of Biscay is bottom trawling. The impacts of trawling are both direct (through abrasion) and indirect (through sediment remobilization) (Daly et al. 2017, Pusceddu et al. 2014). Abrasion can now be quantified from VMS data analysis but historical records only date back one decade. Indirect impacts are still difficult to quantify, although models can help (Payo-Payo et al. 2017). As a consequence, both historical and current intensities of anthropogenic pressures on deep-sea benthic habitats cannot be assessed. Monitoring habitats in MPAs and marine unprotected areas is thus needed in order to progress assessment of GES. The deep-sea trawling ban voted by the European Parliament now protects benthic habitats below 800 m depth. In addition, in the French EEZ of the Bay of Biscay, a network of Natura 2000 areas will further protect reefs on the continental slope. An EU Life Integrated project in France will permit the implemention of a seafloor observatory in a canyon of the Bay of Biscay and promote the monitoring over five years of benthic habitats in protected and unprotected areas.

A major challenge in the study of the deep sea has always been the cost of accessing this remote environment. However, technological developments such as Autonomous Underwater Vehicle (AUVs) now allow the mapping of vast areas and the acquisition of video or images for the creation of 3D mosaics of the seafloor, while methodological developments based on machine learning foster the automatic detection of features and changes to these mosaics. In the future, such developments should significantly improve the cost-effectiveness of deep-sea monitoring.

3.4.2.7 Alborán-Strait of Gibraltar-GoC. (Case Study 7) (Contribution from Covadonga Orejas and José Luis Rueda)

CS 7 comprises the Alborán Sea-Strait of Gibraltar-Gulf of Cádiz (**Fig. 24**). The NEAT analyses could only be performed for the area of the Gulf of Cádiz (GoC) as we did not find currently published literature showing quantitative data for the benthic communities inhabiting the deep areas of Alborán Sea that could allow the application of NEAT. It would be potentially feasible to obtain fisheries data as well as data from the MEDITS surveys, however these only cover commercial and some non-commercial fish and crustacean species from sedimentary habitats and no information for the benthic communities was available. Therefore, we decided to work only with the GoC as some quantitative data are available for the area.

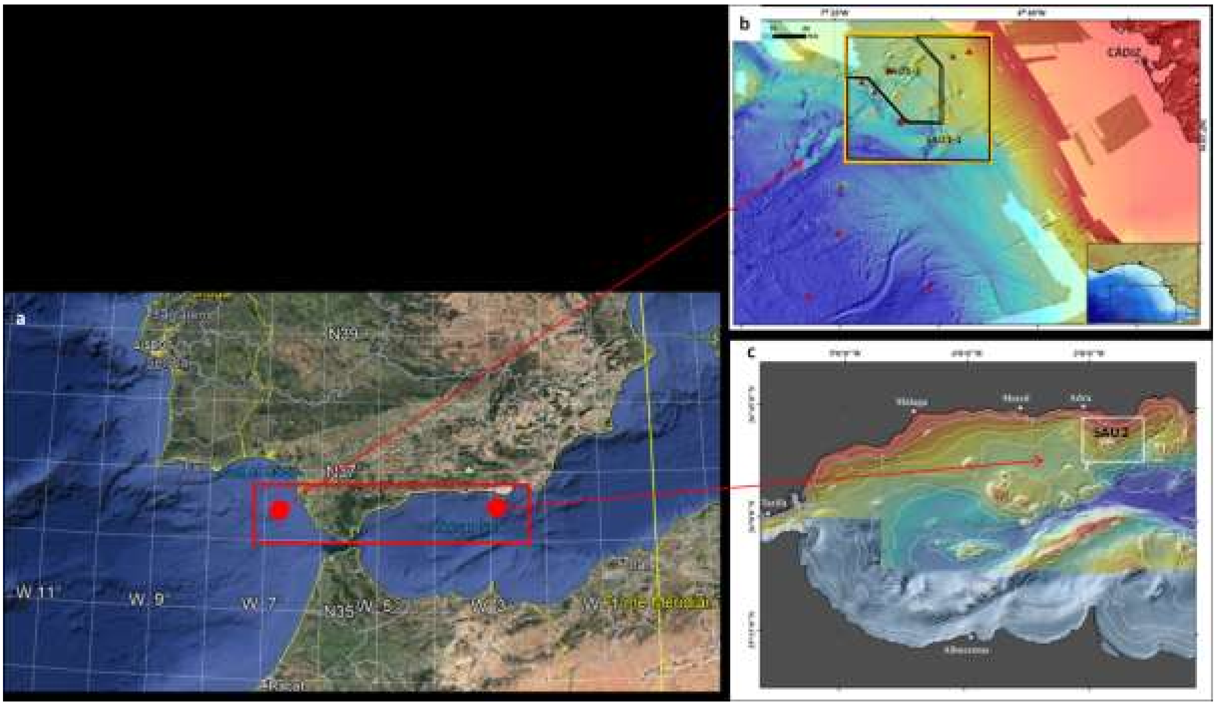

***Fig. 24** a) location of the Alborán Sea-Strait of Gibraltar-Gulf of Cadiz area, b) location of SAU1 (with sub SAU 1-2 and 1-2) and c) location of SAU2 (due to lack of quantitative data only one indicator was addressed here).*

In general, the outcome of NEAT analysis agrees partially with our knowledge on the “benthic component” for the case study regarding the human pressures (mainly bottom trawling, with very few long line fishing boats that operate in shallower waters) in the study area of the GoC. Considering “habitats”, the GES NEAT values for rocky habitats are higher than for sedimentary ones, which was an expected result as most of the human impacts are currently occurring in sedimentary habitats due to the bottom trawling activity (Díaz del Rio et al. 2014).

Regarding the defined SAUs, a lower NEAT value for GES was detected in SAU2 (area exposed to moderate trawling activity) in comparison to SAU1 (with low to null trawling activity), and indeed this agrees with the intensity of the human impacts produce by the trawling fisheries. Nevertheless, although the NEAT value for SAU1 resulted in GES being achieved (0.639), a low value with Poor

Environmental Status was detected in the deepest area of the case study (SAU 1.2). This area is not exposed to human impacts such as bottom trawling because is deeper than 700 m, so the low density of habitat-forming species may be related to other factors and environmental parameters (Díaz del Rio et al. 2014). Indeed, the area is located close to two big channels (Cádiz and Huelva channels) that are eroded by the Mediterranean Outflow Water (MOW) current which is warmer and more saline than other water masses from the GoC (Sánchez-Leal et al. 2018). In this area, near-bottom currents can reach high values (0.6-0.8 m s^{-1}) and may change sediment composition and bottom stability (burial of hard bottoms and removal of fine particles in soft bottoms), which may not favour the development of habitat-forming species such as sea-pens and gorgonians in this area (Sánchez-Leal et al. 2018). This low density of habitat-forming species could be related to these different conditions of the water masses of this area and to the higher hydrodynamism in comparison to other areas of the GoC.

***Table 14** Results of the NEAT assessment for Case Study 7. Alborán Sea-Strait of Gibraltar-Gulf of Cádiz. The outcome of the NEAT analysis includes data on indicators from D 3 and D6.*

Assessment of ecosystem components & habitats										
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Benthic invertebrates"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Benthic"**	**NEAT value for habitat "Rocky"**	**NEAT value for habitat "Sedimentary"**
SAU_Total	4129.38	0.000	0.600	Moderate	51.7	0.561	0.603	0.618	0.459	0.433
SAU_1	1279	0.155	0.639	Good	100	0.561	0.660	0.735	0.459	0.433
SAU_1.1	761	0.092	0.663	Good	94.1	0.611	0.706	0.868	0.591	0.531
SAU_1.2	518	0.063	0.283	Poor	97.4	0.476	0.160	0.293	0.266	0.290
SAU_2	2850.38	0.690	0.582	Moderate	100		0.582	0.582		

The available information for evaluating the GoC area within Case Study 7 was related (1) to densities of habitat-forming species for specific areas (mainly mud volcanoes and trawlable grounds) and (2) to a data set that covered a short time (only a couple of years). This information was gathered during past (INDEMARES) and ongoing projects (ISUNEPCA, ATLAS). Therefore, this data set only covers a small number of indicators and has both spatial and temporal limitations. Nevertheless, previous evaluations of the ecosystem in the GoC-Alborán Sea area have been done with different ecosystem components. Under the framework of fisheries management in the GoC-Alborán Sea, only commercial species of trawlable grounds are currently evaluated every year and no assessment on benthic components has been carried out except some important commercial species (e.g. Norway lobster). Under the framework of the MSFD, a compilation of information on littoral and deep-sea habitats was done in both the GoC and Alborán Sea in 2011. Moreover, some boundary values were given for demersal species (commercial and non-commercial ones) and for some habitat-forming species of soft bottoms, but no information were given for hard bottom species. Unfortunately, the information on the habitat-forming species was obtained with bottom trawling which is not an adequate method for quantifying benthic species, especially the small ones such as some dominant sea pens of the GoC (e.g. *Kophobelemnon stelliferum*).

Since this is the first evaluation that is being doing for both sedimentary and hard bottom habitats in the GoC using adequate methods (underwater images), the boundary values set up should be taken as preliminary. These values will be most probably modified after exploring other areas and including data over a longer time series (several years). Data on other ecosystem components (e.g. plankton, demersal fish, pelagic fish, small benthic species, etc) should be included in further assessments to improve our understanding of the environmental status of the GoC. Data on some selected commercial species will be gathered during the life of the ATLAS project and we expect to include it in a subsequent NEAT analysis.

Considering the information available to perform the NEAT analyses, we consider the level of satisfaction as moderate, since it only covers few indicators, a small area within the GoC and the Case Study and time frame of 2 years. However, with the data supplied the obtained results, as commented in the previous text, fit quite well with our knowledge from the area. To be able to perform a more robust NEAT analyses long term series will be fundamental as this is that will allow to evaluate changes in the area over time and the state of the communities depending on the pressures in the area. Further a map with the pressures and impacts will be necessary to better interpret if the situation of the analyzed community respond to the natural conditions of the area or to the effect of anthropogenic impacts.

As mentioned above, considering the amount of information and quality of data supplied we are moderately satisfied with the obtained results from NEAT. As commented previously, this is the first time that an analysis regarding the GES of the deep-sea in the GoC has been conducted in this form and with focus in the deep-sea benthic communities. The initial evaluation of the MSFD conducted in Spain in this area did not include information on the benthic components gathered with the suitable methodologies. Indeed the boundary values for soft-bottom benthic organisms established for the initial evaluation of the MSFD were based on data obtained during long term surveys as MEDITS and ARSA from bottom trawling. The boundary values set up from these data were much lower (Mean

Biomass of ca. 10 g Km^{-2} for sea pens, which is equivalent to a much lower number of specimens than the density values obtained when processing video images) than the obtained through the analyses of video images (Mean density 2.7 colonies m^{-2} for sea pens, so 2.7 x 10^6 colonies Km^{-2}) from different research projects (INDEMARES, ISUNEPCA, ATLAS). Further for the MSFD initial evaluation it was not possible to include data of hard substrate organisms as no video-photo sampling was conducted, hence it is not possible to establish any comparison with previously obtained results, as these are not available.

Final conclusions

Considering the obtained NEAT results and the information/data supply to conduct the analyses, it is clear that more data is needed from other components of the ecosystem to increase the number of indicators to be included in the NEAT analysis. Nevertheless, even with these low number of indicators the results of the analyses are moderately satisfactory regarding our knowledge of the area, and we think that the addition of more indicators could lead to better, more representative results of NEAT for the area.

Another handicap of these analyses is that the area considered here was small (10% of the whole case study area in the GoC), and the time frame of the studies conducted in that area is short (around five years). We are aware that GES should be evaluated at regional level, however considering the level of information we decided to be more conservative and perform a better analysis even if the area is small. The lack of data from other locations makes it difficult to extrapolate the results obtained to a larger area. In any case, the boundary values should be redefined when increasing the spatial and time coverage of the data set.

As it is the case for many deep-sea areas, in the GoC no baseline can be set up for the area. Therefore, GES cannot be defined, as no previous knowledge exists which would allow us to compare previous and current situations. Furthermore, the area has been exploited by fisheries for decades, and remains of fishing gear have even been detected in areas with very low trawling activity which harbour highly sensitive communities such as the cold-water corals. Consequently, a pristine-like situation cannot be considered.

3.4.2.8 Azores (Case Study 8) (Contribution from Marina Carreiro-Silva and Telmo Morato)

The Condor Seamount is an elongated volcanic ridge located southwest of Faial Island in the Azores, rising from around 2000 m depth to a flat summit at about 200 m (Tempera et al. 2012, **Fig. 25**). The summit of the seamount is characterized rocky outcrops and boulders mixed with areas of soft sediments, while the slopes are dominated by soft sediments. The oceanographic conditions over Condor are mainly characterized by enclosed circulation around the seamount, and pronounced mixing due to semidiurnal tidal effects (Bashmachnikov et al. 2013). This influences the sedimentation processes and organic matter distribution, with less organic matter on the seamount than adjacent areas (Zeppilli et al. 2013). Such environmental setting supports the existence of rich biological communities found in Condor (Tempera et al. 2012, Braga-Henriques 2015). An area of 242 km^2 surrounding the

seamount has been closed to fisheries for research purposes since 2010 (Morato et al. 2010, Giacomello et al. 2013). The area has been included in the Azores Marine Park since 2016.
Condor seamount was an important fishing ground for the bottom longline and handline fleet based in Faial Island in the 1990's (Menezes et al. 2013). The most commercially important species were blackspot seabream (*Pagellus bogaraveo*), alfonsino (*Beryx splendens*), bluemouth rockfish (*Helicolenus dactylopterus*), conger eel (*Conger conger*), and wreckfish (*Polyprion americanus*); which are also some of the most abundant (Menezes and Giacomello 2013). Most species were found to have their abundances significantly reduced in late 2009 due to fishing (Menezes et al. 2013) but there have been signs of recovery since the closure (Eva Giacomello pers. comm.).

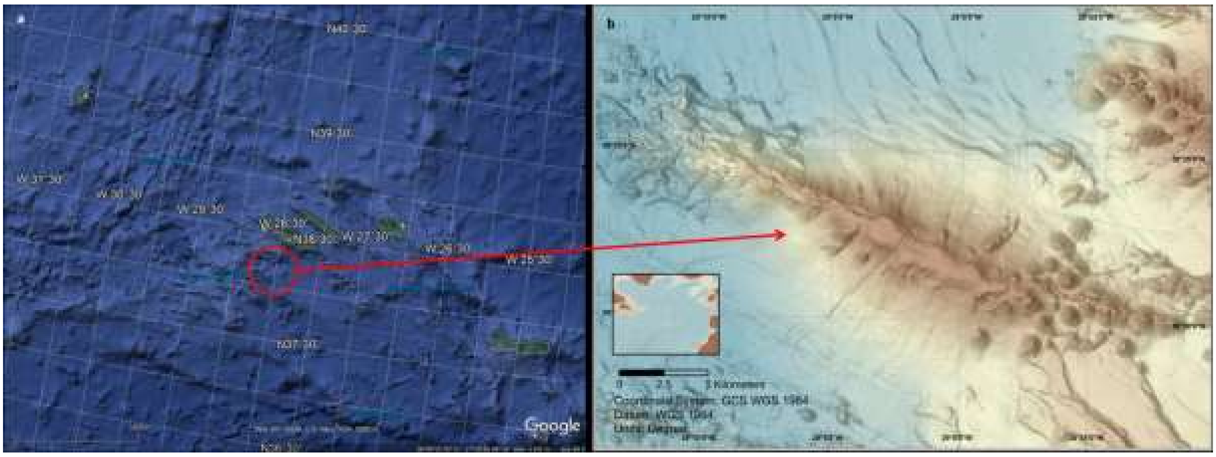

Fig. 25 *a) location of the Condor seamount in the Azores, b) detail of the analysed location (SAU), the Condor seamount.*

Bottom longline fishing not only has a direct impact on fish stocks but also on the benthic communities that are accidentally damaged or caught (Pham et al. 2014), mostly on those with a complex 3D morphology (Sampaio et al. 2012). The Condor seamount harbours multi-species aggregations of cold-water corals (CWCs) known as coral gardens. Until now, 61 coral taxa have been described from the Condor seamount and the highest biomass occurs on the summit between 165 - 262 m water depth (Tempera et al. 2012, Braga-Henriques 2015). There are no historical records on the abundance or condition of these communities before impact, making it difficult to quantitatively assess the condition of these CWC gardens.

Table 15 *Results of the NEAT assessment for Case Study 8. Açores (Condor Seamount). The outcome of the NEAT analysis includes data on indicators from D 3.*

2009-Prior to fisheries closure							
Assessment of ecosystem components & habitats							
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Fish"**	**NEAT value for habitat "Benthic"**
Condor Seamount	280	1	0.500	Moderate	90.70	0.500	0.500
2016-After fisheries closure							
Assessment of ecosystem components							
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Fish"**	**NEAT value for habitat "Benthic"**
Condor Seamount	280	1	0.673	Good	85.70	0.673	0.673

Nevertheless, when put into the Azores context, the Condor seamount is perceived to be in overall good condition or status. Therefore, the outcome of NEAT analysis is moderately concordant with existing knowledge for the case study and regarding the human pressures in the area.

Although it was expected that the overall status of Condor seamount would have improved after the fishing closure, the pre-closure NEAT score (0.50) for the SAU seems to be low when compared with the perceived condition of whole ecosystem (**Table 15**). Although fisheries have had some impacts on local fishing stocks and on some benthic communities, the overall condition of the Condor seamount is perceived to be good since no bottom trawling has ever occurred, coral gardens are still abundant and fish stocks have not dramatically collapsed. Probably focusing the assessment on commercially important fish stocks only is under-estimating the real overall condition of the Condor ecosystem.

It would be desirable to also include non-commercially important fish stocks in the assessment and also other components of the ecosystem, such as benthic communities or even indicators of the pelagic realm. At this stage, neither measurable indicators nor scientific-based threshold values are readily available for such components and so those were not included in the assessment. The overall assessment of the post-closure status seems reasonable, although one might expect a slightly higher score, because the benthic communities are considered healthy and most commercial fish stocks have recovered.

Discussion on the NEAT assessment results

As stated above the overall assessment of GES of the Condor Seamount seems reasonable, although one would expect higher NEAT scores for both the pre- and post-closure. The amount of data supplied was very limited and focused only on the size (measured by length) and abundance (measured by CPUE) of two commercially important deep-water fish (blackspot seabream and bluemouth rockfish) on a very small SAU. In the future, it would be desirable to assess more indicators for fish stocks, more commercially important fish species, non-commercially important fish, and other components of the ecosystem.

Applying indicators of GES for CWC gardens and also for the pelagic component of the Condor seamount would produce a better whole ecosystem score. Nevertheless, the data used here were based on long-term (8 years) scientific surveys and are therefore considered as good quality data.

Defining boundaries of GES is a difficult task. This is mostly because of the lack of pre-impact or historical information that can guide case studies in suggesting meaningful thresholds or just because there is limited knowledge on many aspects of deep-sea ecosystems. Additionally, due to the high spatial-temporal variability of the deep-sea communities, defining local boundaries may give biased NEAT scores when compared (for example) with boundaries defined at an EEZ-scale or ocean basin-scale. Although we have a high degree of confidence in the indicators' estimates, that's not the case for the boundaries provided which are very sensitive to the data available and the methods used. Therefore, we are only moderately satisfied with the quality of the information provided. In general, we considered the NEAT assessment results to be very sensitive to the indicators selected, the estimates provided, and boundaries chosen and therefore we believe it should be used very carefully.

Future research activities to better assess the GES of Condor seamount should take a whole ecosystem approach. Measure of present day indicator scores is paramount as is finding historical support to measure indicators in pre-disturbance conditions. Video analysis of CWC communities in the Condor and elsewhere in the Azores in ATLAS will provide important information to define thresholds and assess CWC garden condition in future GES assessments. Additionally, laboratory experiments may be useful to understand important ecosystem tipping points that could inform thresholds.

3.4.2.9 Reykjanes Ridge (Case study 9) (Contribution from Hrönn Egilsdóttir and Stefan Akí Ragnarsson)

The section of the Mid Atlantic Ridge that includes Iceland is named Reykjanes Ridge and it is the northernmost case study area within ATLAS (**Fig. 26**).

Fig. 26 *a) location of the ATLAS Case Study 9; b) SAU1 and SAU2 shows the SAU analysed delimited by the orange line. The blue short lines represent the Spring fish survey (trawl tracks in 2017 shown), the short red lines represent the Autumn fish survey (trawl tracks in 2017 shown); the dark shadowed area represents the temporarily protected area from bottom trawling, whereas the red diagonally shaded area represents the fully protected area from bottom trawling.*

The results of the NEAT analyses are presented in **Table 16**. Regarding the amount of data available for the three following indicators: species diversity (Shannon index) of non-commercial fish, extent of human affected area (benthic trawling) and areal extent of protected sea areas, CS leader and co-workers were moderately satisfied. The majority of other indicators listed for use within the ATLAS project were too data limited to be considered, including indicators using information on VME species or ecosystems. Considering the type of supplied data, CS leader and co-workers were not at all satisfied. The spatial and temporal trends of the Shannon index were examined. Such analysis revealed various spatial and temporal trends, e.g. increased species diversity concomitant, likely due to ocean warming. Further work is required to identify the underlying drivers for these changes. The human affected area indicator provides indication of the spatial overlap between fishing effort and benthic community distributions, thus enabling identification of areas at risk. Some caveats need to be highlighted. While we have continuous fishing effort data layers on very high spatial resolution, the data on benthic distributions is scanty. The solution could involve generation of species/habitats

layers using species distribution with models, while these are bound to have high uncertainty due to data limitation. The areal extent of protected sea areas is not really meaningful in evaluating environmental status, in the absence of biological data that would compare (for example) inside *versus* outside the protected areas.
Regarding the quality of the supplied data, the data on fish diversity is of good quality, and the information regarding the size of the protected areas are accurate. The data on the extent of human affected area is based on VMS and ELB data from 2008-2013 which provides good information on the fishing footprint on a high spatial resolution. It may be advisable to examine trends in trawling effort on an annual basis rather than for a longer period, as any shift in the fishing effort from year to year will further effectively enlarge the overall footprint.
Considering the time frame covered in this assessment, the analysis of fish diversity was based on annual bottom trawling time series data (1995-2017). Extent of protected area is based on the information of their size and status in 2018. Areal extent of human affected area is based on cumulative VME and ELB data between 2008 and 2013.

The spatial extension of the two SAUs were defined mostly on the basis of their different levels of data availability. The data availability for SAU1 is more limited than for SAU2, mostly some data on pelagic redfish fishery and some oceanographic data, but very limited data on the benthic habitats. For the SAU2, more data is available, e.g. on benthic habitats but most of it remains to be analysed and highly detailed information on fishing effort. The extrapolation of findings from local to regional scale needs to be carried out with caution. Clearly, for the most part of the SAU1, most of which is not impacted by fisheries, it could be argued that such areas could be seen as representative for other areas where fishing effort is low. For the SAU2, where some fishing takes place, using these data to estimate impacts at regional levels, would require some minimal understanding of how the fauna is affected within SAU2 in the first place.

The GES findings for the SAUs should not be extrapolated to a regional (larger) scale as the SAU regions differ significantly from the whole case study area which includes deeper and less rugose topography. The target levels for the indicators used for the NEAT analysis of the Reykjanes ridge were chosen based on an educated guess. The lack of data for this area means that setting a meaningful target value will always be a challenge. This issue raises concerns about the results of the NEAT assessment. As an example, the NEAT value assigned for SAU2 is poor. Based on the knowledge of the case study leaders of the area, this result is unexpected.

The result from the NEAT assessment is unlikely to provide meaningful or realistic information with regard to the Reykjanes Ridge. For the indicators chosen for GES assessment within the ATLAS framework, an obvious and important knowledge-gap for the Reykjanes Ridge relates to the non-fish benthic biota, including those that are habitat-forming ones. More detailed baseline data needs to be collected before such assessment can be carried out. Having said that, there is now large amount of underwater imaging material that is yet to be analysed and which will provide fuller understanding of benthic habitats and their fauna for parts of the Reykjanes Ridge.

Table 16 *Results of the NEAT assessment for Case Study 9. Reykjanes Ridge. The outcome of the NEAT analysis includes data on indicators from D 3 and D6*

Assessment of ecosystem components & habitats								
Spatial Assessment Unit (SAU)	**Area (km²)**	**Total SAU weight**	**NEAT value for SAU**	**Environmental status for SAU**	**Confidence level for the GES assessment (%)**	**NEAT value for ecosystem component "Fish"**	**NEAT value for ecosystem component "Benthos"**	**NEAT value for habitat "Benthic"**
SAU total	214071	0.000	0.552	Moderate	93.6	0.708	0.429	0.552
SAU-1	66732	0.425	0.586	Moderate	63.2	0.708	0.460	0.586
SAU-1-1	32951	0.210	0.544	Moderate	70.5	0.544		0.544
SAU-1-2	36088	0.230	0.858	High	71.5	0.858		0.858
SAU-2	10409	0.135	0.333	Poor	100		0.333	0.333

Overall, the data supplied for the NEAT assessment will provide information on the trends in fish species diversity, fishing impacts and on the size of protected areas. These indicators will thus only measure some specific aspects of the Reykjanes Ridge ecosystem, and do not provide full assessment. The assessment will thus need to be ranked low on the "satisfaction meter". We consider the NEAT a good exercise and a useful tool to identify data gaps, although the results from this analysis are unlikely to represent the true environmental status of the SAU.

Final conclusions

Like many other deep-sea areas, the Reykjanes Ridge is very data limited. The suggested indicators for GES assessment of the area were a) species diversity (Shannon index) of non-commercial fish, b) areal extent of human affected area (benthic trawling) and c) areal extent of protected sea areas. The rationale in this assessment was thus to choose indicators that were well data supported. Inherently this means that indicators that are undoubtedly influential, but more data limited, needed to be left out. The outcome of the assessment may have thus been different if these indicators had been better supported with data. However, these are probably not the best candidates when it comes to evaluating GES for this case study area. Nevertheless, in coming years, data will become available that will enable a more accurate evaluation of benthic community and habitat indicators.

There are two underlying issues that warrant caution when interpreting the results of the NEAT assessment above: 1) The chosen indicators are unlikely to be truly descriptive of the GES of the study region; 2) Although data was available for the indicators used in the assessments, the delineation of the boundaries of the SAUs is arbitrary; 3) The setting of the targets for the two area-based indicators was not data-driven. As an example, we have no idea where to set the target of human pressures for this area, e.g. if we want to ensure sustainability, as we do not have data on the nature and magnitude of the responses of organisms to these pressures. Then comes to the question, which aspects of the Reykjanes Ridge ecosystem are we most concerned about and which indicators are best suited for the purpose? In this exercise, we were constrained by those indicators for which we had enough data. However, a large part of the Reykjanes Ridge is not impacted by direct pressures such as fishing. There is fishing in SAU2, but then again, it is mostly off the ridges, as trawling on the ridges themselves is generally not possible due to their high rugosity. While there certainly are impacts of fishing in this area, it can be regarded overly negative to give it the "poor" status, especially when compared to many other locations that are certainly in a very bad shape.

While the Reykjanes Ridge is data limited, this brings up the question; what is enough data? For data-limited areas at risk, it would probably be better to carry out managing actions aiming to mitigate impacts based on an educated guess, rather than waiting for all the data to emerge for detailed assessment. For the case of the Reykjanes Ridge, only part of it is under pressure from fishing activities. Resilience of the fish communities to such pressures is poorly understood, as these are relatively complex systems. However, in coming years, assessment of various benthic indicators can be evaluated, that would result in an overall stronger NEAT assessment.

To summarize: the results of the GES assessment of the RR case study area should not be considered to give a true estimate of the environmental status of the SAUs or Reykjanes Ridge in general. Nevertheless, we consider this exercise beneficial for identifying important knowledge gaps for the case study region regarding the assessment of environmental status and marine spatial planning in the future.

3.4.3 Summary of main NEAT discussion issues

Considering the results, discussion and conclusions from the NEAT analyses corresponding to the different case studies there are some common aspects to highlight.

The main one is the **scarcity of data** and the fact that most of the data come from very local areas within the case studies, with in general **small spatial coverage**. Most CS leaders were moderately satisfied with the results of the NEAT analysis (see **Table 17**). In most cases (e.g. CS1, CS2 for fisheries data, CS3 for benthic habitats, CS4 for fisheries data, CS5, CS6, CS7 for the Alborán Sea area and fisheries data, CS8 for benthic habitats, CS9) the reasons for the moderate satisfaction were **scarce amount of data provided or data quality.** For instance, in case study 9 (see section 3.4.2.9), the authors have discussed the need to use indicators for which data is available (which is necessary to apply a mathematical tool such as is NEAT) and the fact that sometimes these indicators, for which data are available, are not necessarily the best ones to assess the status of an area. In CS6, the problem of lack of replication for some of the metrics has been also mentioned, which obliged us to compute the standard error (mandatory to perform the NEAT analyses) to zero. This artificially inflates the confidence level, distorting the results of the analyses.

In most cases it was not possible for the CS leaders to confirm if they consider the results of the analysed SAUs as **representative** for the whole case study area, as the overall knowledge of the areas is very scarce and the analysed areas had, in general, a small spatial coverage. In this sense it was generally commented that the results of the NEAT analyses have to be considered with caution mostly due to: 1) the lack of sampling and/or knowledge for many of the areas and 2) the different sampling effort among different areas, 3) the limited spatial extension of the analysed areas, 4) the lack of knowledge on how representative these areas are.

Considering the information supplied for all case studies, a critical aspect that needs to be taken into consideration is **the selection of the SAUs to be assessed and the criteria used for this selection**. CS leaders used different criteria to designate the SAUs in the CS. For instance in the CS9 data availability was the main criteria to select and define the SAU, whereas in CS7, beside the data availability, the main criteria was to select a trawling impacted- and a trawling non-impacted area. We believe that for further NEAT assessment it will be useful to setup some more homogeneous criteria prior to the analyses, if possible, in order to make the different results of the analyses more comparable.

Another common problem for all case studies, especially regarding D1, D6 and D10, is the **lack of a baseline/reference conditions** that do not permit consideration and evaluation of the current state of the areas and if they can be considered in GES or not. The WFD and the MSFD identify four options to define reference conditions or to set targets: (1) comparison with a pristine/undisturbed area, (2) using historical data, (3) performing modelling approaches or (4) using expert judgment (Muxika et al. 2007). In ATLAS, all four options have been applied across CS. In all CS, expert judgement has been applied to different degrees, considering the information available and knowledge of the area. In CS5 a modelling approach has been applied to set up boundary values (2008 MESH model). For CS6, the CS leader discussed the importance of defining thresholds in the frame of the MSFD through discussions among stakeholders. This information is lacking and thresholds have been (as in other CS) arbitrarily defined by the CS leader. For the CS where D3 has been assessed, mostly historical data/temporal data series have been used. This was the case of CS2, CS3, and CS7. For CS4, D3 was also assessed but reference conditions have been set up based mostly on expert judgment, as the data were provided from video records. For CS8 to assess D3, a comparison was established between two different time points, before and after closure to fisheries in Condor Seamount. In the D3 assessment conducted in CS3, it has also been pointed out that threshold and target values used in the assessment have been set up arbitrarily and did not take into account the oceanographic conditions of the area, which are responsible for the high variability that fish stocks experience in Rockall Bank. This leads to the next discussion point: the difficulty in distinguishing between natural variability and anthropogenic effects.

It was also discussed in several assessments (e.g. CS3, CS6) that there were **difficulties in distinguishing in some cases if the occurrence of a species or a specific distribution pattern is due to anthropogenic or to natural effects.** This has been discussed for instance in CS6 where the aggregations of the CWCs *Lophelia pertusa* and *Madrepora oculata* display different percentages of presence among the analysed SAUs. The authors discusses that this situation could be: 1) a result of the characteristics of the optimal ecological niche for the species (see van de Beld et al. 2017) or 2) due to anthropogenic pressure. Other aspects that are being analysed in ATLAS, like the physiological limits of distribution for a species (e.g. related to depth range or temperature) will contribute to a better understanding of the distribution patterns of the species. In the same line, in CS3 this was also one of the most important discussion points as the authors highlighted the high variability of the fish community in Rockall Bank and the implications this natural variability has in setting up realistic GES targets. Ecosystem variability has been already discussed in the literature as one of the more critical issues that make the implementation of the MSFD challenging (Alexander et al. 2015). The leader of CS3 suggested setting up GES targets dependent on the time of the year when the assessment is carried out.

Among the discussion points, the leader of CS6 highlighted the need to describe marine habitats that are not under pressure of human activities, considering the **need to monitor habitats in MPAs as well as in unprotected areas** in order to progress GES assessment. Such an initiative is being implemented in France thanks to a LIFE integrated project that will permit five years’ of monitoring in protected and unprotected areas to be carried out.

The last aspect to mention in this summary is the importance for forthcoming GES assessment in the deep sea of **technological developments** such as, for instance, the use of AUVs that will allow mapping of vast areas and the acquisition of video or images to create 3D mosaics of the seafloor, or methodological development based on machine learning that foster the automatic detection of features and changes on these mosaics. Additionally, the use of outputs from Habitat Predictive Models and Species Distribution models have been mentioned in some of the discussions of the CS assessments, and already used (CS5) to measure indicators. In future, such developments should significantly improve the cost-effectiveness of deep-sea monitoring and facilitate the assessment of the status of the deep sea.

Finally, performing the NEAT analyses within ATLAS was received differently by the ATLAS community. Some CS leaders considered this a worthy trial, as NEAT has been specifically designed to assess GES within the MSFD. Some were reluctant to use NEAT, while others were more neutral. Yet after running the analyses and discussing the results, we believe that most CS leaders value the NEAT analyses as an interesting exercise. The NEAT analyses of 9 ATLAS CS clearly highlight the data scarcity for the deep-sea even taking into consideration that most of the selected case studies are areas where studies have been already conducted and at least some data are already available, which is clearly not the case for most of the deep-sea realm.

Regarding the usefulness of an indicator-based assessment and considering the work carried out to date on GES, the published literature and the current ATLAS work, our opinion is that the use of indicators to assess GES in the deep sea could be appropriate. Indeed, no critical issues have been highlighted on this in the literature, and no other assessment systems have been proposed to our best knowledge by previous published works, nor within the ATLAS consortium. However, as previously commented in this deliverable, the indicator type as well as selection of scales (spatial and temporal) and units to measure GES need to be adapted to the special conditions of the deep sea and monitoring possibilities.

Table 17 *Short summary of the results of the NEAT analyses for Case Studies 1 to 9. Overall NEAT value for GES for each evaluated Case Study (CS) is included (blue: high, green: good, yellow: moderate, orange: poor, red: bad). Overall NEAT values should be treated with caution as in many cases the amount of indicators used to perform the assessment is very low. Further, as almost all CS leaders mentioned, the amount and/or quality of data is not optimal.*

Case Study	Overall NEAT value	Degree of agreement Expert-opinion-NEAT results	Degree of satisfaction with the amount and/or quality of data supplied by CS leader	Specific observations/ suggestions / Improvements needed
1	**0.616**	The outcome of NEAT analysis **agrees completely** with my knowledge/information for the CS regarding the human pressures in the area of study	Moderately satisfied	For SAU2, considering habitat "benthic" and in particular for "benthic invertebrates", a habitat suitability model should be developed for the Hola trough prior to the NEAT assessment. To assess the GES of the entire Hola trough we would suggest performing additional analyses for sand waves and glacial lineations that are present inside and outside SAU1
2	**0.687**	The outcome of NEAT analysis **agrees moderately** with my knowledge/information for the CS regarding the human pressures in the area of study.	Moderately satisfied	The moderate level of satisfaction for the setup of boundary values on sponge-size distribution, is due to the fact that these boundary values have been based on towed-camera images and thus small-size sponges (e.g. 1 cm in diameter) were not detected. Future studies analyzing box core/Veen grab samples will shed light on small-size sponges (and thus in recruitment).
3	**0.13**	The outcome of NEAT analysis **agrees moderately** with my knowledge/information for the CS regarding the human pressures in the area of study.	Moderately satisfied	Setting of threshold values was hampered due to the natural variability which make also difficult to set target values. For benthic components difficult to assess as the ICES VMEs contain qualitative information
4	**0.376**	The outcome of NEAT analysis **agrees moderately** with my knowledge/information for the CS regarding the human pressures in the area of study	Well satisfied but not completely	It would be useful if NEAT could incorporate data uncertainty somehow
5	**0.978**	The outcome of NEAT analysis **fully agrees** with my knowledge/information for the CS regarding the human pressures in the area of study.	Moderately satisfied	More efforts are needed to establish links between fishing pressures and impacts. Comprehensive habitat mapping of deep-sea areas is needed.
6	**0.717**	Considering my knowledge/information for the CS, **I can't tell how good or bad is the outcome of NEAT** analysis regarding the human pressures in the area of study	Moderately satisfied	In the framework of "blue growth", the thresholds should be defined through discussions among stakeholders (i.e. professional fishermen associations, environmental organizations, regulatory bodies)
7	**0.600**	The outcome of NEAT analysis **agrees moderately** with my knowledge/information for the CS regarding the human pressures in the area of study	Moderately satisfied	Boundary values for benthic organisms should be based on information gathered by means of visual methods as data obtained by bottom contact gears highly underestimated the density number of most of them
8	**0.500 (pre-closure)** **0.673 (post-closure)**	The outcome of NEAT analysis agrees moderately with my knowledge/information for the CS regarding the human pressures in the area of study.	Moderately satisfied	Define boundaries is difficult as no historical information is available for the "pre-impact" situation. The high spatial temporal variability also hampered the set up of thresholds and boundary values. Further quantitative video analyses will improve this situation and experimental aquaria work will contribute to define tipping points.
9	**0.552**	The outcome of NEAT analysis **does not agree at all** with my knowledge/information for the CS regarding the human pressures in the area of study	Little satisfied	While fishing effort data layers at a very high spatial resolution are available, data on benthic distributions is scarce. The solution could involve generation of species/habitats layers using species distribution models. In many cases for suitable indicators there are no data available, the authors consider "expert judgment" as fundamental when data are still not available but need for management is urgent.

4 General discussion, conclusions, perspectives

The exercise of assessing GES in the deep sea within ATLAS was useful to confirm some aspects already highlighted in the literature regarding lack of knowledge and difficulties in approaching the assessment of GES in the deep sea. The ATLAS GES exercise was also a step forward in adding some new perspectives and also in stressing the main obstacles to success in the attempt to assess GES in such a challenging environment.

In the previous section we presented the main results of the NEAT analyses performed in 9 ATLAS CS. Some of the previous works where a NEAT analysis was performed, discussed some issues regarding NEAT. For instance, Uusitalo et al. (2016) highlighted the importance of the design of NEAT analyses, as the selection of indicators, target values and a specific regional dimension, habitats and ecosystem components, can have a high impact on the result. Hence, for the correct interpretation of the results obtained it is fundamental to evaluate the assessment structure. This has been done by CS leaders in the discussion of each CS and the interpretation has been done in the light of the information supplied. Another recent application of NEAT (Pavlidou et al. 2019) shows the comprehensive performance of NEAT as it allowed the integration of data from different sources, spatial and temporal scales and consequently, a real ecosystem assessment. The nested structure of GES allows the integration of information from different spatial and temporal scales, allowing at the same time the tracking of problems and cases not in GES that should be addressed at lower levels than ecosystem or habitat (e.g. species or species groups). This was the case in the assessment of GES for fish in CS4, for instance, where due to the methodology applied the results did not reflect the real situation of the area. The design of the analyses in different components allowed the tracking and interpreting of the NEAT results obtained (see section 3.4.2.4).

Considering the issues previously mentioned, which are highlighted in published works and which we also confirm in our ATLAS work, a list was made of the main gaps detected. This included gaps mentioned in other documents, reports and in the scientific literature in general, including the main results of the initial evaluation by countries. Also included are aspects commented during the discussion on “assessing GES in the deep sea” in the ICES WGDEC conducted in 2017, as well as some points also highlighted by the IDEM project.

GAPS IN ASSESSMENT OF GES

Scientific gaps

- Scarce knowledge on taxonomy, seabed substrate types and seabed substrate quality, habitats, habitat sensitivity and tolerance to human pressure
- No specific indicators or targets developed for deep-sea species
- No size-based indicators specific for non-commercial fish species
- High level of environmental variability (how to gather this?)
- Lack of baseline and reference values
- Lack of setting of targets, difficulty in setting up targets
- Difficulties in separating natural from anthropogenic effects

- Lack of pressure maps for most deep-sea areas

Methodological gaps
- Difficulties regarding sampling and measurements
- Lack of standardised protocols and methodologies
- Difficult to establish deep-sea monitoring programs

Complementing the list above, we include a second list of main aspects to deal with when assessing GES in the deep sea, detected through the NEAT analyses and more generally in the ATLAS work on GES, as well as in the reviewed main results of the initial evaluation and the technical and scientific literature:

ASPECTS TO TAKE INTO ACCOUNT - NEEDS WHEN ASSESING GES IN THE DEEP-SEA

Scientific
- Integration of D1 and D6 (as was later done in the EC decision of 2017)
- Identification of the ecological structures and functions of particular importance in deep-sea ecosystems
- Importance of considering environmental drivers as well as random year and station effects, in order to make anthropogenic impacts identifiable considering the substantial natural variation
- Temporal and spatial scale of evaluation is different across different indicators (e.g. benthic ecosystem features are patchy on many scales, pressure caused by human activities operate at different spatial scales)
- Integration of results from local scales to much larger sub regional and regional scales
- It is considered (OSPAR 2012) that although knowledge is less complete offshore and in the deep sea than in coastal areas, the dominant space and time scales are both greater in deep-sea ecosystems
- Difficulties in setting up reference values, but the ”trend” with respect to a reference level (which could be the current state) can be also used
- The selection of reference points and choices of period for the long-term historic average should be made on a (sub) regional basis by the authoritative scientific institutions
- Identification of natural disturbances on the seafloor
- Identification of recoverability capacity (closely related to resilience and recovery potential of the seafloor)
- For ecosystem components and pressures identified as being of greatest importance (e.g. fisheries impact), use of a suite of appropriate attributes and indicators to assess GES
- The standards for GES on various indicators must reflect the different sensitivity and resilience of the indicators and their functions in ecosystem processes. Risk-based approaches to monitoring and assessment are proposed to deal with the local-scale patchiness of seafloor attributes, pressures, and impacts
- To ensure resilience of the seafloor, the reference points of selected indicators should best reflect the possible tipping point (e.g. level of disturbance at which the decline of the system functionality begins to accelerate)

- Recoverability needs to be considered in the spatial context within which a disturbed area is located (i.e. connectivity between impacted and non-impacted sites in the region)
- To assess functionality and recoverability, information on sensitivity and pressures needs to be considered together to evaluate overall impact

Pressures
- Identify the human pressures known or likely to reach levels that degrade environmental status
- Identify physical damage in substrate characteristics
- Identify physical damage regarding climate change effects
- When assessing GES, it should be assured that anthropogenic pressures do not hinder the ecosystem components from retaining their natural diversity, productivity and dynamic ecological processes

Methodological
- Exploration of the use of existing methodologies (e.g. Side Scan Sonar, AUVs, machine learning…) as well as development and adaptation of existing methodologies for better and more effective deep-sea mapping

In the following paragraphs some of the major challenges for assessing GES in the deep sea mentioned above will be discussed.

Data scarcity

In the work by Rice et al. (2012) it has been concluded that 8 attributes of the seafloor could provide suitable information meeting the requirements of the MSFD to assess GES: (1) substrate, (2) bioengineers, (3) oxygen concentration, (4) contaminants and hazardous substances, (5) species composition, (6) size distribution, (7) trophodynamics and (8) energy flow and life history traits.

Considering the indicators selected by ATLAS CS leaders, which have been chosen based on the quantitative information available to apply NEAT, only 3 of these attributes (bioengineers, contaminants, species composition) have been considered. Quantitative information for the deep sea on oxygen concentration, contaminants and hazardous substances, trophodynamics and energy flow and life history traits is very scarce and completely absent for many areas. Indeed, even if several indicators related to these attributes were included in the initial list of indicators supplied to CS leaders (**Annex III**), due to the low number of CS leaders voting for those indicators, they have not been included in the indicators shortlist.

Also in Rice et al. (2012) a selection of indicators for sea-floor integrity is included: (1) type, abundance, biomass and areal extent of relevant biogenic substrate; (2) extent of the seabed significantly affected by human activities for the different substrate types; (3) presence of particularly sensitive and/or tolerant species; (4) multi-metric indices assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species; (5) proportion of biomass or number of individuals in the macrobenthos above some specified length/size; and (6) parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community. Within ATLAS several of these indicators have been considered (see Table 7) in the NEAT assessment, however some of them have not been assessed due to the lack of data. **The data scarcity and poor background knowledge have been highlighted in the literature (see sections 1 and 2 of this report) as well as in this ATLAS assessment, as one of the main caveats to assessing GES in the deep sea**. This gap includes the difficulties in identifying the source of variations (this has been specifically highlighted in the discussion of the NEAT assessment from CS3 and C6), and it is an issue also discussed by Carstensen and Lindegarth (2016) who stressed the difficulties in outlining different sources of variation from a single ecosystem (e.g. sources of uncertainty that cannot be quantified due to the lack of replication of the ecosystem components at different levels of the random variations). This is already difficult in ecosystems where, for instance, seasonal sampling is feasible and almost impossible in deep-sea ecosystems where periodic sampling is normally not feasible.

Setting up baselines

The problem of the baseline setting is also one of the most commented aspects when assessing GES. In the OSPAR advice manual, several "baseline setting methods" were presented. One of the preferred approaches is to select areas where anthropogenic influences on seabed habitats are negligible. This has been considered by OSPAR as an approach which may be more easily applied to the deep sea/offshore areas than to coastal ones. Considering the discussion of NEAT assessment of CS8 (where it was highlighted that the coral gardens of the deep-sea areas in Condor can be considered in GES) as well as the results from the Azores IE (where it was asserted that: "habitats at depths of more than 800 metres are considered pristine as most human activities take place at shallower depths or in very limited areas, e.g. deep-sea research"), from all ATLAS CS it could be considered that the data on the Condor Seamount deep-sea areas would constitute a baseline. This could be also the case for other Azorean deep-sea areas explored within ATLAS, for instance the Formigas seamount (which is part of CS8), even if the NEAT analyses have been conducted only for Condor as the data for Formigas are currently being processed. However, this is a not a common situation for other regions, as many deep-sea areas are already impacted by fishing activities. Historical data has been also highlighted by OSPAR as a potential baseline for some off shore sediment habitat types, for which few historical data sets exist. Long-term data series are also available for some commercial fish species, and indeed this was applied in the IE conducted by some countries. However, in many cases it was considered more feasible to speak about "reference values" instead "baseline data". In this way "trends" for the different indicators/criteria can be evaluated when assessing GES. Further, in Rice et al. (2012) it was also concluded that GES cannot be defined exclusively as "pristine environmental status", but rather status when impacts of all uses were sustainable. This aspect has also been taking into account in the ATLAS definition of "what is GES in the deep sea" (see section 3.3).

For specific habitats, as is the case of the deep-sea rock and biogenic reef habitats which are, in general subject to few mechanical pressures (e.g. some CWC reefs and deep-sea sponge aggregations), OSPAR highlighted that the current condition and extent could be used as a baseline (determined through modelling and mapping techniques) (i.e. baseline setting by applying the method that sets as a baseline a current state) and a limit (as opposed to target) could be set at this current condition and extent in line with the HD approach (target-setting method). However, this document considered the mechanical pressures but not other important anthropogenic effects such as those caused by climate change (e.g. ocean acidification, OA) on those reefs. However, recent literature highlights the dramatic effects that OA can have on reef structure (Hennige et al. 2015) and the ATLAS community has considered OA as one of the five main anthropogenic pressures to deep-sea habitats, together with temperature change, pollution, fisheries impacts, and the cumulative effects of these stressors (Results from ATLAS Deliverable 5.2 Arsmstrong et al. 2017). Results from ATLAS on going *ex-situ* experiments (WP2) will also contribute to setting up reference values regarding environmental parameters as temperature, pH or oxygen values. The results from the experiments being carried out will contribute to the definition of tipping points for some of the key structuring species of deep-sea Atlantic ecosystems, like CWC species and sponges.

Methodologies to assess, and monitor GES for D1, D3, D6 and D10. Selection of indicators and measures

Although the use of multimetric indexes has been included in the MSFD as potential indicators for the assessment of GES, and they have been applied on several occasions (see section 2.4.2), none of the more than 10 multimetric indexes included in the list of indicators proposed to CS leaders have been selected (e.g. BEAT, BENTIX, Benthic Ecosystem Quality Index (BEQI), Biomass Fractionation Index (BFI)) by CS leaders. We assume that for the specific case of the ATLAS CS, it was considered that the use of multimetric index is not an adequate indicator, most likely due to data scarcity.

One of the aspects mentioned in several documents and papers and that needs to be considered, is the **different degree of ecological relevance, implementation and operability of the indicators and parameters chosen to address the descriptors**. This has been specifically stressed for D1 (Hummel et al. 2015, see section 2.3.5 of this deliverable) whose work revealed great differences between countries in the ecological relevance and the degree of implementation and operability of the parameters they chose to assess D1. Previously Cochrane et al. (2010) mentioned as important preparatory tasks for GES assessment and monitoring the following: (1) gathering of environmental data to support assessment, (2) identification of biodiversity components present, (3) definition of ecologically-relevant assessment areas, (4) definition of reference state (condition) and (5) definition of targets. In the NEAT analyses performed in ATLAS, the single indicators used to address the environmental characteristics of the studied areas were the areal extent of biogenic and of rocky substrate. This indicator was addressed only by three case studies: CS1, CS4 and CS6, and all three used different units to measure it (see table 7). **It is worth mentioning that seabed features are considered a fundamental aspect for GES assessment as a proxy of potential benthic communities inhabiting the area, and also for the effects of anthropogenic activities**. Indeed, besides the direct mechanical effects of the anthropogenic activity, indirect effects (e.g. sand coverage, turbidity increase) can also be remarkable; the recent paper by Montereale-Gavazzi et al. (2018) tested classification approaches of the seabed features in a specific area in the North Sea. The authors detected that the fauna growth was constrained by sand coverage or increased turbidity levels, which could result from different anthropogenic activities. This work revealed as a good proxy of anthropogenic activity the gravel:sand ratio, and it was considered a relevant indicator of GES in a 9 year survey program. Hence it would be useful to add this kind of information, when available, to the geomorphological characteristics of deep-sea areas.

Identifying biodiversity components present in a community/ecosystem is also a challenging task in the deep sea. For NEAT assessment, species richness and species diversity for non-commercial fish species has been assessed in two case studies, and species richness of benthic organisms and coral species richness have been assessed respectively for one case study. The ways diversity was measured was different for the different indicators. For non-commercial fish species, the species richness per area (km^2) in CS3 was calculated, and the mean species richness per km^2 was calculated in CS4. For benthic organisms species richness was expressed per area (km^2) in CS3, and in coral taxa per image (aprox $3m^2$) for coral species richness for CS4. In this case, the data used by CS3 came from trawling surveys, whereas the data from CS 4 was produced from photographic images. **This highlights the challenge of using different methodologies that produce different types of data which are difficult to compare when trying to make analyses of all data together. A further challenge is to pool information gathered at very different spatial scales in order to make assessments at subregional or regional levels as required by the MSFD.**

Even if the taxonomic resolution from images is not very powerful, it is enough to identify habitat-forming taxa (e.g. corals, sponges) as well as to characterize morphotypes and mobile/sessile fauna. Further deep-sea research involved mostly these type of methodologies, as most bottom contact gears have a great impact on the seafloor and are not considered the best option for working in deep-sea ecosystems. It is worth highlighting that with minimal habitat disturbance on large spatial scales, **imagery provides valuable, cost-effective assessment of habitat features and community structure** (Orejas et al. 2009, Gori et al. 2013, McIntyre et al. 2013, Purser et al. 2013, Arnaud-Haond et al. 2017, van den Beld et al. 2017). Moreover, most of the ROVs currently used for deep-sea surveys allow sample collection that is still necessary to develop a robust record of species richness, including species-level taxonomic identifications, and to establish a baseline.

The difficulties in obtaining information from deep-sea areas make predictive habitat models an interesting tool when considering GES assessment. **Models can be a useful instrument for characterizing the deep sea and also for establishing monitoring programs** following the predictions from the models. These can be also a suitable tool considering the vast extension of the deep sea, and the needs to harmonise MSFD and MSPD.
In addition, molecular studies, combined with larval dispersal models will contribute to better defining the degree of connectivity between populations of deep-sea species and to identify populations sources and sinks, an aspect which is also important for the assessment of GES, contributing to the definition of areas with a special ecological significance. (Fox et al. 2016, Henry et al. 2018).

Structural and functional diversity in benthic ecosystems is directly related to seafloor integrity, and this has been highlighted in the Commission decision of May 2017 where criteria combining D1 and D6 have been included. Beside the measure of species richness, many other indicators contribute to evaluating D1 and D6. Among those, several have been addressed in the NEAT analyses (see table 7). Abundance of non-commercial demersal fish and cephalopods (CS3, CS4) have been measured for both case studies but using different units. To quantify abundance of live coral colonies (CS1, CS6) for both case studies, the same units have been used. To measure areal extent of biogenic reef/VMEs (CS1, CS4, CS6) two different units have been used for these three CS, and to measure areal extent of rocky seafloor/VMEs (CS1, CS6) for both case studies same units have been used. Regarding the quantification of areal extent of human affected area (CS1, CS2, CS3, CS4, CS6, CS7, CS9) for these CS, a total of 4 different units have been used. To measure areal extent of protected areas (CS1, CS3, CS4, CS6, CS7, CS9) for these CS 3 different units have been used. Density of biogenic reef forming species (CS1, CS2, CS4, CS7), have been measured for these 4 CS using different units. Finally to quantify distribution and condition of habitat forming species (CS4), areal extent of sedimentary seafloor/VMEs (CS4), ratio live coral *vs* dead coral (CS1, CS4, CS6), VMEs and VME indicator taxa (CS4), number of size cohorts in a population (CS2), average swept ratio for habitat (CS5) and weighted swept VME area ratio (CS5) the same unit has been used for each indicator in the different cases studies. **These results highlighted the urgent need for standardised methodologies to be able to compare situations among zones (always considering the specific characteristics of the investigated areas) and to pool local assessments to a sub-regional or regional scale**. **The need for standardisation includes not only the units used to measure the different indicators, but also other aspects, such as the time frame covered by the observations given** (e.g. data from a single sampling event or average from several years of observation). Moreover, **regarding the evaluation of "physical loss pressure" (PL), mapping of pressures in a standardized and comparable way would be an important step within the MSFD frame, to assess the spatial pattern of the impacts caused by human pressures as well as how this pattern changes through time**. In this context ATLAS aims for an approach similar to the one presented by Paganelli et al. (2017); these authors proposed a method to estimate the spatial extent of PL pressure overlaid with the distribution of the seabed habitats to estimate the loss of biogenic substrates. The study presents a method that allows comparison of the current situation with future conditions and evaluation of different possible management scenarios. **Within ATLAS we aim to integrate the results obtained from this GES assessment together with the pressure maps that will be supplied for ATLAS CS to WP6 with the aim of approaching the MSP of ATLAS CS considering the habitats, uses and pressures of deep-sea areas.**

The maintenance of benthic diversity and seafloor integrity are directly related to anthropogenic activities, mostly with bottom-trawling activity**. It is remarkable that the single indicator that has been addressed by 7 out of 9 case studies was "areal extent of human affected area", this highlights the existence of this kind of information above other data related to anthropogenic impacts.** However, even if the units are the same for all CS (percentage of trawled area), in some cases, the information corresponds to a single survey and in others the values presented are an average of several years' survey. This is for instance the case of CS6 where values were observed of, for instance > 200%, representing the cumulative area trawled over the year, averaged for 9 years. Korpinen et al. already revealed in 2013, that over the entire sea area explored in the Baltic Sea, deep-sea habitats were more impacted than shallower infralittoral and circalittoral habitats. The authors found that, in the explored area, almost no deep-sea habitat was undisturbed (< 1 %), with the widest impacts estimated for sand and coarse-sediment habitats.

The recently developed BESITO index (BEnthos Sensitivity Index to Trawling Operations) by González-Irusta et al. (2018) aims to classify species, using biological traits, according to their sensitivity to bottom trawling (see also section 2.4 of this deliverable). In González-Irusta's work, the index has been applied using 8 biological traits. The selection of these traits was based on general knowledge of trawling impacts on epibenthic communities from previous studies using BTAs. In order to assign the weight of the traits in the BESITO formula, the variation in the relative biomass of each trait's level was analyzed. Regarding the deep-sea and specifically VMEs, the handicap of this index is that it is mostly based on biomass values. For many deep-sea ecosystems, and always for VMEs, the available data are frequently presence/absence, abundances or densities. This might hamper the use of the BESITO index for many deep-sea areas from which no data are available for species biomass. Development of conversion factors to transform biomass values in density values, could be a potential way to make the applicability of these kind of indexes more adequate for benthic invertebrates.

Regarding commercial fish species five CS leaders assessed this descriptor using the following indicators: body length distribution of fish (CS9), biomass of demersal fish (CS2), biomass of selected fish species (CS3, CS8) and fishing effort (CS4, CS7). It is worth mentioning that, again, to address the indicators, different CS used different ways to measure the indicators (see table 7); this highlights once again the need to establish methodological standards and to follow already existing guidance on reporting results (e.g. see Commission Decision (EU) 2017/848) to facilitate integration of the evaluation of different locations/areas at a sub-regional or regional level. Furthermore, the use of standardised measurement methods will contribute to making comparable the results from different geographical locations.
It is worth mentioning that a D3 indicator that has neither been included in the ATLAS NEAT analyses nor in the suggested indicators from the European Commission, but that has been suggested in a recent work (Jayasinghe et al. 2017), is the **Mean Trophic Level (MTL). This indicator has been demonstrated as useful to understand the status and the trends of fish stocks in the European marine subareas, and it has been used as an indicator of fisheries sustainability (e.g. Pauly et al. 1998, Branch et al. 2010) and biodiversity status (Pauly and Watson 2005, Foley 2013). For forthcoming GES assessments it could be useful to take this indicator into consideration**.
Another important suggestion regarding D3 is the reorganization of indicators and criteria within two pressure-state response (PSR) scenarios associated with two new criteria: fishing intensity assessment and selectivity pattern (Probst et al. 2016, see **figure 27**).
For forthcoming GES assessment in the deep sea it would be worthy to consider these new approaches and explore if it can be feasible to apply them in the deep-sea realm.

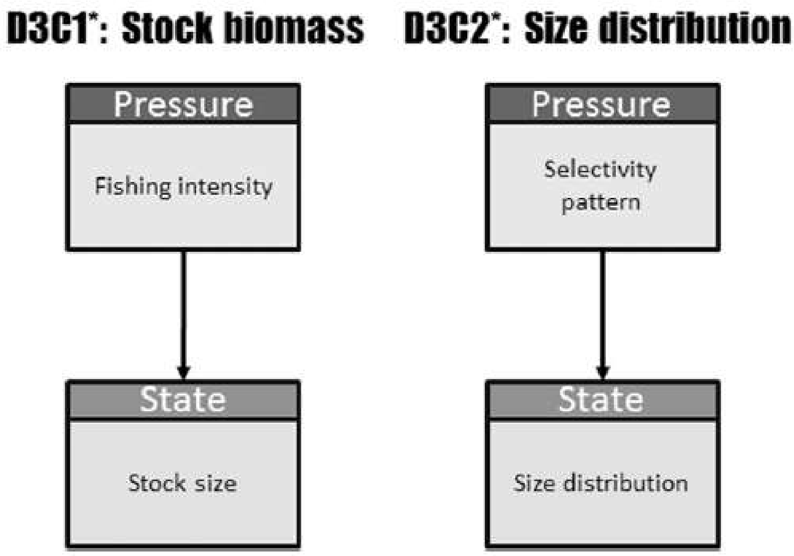

Fig. 27 *Pressure-state relationships to the proposed criteria (D3C1* & D3C2*) of Descriptor 3. * criteria are labelled with an asterisk (*) since they constitute new suggestions by Probst et al. 2016 (source: Probst et al. 2016).*

Regarding marine litter, two indicators have been addressed in ATLAS CS: Areal extent of litter: type (e.g. Plastic, Glass)/abundance/density/weight (CS2, 4, 6) and density of abandoned fishing gear (e.g. lines, nets, etc.) (CS6). As was the case for the other descriptors, the D10 indicator measured by three different CS was approached in three different manners, highlighting once again the lack of standardization. **For the assessment of litter in the deep-sea, approaches like the one suggested by Baudrier et al. (2018) could be very useful as the authors suggested to make the data collection efforts more efficient and effective, optimising vessel time and implementing an ecosystem approach in collecting data for fisheries management**. The authors suggest the characterization (composition, amount and spatial distribution) of litter and micro-litter on the coastline, in the surface layer of the water column, and on the seabed, using the fisheries trawl surveys (see also section 2.3.5).

Beside the direct effects of the anthropogenic activity such as is mentioned above and assessed by NEAT within ATLAS, there are also indirect effects (e.g. sand coverage, turbidity increase) that have been highlighted in the scientific literature. The recent study by Montereale-Gavazzi et al. (2018) tested classification approaches of the seabed features in a specific area in the North Sea. It was detected that the fauna growth was constrained by sand coverage or increased turbidity levels, which could result from different anthropogenic activities. **This work revealed as a good proxy of anthropogenic activity the gravel to sand ratio, and it was considered a relevant indicator of GES in a survey program over 9 years. Hence this could be an interesting indicator to address in the deep sea that will need to be evaluated together with pressure maps in the investigated area**, as commented earlier, following the approach by Paganelli et al. (2017).

Monitoring the environmental status in the deep sea

After the challenge of assessing GES in the deep sea, the next step is to design a monitoring program to evaluate changes in the environment (e.g. bad, poor, moderate, good, high related to baseline or reference values).

Cochran et al. (2010) suggested specific steps for GES monitoring: (1) prioritising where to monitor in relation to the location and types of human activities and their associated pressures on and risks to biodiversity; (2) prioritising which biodiversity components and criteria to monitor, based on an assessment of risk to targets; (3) selecting indicators to inform the state of the selected biodiversity components in relation to the targets set; (4) collecting the evidence (monitoring) needed to support the assessment of state and trends; (5) assessment of the evidence to draw conclusions the proximity to GES, direction and rate of change and progress towards (or away from) GES; (6) reporting of assessments; (7) developing a programme of measures to define appropriate remedial actions; (8) adaptive management, adjusting the spatial and temporal intensity of a) the monitoring programme and b) the programme of measures.

Currently no monitoring programs have been established to specifically assess GES in the deep sea. **Probably one of the most feasible ways to regularly monitor the deep sea will be, as previously mentioned, to take profit of the scientific surveys regularly conducted by different European countries**. However, it is worth mentioning the case of the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) in the NE Atlantic where monitoring of benthos and water column has been carried out for more than 30 years. These long-term studies provide very useful information especially when disentangling the role of natural variability from the impact of human activities. **Regarding the regular scientific trawl surveys conducted by European countries, these can be very useful, besides the monitoring of fish species, for monitoring of litter**. However, it is worth considering that these scientific campaigns, mostly based on trawl surveys, do not offer the most appropriate way to monitor the deep sea and are not suitable at all for monitoring VMEs. Benthic organisms frequently display a patched distribution and to quantify species density and analysed distribution patterns, only image methods or in specific cases box-corer sampling are suitable. Photo and video sampling are expensive sampling methodologies and not all research institutions have access to these infrastructures. This makes it challenging to investigate these ecosystems. It is even more challenging (and sometimes impossible) to establish a monitoring programme. However, the fast development of new and more effective methodologies will in the coming years contribute to improving this situation and covering these caveats. For instance, as mentioned before, **the use of AUVs combining MB and photography will allow mapping of much extensive zones and simultaneously characterizing benthic communities. Further, the new machine learning methodologies will allow a more effective way to quantitatively process underwater images**.

Beside the technological development currently taking place, some authors also **explore the potential synergies between research and industry regarding monitoring tasks**. Barrio Froján et al. (2016) explore exiting monitoring approaches in the UK from industry, private companies and the government, highlighting the synergies between them and the potential for development into an integrated approach to marine benthic monitoring. Considering the already established links between the deep-sea ecosystem research and the sustainable exploitation of the deep-sea realm (e.g. oil companies such as BP, Equinor) the opportunities to join monitoring efforts should be explored and enhanced (e.g. see Jones et al. 2006, 2007, 2012, see also Murray et al. 2018).
Also, improvements in access to databases as well as in the uploading of new data to these databases (e.g. EMODNET) is an important task which will improve our knowledge and understanding of the marine realm and thus ultimately enhance the assessment of GES and the design and establishment of appropriate monitoring, sustainable exploitation and conservation strategies.

Deep-sea ecosystems goods and services and GES

In several papers dealing with the MSFD the need to take into account the sustainable use of marine resources when assessing GES has been mentioned, avoiding identifying GES with pristine situations. Indeed Rice et al. (2012) refer to GES not necessarily as a “pristine situation”, but a status where impacts of all uses were sustainable. This, to our eyes, means it is **relevant to consider deep-sea ecosystems goods and services as an important element in the assessment of GES in the deep sea**. Although there are some works dealing with the goods and services provided by benthic ecosystems in European waters, studies in the deep sea, and in particular benthic habitats, are mostly lacking in ecosystem services assessments (Armstrong et al. 2012, Thurber et al. 2013). The first assessment in ecosystems services for the Atlantic a European scale was published by Galparsoro et al. (2014). The authors concluded that (1) more than 90% of the mapped area provides biodiversity maintenance and food provision services; meanwhile, grounds providing reproduction and nursery services are limited to half of the mapped area, and (2) the ecosystem services assessment categories are significantly related to the distance to the coast and to depth (higher near the coast and in shallow waters, this gradient is likely to be explained by difficult access (i.e. remoteness and depth) and lack of scientific knowledge for most of the services provided by distant benthic habitats. Beside this large scale work by Galparsoro et al. (2014), the work by Armstrong et al. (2012) deals exclusively with the deep sea, presenting the goods and services (see **fig. 28**) that deep-sea ecosystems can offer as well as an attempt to give values to them. Furthermore, in ATLAS deliverable 5.1 a first synthesis of the ecosystem good and services of ATLAS CS has been obtained (Armstrong et al. 2017), with the overall conclusion that a large number of different services emanates from the deep sea and that the quantification of those remains extremely challenging, as many deep-sea ecosystems support services that are removed in time and space from the final services that can be valued. The deliverable 5.2 (Armstrong et al. 2017), includes the expert assessment of risks to ecosystem services from diverse human drivers; the results of this assessment pointed to four high risk human drivers for deep-sea ecosystems: pollution, temperature change, OA and fisheries, in addition to the cumulative effects; the results agreed with the results from Halpern et al. (2008), who using a number of databases combined with an expert judgement-based area assessment, show how Northern Atlantic ecosystems, especially in the east, are highly impacted, and identify central drivers behind these impacts. In the risk assessment conducted in ATLAS, the four high-risk human drivers identified are followed by oil/gas and mining; these two industries are seen by the ATLAS consortium as far less risky in relation to ecosystem services. Blue biotechnology and tourism are perceived to provide the greatest positive effects and likelihoods, with oil/gas and mining following them.

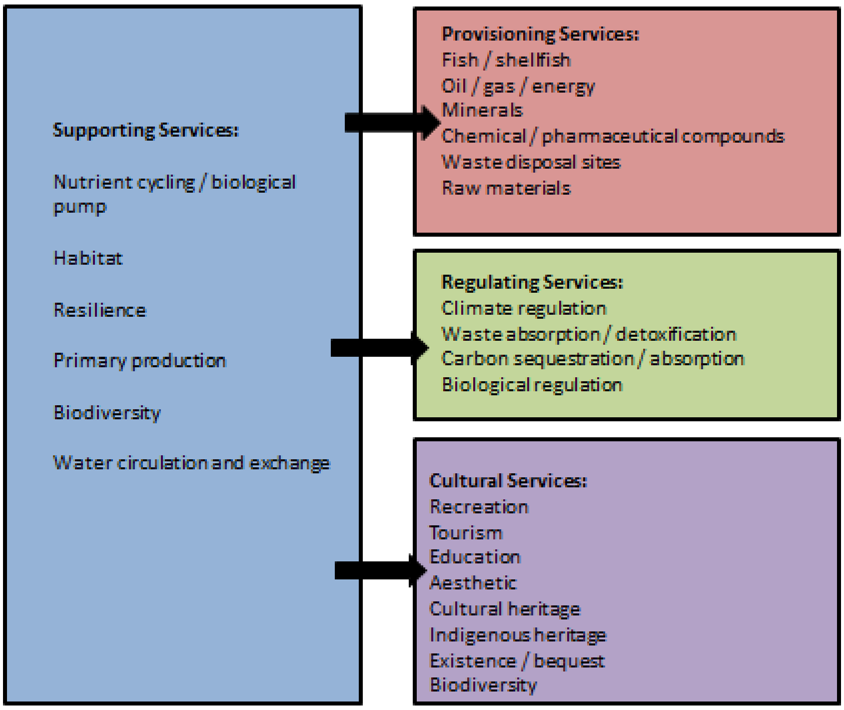

Fig. 28. *Deep-sea ecosystem goods and services (Source: ATLAS deliverable 5.1, modified from Armstrong et al. 2012).*

Overall, expert opinion is that it is fundamental to take into account in the assessment of GES in the deep-sea (and elsewhere), the importance of expert judgment which has been highlighted in several papers (see for instance Utizi et al. 2018 and references therein). The scarcity of data needs

necessarily to be supplemented by the knowledge of the area by the experts and this judgment is necessary to correctly interpret the output results from any multimetric index and/or models. This was also fundamental in the NEAT analyses performed in ATLAS.

Marine Strategy Framework Directive and Marine Spatial Planning Directive

As previously mentioned in this document, the assessment of GES should be used as a paramount element when addressing Marine Spatial Planning (MSP). Several papers already highlighted this aspect and this is fundamental in ATLAS, as **the results obtained from GES assessment (WP3) will also be taken into account in WP6 (MSP)**. Elliot et al. (2018) explore a new approach combining the expertise of main stakeholders on a hypothetical marine scenario that allowed the severity of the human activity effects on GES to be determined with the weighing of the severity of the impacts according to the area of each activity footprint. The approach also allows the calculation of GES of marine regions, indicating in which cases the adoption of quality assessment and spatial planning can be mutually beneficial, or are antagonistic in meeting environmental targets. The work by Elliot et al. (2018) discussed this approach with the aim of maximising the use of a marine area but minimising the environmental degradation due to human activities. This novel approach shows again the role of Best Expert Judgement (BEJ) in cases where marine adaptive management is still required, in situations where lack of information and data frequently make it difficult to take decisions.

Considering only the descriptors specifically addressed in ATLAS, in the context of the paper by Gilbert et al. (2015), a clear example is given on the integration of MSFD and MSP in a cold-water coral reef: for instance planning for D1 the creation of a “no-take” MPA could prevent further destruction of reefs and preserve habitat/nursery areas for associated species; for D3, requiring healthy stocks of commercially exploited species, could also be positively affected through MSP; further fish move into and out of the MPA, hence restored stocks in the MPA can directly benefit, and finally, the end of trawling activities should lead to the recovery of benthic communities within the MPA (Hiddink et al. 2006), contributing to D6. The decrease in fishing nets contributes also to a reduction in marine litter, D10. This case study demonstrates the potential of MSP to benefit maritime activities and the marine environment. This is a nice, clear example on the direct link between protection, GES achievement and also a rationale for MSP that could be applied to other deep-sea ecosystems.

As a main general conclusion from the NEAT discussion and revised documents and literature, due to the data-limited situation and challenges posed for monitoring, it may well be the case that GES in the deep sea will have to be assessed at habitat and ecosystem level (rather than at species level) and at large spatial and temporal scales (considering aspects such as seasonality and the need to nest results of analyses conducted at different spatial and temporal scales) when compared to the shallower waters of the European Seas. For similar reasons, the type of indicators to be used may have to be simplified and likely be based on high level analyses related to traits, pressures/risks, and habitat/ecosystem resilience, among those the potential use of indicators based on multimetric indexes should be taken into consideration, also ecological models can be a useful tool to assess GES in the deep sea to optimise the use of the scarce available data.

Suggestions for GES assessment in the deep sea - perspectives

Data needs and potential data sources to assess GES in the deep sea

- Accessibility to VMS (Vessel Monitoring System) data

- Accessibility to data on habitats (e.g. habitat location an extension, data on density of structuring species), and human activities (e.g. VMS but also oil and gas, telecommunications, shipping). Examples are the portal from Marine Scotland (https://marinescotland.atkinsgeospatial.com/nmpi/) where GIS layers for many parameters can be freely downloaded; the MAREANO website (http://www.mareano.no/en) or the VME ICES database

- Good quality photo and video data are needed to better assess the state of the deep sea

- Need for quantitative video analyses to allow the use of real measures and not relative (e.g. records/hour of transect should be replaced by records/transect length or area)

- Data on the effects of human activities (e.g. oil and gas exploration, plastics) on the biology and ecological role of ecosystem engineers (e.g. effects of an oil spill on the reproductive capacity of *Lophelia pertusa*)

- Results from aquaria experiments could be used to define tipping points for some structuring species and to establish baselines and target values
- Environmental features from the water column should be considered for GES assessment in the deep sea, when available (e.g. oxygen concentration, pH)
- Environmental features from the seafloor should be considered for GES assessment in the deep sea, ratio of sand to gravel would be a good proxy for mechanical anthropogenic impacts
- Introduce quantitative information in the ICES VME database to contribute to the GES assessment (e.g. density data of ecosystem engineer species)
- Setting up of reference areas (e.g. MPAS) and monitoring them (e.g. through the deployment of landers, AUVS, etc) as baselines/reference for GES assessment.
- Litter evaluation from regular scientific trawl surveys (e.g. type, density)
- Species Distribution Models and Habitat Suitability Models as a tool that could provide better information to assess GES in current and future scenarios.
- Identification of source and sink populations to select key areas for geographical connectivity and establish priorities to assess GES.

Methodological improvements (field and data processing)

- Standardization of measures is a needed step to pool together local assessments in order to be able to assess GES at regional, sub-regional scale
- Adjust scales to measure indicators and pressures
- Adjust temporal scales (single events, averaged values from several years)
- Evaluate the potential use of MTL as indicator for D3
- New and/or improved methodologies (e.g. AUVs+Photo) will contribute to better mapping and gathered information at larger scales to better assess GES in the deep-sea
- Improvement in automatisation of video data processing
- Multivariate indexes based in biomass values could be useful for demersal fish species but not for benthic organisms
- Establish pathways for collaboration between industry and academia
- Promote the archiving of collected information in data bases
- Promote the use of databases e.g. EMODNET

Impacts and pressures

- Atlas WP5 identified from ATLAS community consultation five main human risks for deep-sea ecosystems: pollution, temperature change, ocean acidification, fisheries and cumulative effects of stressors
- Pressure maps need to be analysed together with NEAT results to better interpret the data and help to separate anthropogenic effects from natural effects

Selection of basic indicators

- Considering ATLAS outputs and previous work on GES, potential basic indicators for any deep-sea area to assess:
    - Environmental parameters water column: temperature, pH, oxygen
    - Environmental parameters seafloor: geomorphology, sediment characterization (sand to gravel ratio)
    - Density structuring/ecosystem engineer species (not valid for most soft bottom areas)
    - percentage of area covered by structuring species
    - percentage of area affected by human activities
    - Biomass of commercial fish species
    - Fishing effort
    - MTL has been recommended
    - Density of litter in the seafloor

Monitoring

- Selection of specific areas considered of special relevance (e.g. ecological relevance, relevance for fisheries or other anthropogenic activities) to conduct monitoring programs
- Selection of appropriate monitoring scales (spatial and temporal) considering indicators and pressures (e.g. local scales to be pooled for subsequent assessment at subregional/regional scale)
- Selection of appropriate time frame. Ten years have been considered as an adequate time frame for GES monitoring in the deep sea
- Assessment of the financial and technical requirements needed for the pursuing of the suggested monitoring programmes. This will also guide further the establishment of priorities in terms of areas and indicators to be monitored.
- Establishment of a protocol of actions to be followed when monitoring reveals that the quality of the environmental status has declined.

5 Acknowledgements

This deliverable has been prepared with the help of many individuals besides the fundamental collaboration and inputs of all contributors. Thanks goes to Maria Uyarra who introduced us to the NEAT software. We would like to thank Lena Avellan from OSPAR for facilitating useful information for this deliverable. Thanks are also due to Filipe Porteiro from the Azores Government for answering our queries regarding the results of the initial evaluation. We thank Claire Armstrong for supplying information from WP5 which was useful to feed into this deliverable. Thanks also to Gerald Duineveld for providing MBES data for Mingulay Reef Case Study. Laura La Beur provided information on marine litter that has been also used in the assessment of the Mingulay Case Study. Information and data provided by Equinor and MAREANO for the assessment of Case Study Love Observatory are also acknowledged. Thanks to Miguel Hernández and Cruz Iglesias for helping us with the literature research performed within this deliverable and also to Julia Eighteen who greatly improved the English. Discussions in the GES breakout groups also highly contributed to this work. Thanks also to the many individuals that participated in the data gathering and the process of offering this information to apply NEAT. Discussions within ICES WGDEC were extremely useful and productive in improving the assessment of GES in the deep sea.

6 Bibliography

Alexander KA, Kershaw P, Cooper P, Gilbert AJ, Hall-Spencer JM, Heymans JJ, Kannen A, Los HJ, O'Higgins T, O'Mahony C, et al. (2015) Challenges of achieving good environmental status in the Northeast Atlantic. Ecology and Society, 20

Alheit J, Hagen E (1997) Long-term climate forcing of European herring and sardine populations. Fish Oceanogr 6: 130–139

Andaloro F, Ferraro M, Mostarda E, Romeo T, Consoli P (2013) Assessing the suitability of a ROV to study the fish community associated with offshore gas platforms in the Ionian Sea: a comparative analysis with underwater visual censuses (UVCs). Helgoland Marine research, 67:241

Andersen JH, Dahl K, GÃ¶ke C, Hartvig M, Murray Cn, Rindorf A, Skov H, Vinther M, Korpinen S (2014) Integrated assessment of marine biodiversity status using a prototype indicator-based assessment tool. Frontiers in Marine Science 1

Andrew NL, Mapstone BD (1987) Sampling and the description of spatial patterns in marine ecology. Oceanogr Mar Biol Annual Review 25: 39-90

Arnaud-Haond S, Van den Beld IMJ, Becheler R, Orejas C, Menot L, Frank N, Grehan A, Bourillet JF (2017) Two "pillars" of cold-water coral reefs along Atlantic European margins: Prevalent association of *Madrepora oculata* with *Lophelia pertusa*, from reef to colony scale. Deep Sea Res Part II: Topical Studies in Oceanography 145, 110-119, https://doi.org/10.1016/j.dsr2.2015.07.013.

Armstrong CW, Foley NS, Tinch R, van den Hove S (2012) Services from the deep: Steps towards valuation of deep sea goods and services. Ecosystem Services 2:2-13

Barrio Frojan CR, Cooper KM, Bolam SG (2016) Towards an integrated approach to marine benthic monitoring. Mar Pollut Bull 104:20-28

Bashmachnikov I, Loureiro CM, Martins A (2013) Topographically induced circulation patterns and mixing over Condor seamount. Deep Sea Research Part II: Topical Studies in Oceanography 98:38-51

Baudrier J, Lefebvre A, Galgani F, Saraux C, Doray M (2018) Optimising French fisheries surveys for marine strategy framework directive integrated ecosystem monitoring. Marine Policy 94:10-19

Beisiegel K, Darr A, Gogina M, Zettler ML (2017) Benefits and shortcomings of non-destructive benthic imagery for monitoring hard-bottom habitats. Mar Pollut Bull 121:5-15

Berg T, Murray C, Jacob Carstensen J, Andersen JH (2016) NEAT-Nested Environmental status Assessment Tool – Manual version 1.3. 38 pp.

Berx B, Payne MR (2017) The Sub-Polar Gyre Index – a community data set for application in fisheries and environment research. Earth Syst Sci Data 9: 259–266

Blacker RW (1982) Rockall and its fishery. Laboratory Leaflet, MAFF Directorate of Fisheries Research, Lowestoft 55: 23 pp

Bøe R, Bellec VK, Dolan MFJ, Buhl-Mortensen P, Buhl-Mortensen L, Slagstad D, Rise L (2009) Giant sandwaves in the Hola glacial trough off Vesterålen, North Norway. Mar Geol 267: 36-54

Bøe R, Bellec VK, Dolan MFJ, Buhl-Mortensen P, Rise L, Buhl-Mortensen L (2016) Cold-water coral reefs in the Hola glacial trough off Vesterålen, North Norway. In: Dowdeswell JA, Canals M, Jakobsson M, Todd BJ, Dowdeswell EK (eds.) Atlas of Submarine Glacial Landforms: Modern, Quarternary and Ancient. Geological Society, London, Memoirs, 46: 309-310

Borja A, Elliott M, Carstensen J, Heiskanen AS, van de Bund W (2010) Marine management--towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Mar Pollut Bull 60:2175-2186

Borja A, Galparsoro I, Irigoien X, Iriondo A, Menchaca I, Muxika I, Pascual M, Quincoces I, Revilla M, German Rodriguez J, Santurtun M, Solaun O, Uriarte A, Valencia V, Zorita I (2011) Implementation of the European Marine Strategy Framework Directive: a methodological approach for the assessment of environmental status, from the Basque Country (Bay of Biscay). Mar Pollut Bull 62:889-904

Borja A, Elliott M, Andersen JH, Cardoso AC, Carstensen J, Ferreira JG, Heiskanen AS, Marques JC, Neto JM, Teixeira H (2013) Good Environmental status of marine ecosystems: what is it and how do we know when we have attained it? Mar Pollut Bull 76: 16–27.

Bourillet JF, de Chambure L, Menot L, Simplet L, Loubrieu B (2016) Classification Géomorphologique de la pente continentale du Golfe de Gascogne (1/500 000). Ifremer - Géosciences Marines, Brest, France. http://doi.org/10.12770/d5da916a-163c-47b9-8a8e-73dcaeec7986.

Boyes SJ, Elliott M, Murillas-Maza A, Papadopoulou N, Uyarra MC (2016) Is existing legislation fit-for-purpose to achieve Good Environmental Status in European seas? Mar Pollut Bull 111:18-32

Braga Henriques A (2015) Cold-water coral communities in the Azores: diversity, habitat and biological response to anthropogenic impacts. PhD Dissertation, University of the Azores, Azores, Portugal

Branch TA, Watson R, Fulton EA, Jennings S, Mc Gilliard CR, Pablico T, Ricard D, Tracey SR (2010) The trophic fingerprint of marine fishes. Nature 468: 431e435. http://dx.doi.org/10.1038/nature09528

Broszeit S, Beaumont NJ, Uyarra MC, Heiskanen A-S, Frost M, Somerfield PJ, Rossberg AG, Teixeira H, Austen MC (2017) What can indicators of good environmental status tell us about ecosystem services?: Reducing efforts and increasing cost-effectiveness by reapplying biodiversity indicator data. Ecological Indicators 81:409-442

Cánovas-Molina A, Montefalcone M, Bavestrello G, Cau A, Bianchi CN, Morri C, Canese S, Bo M (2016) A new ecological index for the status of mesophotic megabenthic assemblages in the mediterranean based on ROV photography and video footage. Cont Shelf Res

Cardoso AC, Cochrane S, Doerner H, Ferreira JG, Galgani F, Hagebro C,Hoepffner N, Keizer PD, Law R, Olenin S, Piet GJ, Rice J, Rogers SI, Swartenbroux F, Tasker ML, van de Bund W (2010) Scientific support to theEuropean Commission on the marine strategy framework directive – JRC man-agement group report. In: Piha, H. (Ed.), JRC Scientific and Technical Reports.European Commission and ICES, Luxembourg, p. 54.

Carstensen J, Lindegarth M (2016) Confidence in ecological indicators: A framework for quantifying uncertainty components from monitoring data. Ecological Indicators 67:306-317

Cavallo M, Elliott M, Touza J, Quintino V (2016) The ability of regional coordination and policy integration to produce coherent marine management: Implementing the Marine Strategy Framework Directive in the North-East Atlantic. Marine Policy 68:108-116

Cavallo M, Elliott M, Quintino V, Touza J (2018) Can national management measures achieve good status across international boundaries? - A case study of the Bay of Biscay and Iberian coast sub-region. Ocean Coastal Manage 160:93-102

Christensen V, Walters CJ (2005) Using ecosystem modeling for fisheries manage-ment: where are we. ICES CM 1000, 19.

Chust G, Allen J, Bopp L, Schrum C, Holt J, Tsiaras K, Zavatarelli M, Chifflet M, Cannaby H, Dadou I(2014) Biomass changes and trophic amplification ofplankton in a warmer ocean. Glob Change Biol 20: 2124–2139.

Claussen U, Connor D, de Vrees L, Leppänen J, Percelay J, Kapari M, Mihail O, Ejdung G, Rendell J (2011) Common Understanding of (Initial) Assessment,Determination of Good Environmental Status (GES) and Establishment of Envi-ronmental Targets (Art, 8, 9 & 10 MSFD). WG GES EU MSFD

Cochrane SKJ, Connor DW, Nilsson P, Mitchell I, Reker J, Franco J, Valavanis V, Moncheva S, Ekebom J, Nygaard K, Serrão Santos R, Narberhaus I, Packeiser T, van de Bund W, Cardoso AC (2010) Marine Strategy Framework Directive. Task Group 1 Report Biological diversity, Ed. by N. Zampoukas 120p.

Consoli P, Andaloro F, Altobelli C, Battaglia P, Campagnuolo S, Canese S, Castriota L, Cillari T, Falautano M, Peda C, Perzia P, Sinopoli M, Vivona P, Scotti G, Esposito V, Galgani F, Romeo T (2018) Marine litter in an EBSA (Ecologically or Biologically Significant Area) of the central Mediterranean Sea: Abundance, composition, impact on benthic species and basis for monitoring entanglement. Environmental pollution 236:405-415

Crise A, Kaberi H, Ruiz J, Zatsepin A, Arashkevich E, Giani M, Karageorgis AP, Prieto L, Pantazi M, Gonzalez-Fernandez D, Ribera d'Alcala M, Tornero V, Vassilopoulou V, Durrieu de Madron X, Guieu C, Puig P, Zenetos A, Andral B, Angel D, Altukhov D, Ayata SD, Aktan Y, Balcioglu E, Benedetti F, Bouchoucha M, Buia MC, Cadiou JF, Canals M, Chakroun M, Christou E, Christidis MG, Civitarese G, Coatu V, Corsini-Foka M, Cozzi S, Deidun A, Dell'Aquila A, Dogrammatzi A, Dumitrache C, Edelist D, Ettahiri O, Fonda-Umani S, Gana S, Galgani F, Gasparini S, Giannakourou A, Gomoiu MT, Gubanova A, Gucu AC, Gurses O, Hanke G, Hatzianestis I, Herut B, Hone R, Huertas E, Irisson JO, Isinibilir M, Jimenez JA, Kalogirou S, Kapiris K, Karamfilov V, Kavadas S, Keskin C, Kideys AE, Kocak M, Kondylatos G, Kontogiannis C, Kosyan R, Koubbi P, Kuspilic G, La Ferla R, Langone L, Laroche S, Lazar L, Lefkaditou E, Lemeshko IE, Machias A, Malej A, Mazzocchi MG, Medinets V, Mihalopoulos N, Miserocchi S, Moncheva S, Mukhanov V, Oaie G, Oros A, Ozturk AA, Ozturk B, Panayotova M, Prospathopoulos A, Radu G, Raykov V, Reglero P, Reygondeau G, Rougeron N, Salihoglu B, Sanchez-Vidal A, Sannino G, Santinelli C, Secrieru D, Shapiro G, Simboura N, Shiganova T, Sprovieri M, Stefanova K, Streftaris N, Tirelli V, Tom M, Topaloglu B, Topcu NE, Tsagarakis K, Tsangaris C, Tserpes G, Tugrul S, Uysal Z, Vasile D, Violaki K, Xu J, Yuksek A, Papathanassiou E (2015) A MSFD complementary approach for the assessment of pressures, knowledge and data gaps in Southern European Seas: The PERSEUS experience. Mar Pollut Bull 95:28-39

Daly E, Johnson MP, Wilson AM, Gerritsen HD, Kiriakoulakis K, Allcock AL, White M (2017) Bottom trawling at Whittard Canyon: Evidence for seabed modification, trawl plumes and food source heterogeneity. Progress in Oceanography, https://doi.org/10.1016/j.pocean.2017.12.010.

Davies AJ, Roberts JM, Hall-Spencer J (2007) Preserving deep-sea natural heritage: Emerging issues in offshore conservation and management. Biological Conservation 138:299-312

Davies JS, Guillaumont B, Tempera F, Vertino A, Beuck L, Ólafsdóttir SH, Smith CJ, Fosså JH, van den Beld IMJ, Savini A, Rengstorf A, Bayle C, Bourillet JF, Arnaud-Haond S, Grehan A (2017) A new classification scheme of European cold-water coral habitats: Implications for ecosystem-based management of the deep sea. Deep Sea Res Part II: Topical Studies in Oceanography 145 (Supplement C), 102-109, https://doi.org/10.1016/j.dsr2.2017.04.014.

De Chambure L, Bourillet J, Bartel C (2013) Geomorphological classification in Bay of Biscay - Morpo-sedimentary mapping of the seabed in selected areas -part of CoralFISH D38 deliverable. http://archimer.ifremer.fr/doc/00249/36033/. Ifremer, Brest, p. 51.

Dickey-Collas M, McQuatters-Gollop A, Bresnan E, Kraberg AC, Manderson JP, Nash RDM, Otto SA, Sell AF, Tweddle JF, Trenkel VM, Hidalgo M (2017) Pelagic habitat: exploring the concept of good environmental status. ICES Journal of Marine Science 74:2333-2341

de Juan S, Thrush SF, Demestre M (2007) Functional changes as indicators of trawling disturbance on a benthic community located in a fishing ground (NW Mediterranean Sea). Marine Ecology-Progress Series 334:117-129

de Juan S, Demestre M (2012) A Trawl Disturbance Indicator to quantify large scale fishing impact on benthic ecosystems. Ecological Indicators 18:183-190

Díaz del Río V, Bruque G, Fernández-Salas LM, Rueda JL, González E, López N, Palomino D, López FJ, Farias C, Sánchez R, Vázquez JT, Rittierott C, Fernández A, Marina P, Luque V, Oporto T, Sánchez O, García M, Urra J, Bárcenas P, Jiménez MP, Sagarminaga R, Arcos JM (2014) Volcanes de fango del golfo de Cádiz, Proyecto LIFE + INDEMARES. Ed. Fundación Biodiversidad del Ministerio de Agricultura, Alimentación y Medio Ambiente. 130 pp

Ebert DA, Stehmann MFW (2013) Sharks, batoids, and chimaeras of the North Atlantic. FAO Species Catalogue for Fishery Purposes. No. 7. Rome, FAO. 523 pp.

EC, 2008:Directive2008/56/EC of the European Parliament and the Council of June 17th 2008 establishing a framework for community action in the field of marine environmental policy.

EC, 2010: Commission decision 2010/477/EU (notified under document C(2010) 5956) on criteria and methodological standards on good environmental status of marine waters

EC, 2017: Commission decision 2017/848/EU Laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU (Text with EEA relevance)

Edwards M, Beaugrand G, Helaouët P, Alheit J, Coombs S (2013) Marine Ecosystem Response to the Atlantic Multidecadal Oscillation. PLOS ONE, 8, e57212

Eigaard OR, Bastardie F, Hintzen NT, Buhl-Mortensen L, Buhl-Mortensen P, Catarino R, Dinesen GE, Egekvist J, Fock HO, Geitner K, Gerritsen HD, González MM, Jonsson P, Kavadas S, Laffargue P, Lundy M, Gonzalez-Mirelis G, Nielsen JR, Papadopoulou N, Posen PE, Pulcinella J, Russo T, Sala A, Silva C, Smith CJ, Vanelslander B, Rijnsdorp AD (2016) The footprint of bottom trawling in European waters: distribution, intensity, and seabed integrity. ICES Journal of Marine Science: Journal du Conseil:fsw194

Elliott M, Borja A, McQuatters-Gollop A, Mazik K, Birchenough S, Andersen JH, Painting S, Peck M (2015) Force majeure: Will climate change affect our ability to attain Good Environmental Status for marine biodiversity? Mar Pollut Bull 95:7-27

Elliott M, Boyes SJ, Barnard S, Borja A (2018) Using best expert judgement to harmonise marine environmental status assessment and maritime spatial planning. Mar Pollut Bull 133:367-377

European Commission, 2010. Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (notified under document C(2010)5956)(2010/477/EU).Off.J.Eur.UnionL232, 12–24
Fernandes MDL, Quintela A, Alves FL (2018) Identifying conservation priority areas to inform maritime spatial planning: A new approach. The Science of the total environment 639:1088-1098
Foley CMR (2013) Management implications of fishing up, down, or through the marine food web. Mar Policy 37: 176e182. http://dx.doi.org/10.1016/j.marpol.2012.04.016.
Fox AD, Henry L-A, Corne DW, Roberts JMR (2016) Sensitivity of marine protected area network connectivity to atmospheric variability. Royal Society Open Science 3:160494. http://dx.doi.org/10.1098/rsos.160494
Fulton EA (2010) Approaches to end-to-end ecosystem models. J Mar Syst 81: 171–183.
Fulton E, Smith A (2004) Lessons learnt from a comparison of three ecosystemmodels for Port Phillip Bay, Australia. Afr J Mar Sci 26: 219–243
Galgani F, Fleet D, van Franeker J, Katsavenakis S, Maes T, Mouat J, Oosterbaan L. et al. (2010). Marine Strategy Framework Directive Task Group 10 Report Marine litter, JRC Scientific and Technical Report, ICES/JRC/IFREMER Joint Report (No. 31210–2009/2010), Ed. by N. Zampoukas. 57 pp.
Galgani F,Hanke G, Werner S, Piha H (2011) MSFDGESTechnical Subgroup on Marine Litter. Technical Recommendations for the Implementation of MSFD Requirements. JRC Scientific and Technical Report, EUR 25009 EN – 2011. 93 pp.
Galparsoro I, Borja A, Uyarra MaC (2014) Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean. Frontiers in Marine Science 1
Giacomello E, Menezes GM, Bergstad OA (2013) An Integrated Approach for Studying Seamounts: CONDOR Observatory. Deep Sea Rese Part II: Topical Studies in Oceanography, 98: 1-6
Gilbert AJ, Alexander K, Sardá R, Brazinskaite R, Fischer C, Gee K, Jessopp M, Kershaw P, Los HJ, March Morla D, O'Mahony C, Pihlajamäki M, Rees S, Varjopuro R (2015) Marine spatial planning and Good Environmental Status: a perspective on spatial and temporal dimensions. Ecology and Society 20
Gislason H, Bastardie F, Dinesen GE, Egekvist J, Eigaard OR (2017) Lost in translation? Multi-metric macrobenthos indicators and bottom trawling. Ecological Indicators 82:260-270
González-Irusta J, De la Torriente A, Punzón A, Blanco M, Serrano A (2018) Determining and mapping species sensitivity to trawling impacts: the BEnthos Sensitivity Index to Trawling Operations (BESITO). ICES Journal of Marine Science doi:10.1093/icesjms/fsy030
Gori A, Orejas C, Madurell T, Bramanti L, Martins M, Quintanilla E, Marti-Puig P, Lo Iacono C, Puig P, Requena S (2013) Bathymetrical distribution and size structure of cold-water coral populations in the Cap de Creus and Lacaze-Duthiers canyons (northwestern Mediterranean). Biogeosciences 10:2049-2013
Gormley K, Hull A, Porter J, MC B, WG S (2015) Adaptive management,international co-operation and planning for marine conservation hotspots in a changing climate. Marine Policy 53:54-66
Hall-Spencer J, Allain V, Fossa JH (2002) Trawling damage to Northeast Atlantic ancient coral reefs. Proceedings of the Royal Society B: Biological Sciences 269:507-511
Hall-Spencer JM, Tasker M, Soffker M, Christiansen S, Rogers S, Campbell M, Hoydal K (2009) Design of Marine Protected Areas on high seas and territorial waters of Rockall Bank. Marine Ecology Progress Series 397:305-308
Halpern BS, Longo C, Hardy D, McLeod KL, Samhouri JF, Katona SK, Kleisner K, Lester SE, O'Leary J, Ranelletti M, Rosenberg AA, Scarborough C, Selig ER, Best BD, Brumbaugh DR, Chapin FS, Crowder LB, Daly KL, Doney SC, Elfes C, Fogarty MJ, Gaines SD, Jacobsen KI, Karrer LB, Leslie HM, Neeley E, Pauly D, Polasky S, Ris B, St Martin K, Stone GS, Sumaila UR, Zeller D (2012) An index to assess the health and benefits of the global ocean. Nature 488:615-+
Halpern B, Walbridge SS, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KF, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Perry MT, Selig ER, Spalding M, Steneck R, Watson R (2008) A Global Map of Human Impact on Marine Ecosystems Science 319 (5865):948-952. doi: 10.1126/science.1149345
Henry L-A, Mayorga-Adame CG, Fox AD, Polton JA, Ferris JS, McLellan F, McCabe C, Kutti T, Roberts JM (2018) Ocean sprawl facilitates dispersal and connectivity of protected species. Scientific Reports 8:11346. DOI:10.1038/s41598-018-29575-4
Hátún H, Payne MR, Beaugrand G, Reid PC, Sandø AB, Drange H, Hansen B, Jacobsen JA, Bloch D (2009a) Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the subpolar gyre, via plankton, to blue whiting and pilot whales. Progr Oceanogr 80: 149–162
Hátún H, Payne MR, Jacobsen JA (2009b) The North Atlantic subpolar gyre regulates the spawning distribution of blue whiting (*Micromesistius poutassou*). Can J Fish Aquat Sci 66: 759–770
Hennige SJ, Wicks LC, Kamenos NA, Perna G, Findlay HS, Roberts JM (2015) Hidden impacts of ocean acidification to live and dead coral framework. Proceedings Biological sciences / The Royal Society 282
Henry LA, Moreno-Navas J, Hennige SJ, Wicks LC, Vad J, Roberts JM (2013) Cold-water coral reef habitats benefit recreationally valuable sharks. Biological conservation 161:67-70
Henry LA, Roberts JM (2014) Applying the OSPAR habitat definition of deep-sea sponge aggregations to verify suspected records of the habitat in UK waters, JNCC Report No 508, 41pp.
Hiddink JG, Jennings S, Kaiser MJ (2006) Indicators of the ecological impact of bottom-trawl disturbance on seabed communities. Ecosystems 9:1190-1199
Howell KL, Davies JS, Jacobs C, Narayanaswamy, BE (2009) Broadscale Survey of the Habitats of Rockall Bank, and mapping of Annex I Reef' Habitat.JNCC Report 422
Hummel H, Frost M, Juanes JA, Kochmann J, Castellanos Perez Bolde CF, Aneiros F, Vandenbosch F, Franco JN, Echavarri B, Guinda X, Puente A, Fernández C, Galván C, Merino M, Ramos E, Fernández P, Pitacco V, Alberte M, Wojcik D, Grabowska M, Jahnke M, Crocetta F, Carugati L, Scorrano S, Fraschetti S, García PP, Sanabria Fernández JA, Poromov A, Iurchenko A, Isachenko A, Chava A, Pavloudi C, Bordeyne F, Andersen SF, Eronat EGT, Cakmak T, Louizidou P, Rico J, Ruci S, Corta Diego D, Mendez S, Rousou M, de Clippele L, Eriksson A, van Zanten W, Diamant A, de Matos VKF (2015) A comparison of the degree of implementation of marine biodiversity indicators by European countries in relation to the Marine Strategy Framework Directive (MSFD). Journal of the Marine Biological Association of the United Kingdom 95:1519-1531
ICES (2012) *Report of the Working Group on Elasmobranch Fishes (WGEF), 19–26 June 2012 Lisbon, Portugal.* ICES CM 2012/ACOM:20. 551 pp.
ICES (2014) Report of the Workshop to review the 2010 Commission Decision on cri-teria and methodological standards on good environmental status (GES) of marine waters; Descriptor 6, 2-3 September 2014, ICES Headquarters, Denmark. ICES CM 2014/ACOM:61. 37pp.

ICES (2015) Report of the Workshop on guidance for the review of MSFD decision descriptor 3 – commercial fish and shellfish II (WKGMSFDD3-II), 10-12 February 2015, ICES Headquarters, Denmark. ICES CM 2015\ACOM:48. 36 pp.
ICES (2016) Report of the Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC), 15–19 February 2016, Copenhagen, Denmark. ICES CM 2016/ACOM:28. 82 pp.
ICES (2017) Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 20–24 March 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:25. 121 pp.
Jayasinghe RPPK, Amarasinghe US, Newton A (2017) Evaluation of status of commercial fish stocks in European marine subareas using mean trophic levels of fish landings and spawning stock biomass. Ocean Coastal Manage 143:154-163
JNCC (2018a) Statements on conservation benefits, condition & conservation measures for East Rockall Bank Special Area of Conservation. http://jncc.defra.gov.uk/pdf/EastRockallBank_ConservationStatements_V1.0.pdf.
JNCC (2018b) Statements on conservation benefits, condition & conservation measures for North West Rockall Bank Special Area of Conservation. http://jncc.defra.gov.uk/pdf/NWRB_ConservationStatements_V1.0.pdf
Johnson C, Inall M, Häkkinen S (2013) Declining nutrient concentrations in the northeast Atlantic as a result of a weakening Subpolar Gyre. Deep Sea Res Part I: Oceanogr Res Papers, 82: 95–107
Jones DOB, Hudson IR, Bett B (2006) Effects of physical disturbance on the cold-water megafaunal communities on the Faroe-Shetland Channel. Mar Ecol Prog Ser 319: 43-54
Jones DOB, Wigham BD, Hudson IR, Bett BJ (2007) Anthropogenic disturbance of deep-sea megabenthic assemblages: a study with remotely operated vehicles in the Faroe-Shetland Channel, NE Atlantic. Mar Biol 151: 1731–1741.
Jones DOB, Gates AR, Lausen B (2012) Recovery of deep-water megafaunal assemblages from hydrocarbon drilling disturbance in the Faroe−Shetland Channel. Mar Ecol Prog Ser 461: 71-82.
Joubin ML (1922) Les coraux de mer profonde nuisibles aux chalutiers. Ed Blondel La Rougery, Paris.
Kazanidis G, Antoniadou C, Lolas AP, Neofitou N, Vafidis D, Chintiroglou C, Neofitou C (2010) Population dynamics and reproduction of Holothuria tubulosa (Holothuroidea: Echinodermata) in the Aegean Sea. J Mar Biol Assoc UK 90:895-901.
Kazanidis G, Vad J, Henry LA, Neat F, Berx B, Georgoulas K, Roberts JM (in preparation for Frontiers in Marine Science). Distribution of Deep-Sea Sponge Aggregations and the Role of Environmental Variability in the Faroe-Shetland Channel.
Katsanevakis S, Verriopoulos G, Nicolaidou A, Thessalou-Legaki M (2007) Effect of marine litter on the benthic megafauna of coastal soft bottoms: a manipulative field experiment. Mar Pollut Bull 54:771-778
Katsanevakis S, Coll M, Piroddi C, Steenbeek J, Ben Rais Lasram F, Zenetos A, Cardoso AC (2014) Invading the Mediterranean Sea: biodiversity patternsshaped by human activities. Front Mar Sci 1: 32
Kontogianni A, Tourkolias C, Damigos D, Skourtos M, Zanou B (2015) Modeling expert judgment to assess cost-effectiveness of EU Marine Strategy Framework Directive programs of measures. Marine Policy 62:203-212
Korpinen S, Meidinger M, Laamanen M (2013) Cumulative impacts on seabed habitats: an indicator for assessments of good environmental status. Mar Pollut Bull 74:311-319
Kutti T, Bannister RJ, Fosså JH, Krogness CM, Tjensvoll I, Sovik G (2015) Metabolic responses of the deep-water sponge *Geodia barretti* to suspended bottom sediment, simulated mine tailings and drill cuttings. J Exp Mar Biol Ecol 473: 64-72
Large PA, Graham NG, Hareide NR, Misund R, Rihan DJ, Mulligan MC, Randall PJ, et al. (2009) Lost and abandoned nets in deep-water gillnet fisheries in the Northeast Atlantic: retrieval exercises and outcomes. ICES Journal of Marine Science, 66: 323–333
Le Danois E (1948) Les Profondeurs de la Mer. Payot, Paris.
Le Suavé R, Bourillet JF, Coutelle A (2000) La marge nord du golfe de Gascogne: Connaissances générales et apport des nouvelles synthèses de données multifaisceaux. Ifremer, Brest.
Main CE, Ruhl HA, Jones DOB, Yool A, Thornton B, Mayor DJ (2015) Hydrocarbon contamination affects deep-sea benthic oxygen uptake and microbial community composition. Deep-Sea Res I 100:79-87
McGrath T, Nolan G, McGovern E. (2012) Chemical characteristics of water masses in the Rockall Trough. Deep Sea Res Part I: Oceanogr Res Papers 61: 57–73
McIntyre FD, Collie N, Stewart M, Scala L, Fernandes PG (2013) A visual survey technique for deep-water fishes: estimating anglerfish Lophius spp. abundance in closed area. J Fish Biol 83:739-753.
McIntyre FD, Drewery J, Eerkes-Medrano D, Neat FC (2016) Distribution and diversity of deep- sea sponge grounds on the Rosemary Bank Seamount, NE Atlantic. Mar Biol 163: 142-152.
McKenna C, Berx B, Austin WEN (2016) The decomposition of the Faroe-Shetland Channel water masses using Parametric Optimum Multi-Parameter analysis. Deep-Sea Res I 107:9-21.
Menezes GM, Diogo H, Giacomello E (2013) Reconstruction of demersal fisheries history on the Condor seamount, Azores archipelago (Northeast Atlantic). Deep Sea Res Part II: Topical Studies in Oceanography, 98: 190-203
Menezes GM, Giacomello E (2013) Spatial and temporal variability of demersal fishes at Condor seamount (Northeast Atlantic). Deep Sea Res Part II: Topical Studies in Oceanography, 98: 101-113
Modica L, Córdoba P, Rodríguez-Cabello C, Sánchez F, Velasco F (2016) A new approach to species distributional indicators for the Marine Strategy Framework Directive (MSFD). Ecological Indicators 67:21-30
Montereale-Gavazzi G, Roche M, Lurton X, Degrendele K, Terseleer N, Van Lancker V (2017) Seafloor change detection using multibeam echosounder backscatter: case study on the Belgian part of the North Sea. Mar Geophys Res 39:229-247
Muxika I, Borja A, Bald J (2007) Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. Mar. Pollut. Bull. 55, 16–29
Nemati H, Shokri MR, Ramezanpour Z, Ebrahimi Pour GH, Muxika I, Borja Á (2017) Using multiple indicators to assess the environmental status in impacted and non-impacted bathing waters in the Iranian Caspian Sea. Ecological Indicators 82:175-182
Nemati H, Shokri MR, Ramezanpour Z, Ebrahimi Pour GH, Muxika I, Borja A (2018) Sensitivity of indicators matters when using aggregation methods to assess marine environmental status. Mar Pollut Bull 128:234-239
Newton A, Borja A, Solidoro C, Grégoire M (2015) Implementing the European Marine Strategy Framework Directive: Scientific challenges and opportunities. Cont Shelf Res 108:141-143
Newton AW, Peach KJ, Coull KA, Gault M, Needle CL (2008) Rockall and the Scottish haddock fishery. Fish Res 94: 133–140
Norton D, Hynes S (2018) Estimating the Benefits of the Marine Strategy Framework Directive in Atlantic Member States: A Spatial Value Transfer Approach. Ecological Economics 151:82-94
OSPAR (1992) Convention for the protection of the marine environment of the North East Atlantic (Text as amended on 24 July 1998, updated 9 May 2002, 7 February 2005 and 18 May 2006 Amendments to Annexes II and III adopted at OSPAR 2007) 33 p.

OSPAR (2008) OSPAR List of Threatened and/or Declining Species and Habitats (Reference Number: 2008-6). OSPAR Secretariat, London.

OSPAR (2017) EIHA 17/05/1. Meeting of the Environmental Impact of Human Activities Committee (EIHA), 2017, Agenda Item 5, Agenda Item 5 – Management of specific human pressures

Paganelli D, La Valle P, Pulcini M, Proietti R, Nicoletti L, La Porta B, Lattanzi L, Pazzini A, Targusi M, Gabellini M (2017) Towards an evaluation of physical loss pressure in the Italian seas for the implementation of the marine strategy framework directive. Journal of the Marine Biological Association of the United Kingdom 98:61-69

Pauly D, Christensen V, Dalsgaard J, Froese R, Torres Jr FC (1998¡) Fishing down marine food webs. Science 279, 860e863. http://dx.doi.org/10.1126/ science.279.5352.860.

Pauly D, Watson R (2005) Background and interpretation of the 'marine trophic Index' as a measure of biodiversity. Phil Trans R Soc B Biol Sci 360: 415e423. http://dx.doi.org/10.1098/rstb.2004.1597.

Pavlidou A, Simboura N, Pagou K, Assimakopoulou G, Gerakaris V, Hatzianestis I, Panayotidis P, Pantazi M, Papadopoulou N, Reizopoulou S, Smith C, Triantaphyllou M, Uyarra MC, Varkitzi I, Vassilopoulou V, Zeri C, Borja A (2019) Using a holistic ecosystem-integrated approach to assess the environmental status of Saronikos Gulf, Eastern Mediterranean. Ecological Indicators 96:336-350

Payne MR, Egan A, Fässler SM, Hátún H, Holst JC, Jacobsen JA, Slotte A, Loeng H (2012) The rise and fall of the NE Atlantic blue whiting (*Micromesistius poutassou*). Mar Biol Res 8: 475–487

Pergent G, Monnier B, Clabaut P, Gascon G, Pergent-Martini C, Valette-Sansevin A (2017) Innovative method for optimizing Side-Scan Sonar mapping: The blind band unveiled. Estuarine, Coastal and Shelf Science 194:77-83

Pham CK, Diogo H, Menezes G, Porteiro F, Braga-Henriques A, Vandeperre F, Morato T (2014) Regulated bottom longline helps achieving sustainability of deep-sea fisheries. Scientific Reports 4:4837

Piroddi C, Teixeira H, Lynam CP, Smith C, Alvarez MC, Mazik K, Andonegi E, Churilova T, Tedesco L, Chifflet M, Chust G, Galparsoro I, Garcia AC, Kämäri M, Kryvenko O, Lassalle G, Neville S, Niquil N, Papadopoulou N, Rossberg AG, Suslin V, Uyarra MC (2015) Using ecological models to assess ecosystem status in support of the European Marine Strategy Framework Directive. Ecological Indicators 58:175-191

Plagányi ÉE (2007) Models for an ecosystem approach to fisheries. FAO FisheriesTechnical Paper. No. 477, Rome, pp. 108 Probst WN, Lynam CP (2016) Integrated assessment results depend on aggregation method and framework structure – A case study within the European Marine Strategy Framework Directive. Ecological Indicators 61:871-881

Probst WN, Rau A, Oesterwind D (2016) A proposal for restructuring Descriptor 3 of the Marine Strategy Framework Directive (MSFD). Marine Policy 74:128-135

Pusceddu A, Bianchelli S, Martín J, Puig P, Palanques A, Masqué P, Danovaro R (2014) Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. Proc Nat Acad Sci 10.1073/pnas.1405454111.

Ramirez-Llodra E, Tyler PA, Baker MC, Bergstad OA, Clark MR, Escobar E, Levin LA, Menot L, Rowden AA, Smith CR, Van Dover CL (2011) Man and the Last Great Wilderness: Human Impact on the Deep Sea. Plos One 6

Rice J, Arvanitidis C, Borja A, Frid C, Hiddink J, Krause J, Lorance P, Ragnarsson SA, Sköld B, Trabucco B, Enserink L, Norkko A (2010) Final Report TG – 6, Seafloor integrity. European Marine Strategy Framework directive, ICES and European Commission, 77 pp.

Rice J, Arvanitidis C, Borja A, Frid C, Hiddink JG, Krause J, Lorance P, Ragnarsson SÁ, Sköld M, Trabucco B, Enserink L, Norkko A (2012) Indicators for Sea-floor Integrity under the European Marine Strategy Framework Directive. Ecological Indicators 12:174-184

Sampaio I, Braga-Henriques A, Pham C, Ocana O, De Matos V, Morato T, Porteiro FM (2012) Cold-water corals landed by bottom longline fisheries in the Azores (north-eastern Atlantic). J Mar Biol Ass UK 92: 1547-1555

Sánchez-Leal RF, Bellanco MJ, Fernández-Salas LM, García-Lafuente J, Gasser-Rubinat M, González-Pola C, Hernández-Molina FJ, Pelegrí JL, Peliz A, Relvas P, Roque D, Ruiz-Villarreal M, Sammartino S, Sánchez-Garrido JC (2017) The Mediterranean Overflow in the Gulf of Cádiz: A rugged journey. Science Advances 3, eaao0609

Shin YJ, Shannon L, Cury P (2004) Simulations of fishing effects on the south-ern Benguela fish community using an individual-based model: learning from acomparison with Ecosim. Afr J Mar Sci 26: 95–114

Söderström S, Kern K (2017) The Ecosystem Approach to Management in Marine Environmental Governance: Institutional interplay in the Baltic Sea Region. Environmental Policy and Governance 27:619-631

Southward A, Boalch G, Maddock L (1988) Fluctuations in the herring and pilchard fisheries of Devon and Cornwall linked to change in climate since the 16th century. J MarBiol Ass UK 68: 423–445

Stenseth NC, Mysterud A, Ottersen G, Hurrell JW, Chan KS, Lima M (2002) Ecological effects of climate fluctuations. Science 297: 1292–1296

Teixeira H, Borja A, Weisberg SB, Ranasinghe JA, Cadien DB, Dauer DM, Dauvin JC, Degraer S, Diaz RJ, Gremare A, Karakassis I, Llanso RJ, Lovell LL, Marques JC, Montagne DE, Occhipinti-Ambrogi A, Rosenberg R, Sarda R, Schaffner LC, Velarde RG (2010) Assessing coastal benthic macrofauna community condition using best professional judgement--developing consensus across North America and Europe. Mar Pollut Bull 60:589-600

Teixeira H, Berg T, Uusitalo L, Fürhaupter K, Heiskanen AS, Mazik K, Lynam CP et al. (2016) A Catalogue of Marine Biodiversity Indicators, Front Mar Sci 3, http://dx.doi.org/10.3389/fmars.2016.00207

Tempera F, Giacomello E, Mitchell N, Campos AS, et al. (2012) Mapping the Condor seamount seafloor environment and associated biological assemblages (Azores, NE Atlantic). In: Baker E, Harris P (eds) Seafloor Geomorphology as Benthic Habitat: Geohab Atlas of Seafloor Geomorphic Features and Benthic Habitats. Elsevier, New York, p 807-818

Tett P, Gowen RJ, Painting SJ, Elliott M, Forster R, Mills DK, Bresnan E,Capuzzo E, Fernandes TF, Foden J, Geider RJ, Gilpin LC, Huxham M,McQuatters-Gollop AL, Malcolm SJ, Saux-Picart S, Platt T, Racault MF, Sathyendranath S, van der Molen J, Wilkinson M (2013) Framework for under-standing marine ecosystem health. Mar Ecol Prog Ser 494: 1–27

Thurber AR, Sweetman AK, Narayanaswamy BE, Jones DOB, Ingels J, Hansman RL 82013) Ecosystem function and services provided by the deep sea. Biogeosciences Discuss., 10, 18193–18240

Tillin H, Hiddink J, Jennings S, Kaiser M (2006) Chronic bottom trawling alters the functional composition of benthic invertebrate communities on a sea-basin scale. Mar Ecology Progr Ser 318:31–45

Tomczak MT, Heymans JJ, Yletyinen J, Niiranen S, Otto SA, Blenckner T (2013)Ecological network indicators of ecosystem status and change in the Baltic Sea. PLOS ONE 8, e75439.

Trenkel, V.M. and Rochet, M.J. (2009) Intersection-union tests for characterising recent changes in smoothed indicator time series. *Ecological Indicators*, 9, 732-739.

Utizi K, Notti E, Sala A, Buzzi A, Rodella I, Simeoni U, Corbau C (2018) Impact assessment of EMFF measures on Good Environmental Status (GES) as defined by Italy. Marine Policy 88:248-260

Uusitalo L, Blanchet H, Andersen JH, Beauchard O, Berg T, Bianchelli S, Cantafaro A, Carstensen J, Carugati L, Cochrane S, Danovaro R, Heiskanen A-S, Karvinen V, Moncheva S, Murray C, Neto JM, Nygård H, Pantazi M, Papadopoulou N, Simboura N, Srėbalienė G, Uyarra MC, Borja A (2016) Indicator-Based Assessment of Marine Biological Diversity–Lessons from 10 Case Studies across the European Seas. Frontiers in Marine Science 3

Vad J, Kazanidis G, Henry LA, Jones DOB, Tendal OS, Christiansen S, Henry TB, Roberts JM (2018) Potential impacts of offshore oil and gas activities on deep-sea sponges and the habitats they form. Adv Mar Biol 79:33-60.

van den Beld IMJ, Bourillet JF, Arnaud-Haond S, de Chambure L, Davies JS, Guillaumont B, Olu K, Menot L (2017) Cold-Water Coral Habitats in Submarine Canyons of the Bay of Biscay. Frontiers in Marine Science 4 (118), 10.3389/fmars.2017.00118.

van Denderen PD, Bolam SG, Hiddink JG, Jennings S, Kenny A, Rijnsdorp AD, van Kooten T ((2015) Similar effects of bottom trawling and natural disturbance on composition and function of benthic communities across habitats 541:31-43

Villnäs A, Hewitt J, Norkko A (2015) Evaluating the performance of benthic multi-metric indices across broad-scale

Webster L, Russell M, Shepherd N, Packer G, Dalgarno EJ, Neat F (2018) Monitoring of polycyclic aromatic hydrocarbons (PAHs) in Scottish deepwater environments. Mar Poll Bull 128:456-459.

Woillez M, Laffargue P, Rochette S, Menot L (2018) Fishing activity, distribution of commercial fish species and interaction with VMEs in the Bay of Biscay. Atlas 3rd General Assembly.

Zeppilli D, Bongiorni L, Cattaneo A, Danovaro R, Santos RS (2013) Meiofauna assemblages of the Condor Seamount (North-East Atlantic Ocean) and adjacent deep-sea sediments. Deep Sea Research Part II: Topical Studies in Oceanography 98:87-100

7 Annexes

Annex I

Report of the ICES WG DEC (2017)

ICES WGDEC REPORT 2017

ICES Advisory Committee

ICES CM 2017/ACOM:25

Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC)

20–24 March 2017

Copenhagen, Denmark

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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

Recommended format for purposes of citation:

ICES. 2017. Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 20–24 March 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:25. 121 pp.

Contents

Executive summary

On 20th March 2017, the joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC), chaired by Neil Golding (UK) and attended by fourteen members (ten in person and four via WebEx video conferencing), met at ICES HQ, Copenhagen, to consider the Terms of Reference listed in Section 2.

WGDEC was requested to provide all new information on the distribution of vulnerable marine ecosystems (VMEs) in the North Atlantic. A total of 1193 new records were submitted through the ICES VME data call in 2017 and included within the ICES VME database; 44 for the NEAFC Regulatory Area (RA) and 1149 for the EEZs of ICES Member Countries. No records originated in the NAFO regulatory area. A substantial contribution of new information on VMEs was made by Iceland, with 949 VME indicator records submitted. With respect to new information relating to VMEs within the NEAFC RA, these records originated from two areas; the Hatton-Rockall Basin and Rockall Bank. There were three new observations of *bona fide* VME from the Hatton-Rockall Basin; a recommendation to extend the current Hatton-Rockall Basin bottom fishing closure was made. New VME indicator records were submitted for Rockall Bank; no recommendations were made to modify existing or recommend new closures.

For the first time, and for all areas considered by WGDEC, all records from the VME database were presented as outputs from the VME weighting system, showing the likelihood of VMEs being encountered on the seabed along with an associated confidence assessment.

A member of the ICES Working Group on Spatial Fisheries Data (WGSFD) worked with WGDEC and analysed NEAFC VMS data from 2016. Plots of fishing effort for mobile bottom contact gear and static gear are shown for key areas where vulnerable seabed habitats are known to exist. Separate plots have also been shown for those vessels with no gear type registered.

The process by which WGDEC considers new information on VMEs, identifies sensitive areas of the seabed, and if appropriate, proposes boundaries around these sensitive habitats has been outlined. A flow chart has been developed which neatly summarises the process from beginning to end.

WGDEC undertook an extensive review looking at the current understanding and knowledge of the connectivity of deep-sea populations, with a view to the management of deep-sea ecosystems.

WGDEC commenced the development of a 'road map' to start exploring the concepts and outline the process for evaluating Good Environmental Status (GES) under the Marine Strategy Framework Directive. Work will continue during WGDEC 2018.

Finally, WGDEC reported on the distribution of VME indicators and habitats with the Haddock Box closure, as well as reviewing the appropriateness of NEAFC bottom fishing closures defined in Annex 2 of NEAFC Regulation 19:2014. All closures were considered appropriate, but WGDEC stressed that this may be subject to change as new information on VME distribution comes to light in future.

1 Opening of the meeting

The Working Group on Deep-water Ecology (WGDEC) commenced at 09:30 on Monday 20th March 2017 in plenary. The lead(s) for each Terms of Reference were appointed, and are outlined below:

- ToR [a] lead: James Albrecht
- ToR [b] leads: Telmo Morato and Covadonga Orejas
- ToR [c] leads: James Albrecht and Steinunn Ólafsdóttir
- ToR [d] lead: Laura Robson
- ToR [e] leads: Kerry Howell and Anna Metaxas
- ToR [f] lead: Francis Neat
- ToR [g] lead: Francis Neat

Following the review and adoption of the agenda, the WGDEC began working through the Terms of Reference. Each ToR lead outlined how they intended to tackle the ToR, and led the discussion. Dedicated plenary sessions were held every morning and afternoon; these were via WebEx allowing remote participants to participate. During these plenary sessions, ToR leads updated the group with progress and issues were discussed. Remote participants could comment on working documents via the WGDEC SharePoint site. At the end of the week, the Working Group was formally closed at midday on Friday 24th March 2017 by the Chair.

2 Adoption of the agenda

WGDEC - ICES/NAFO Joint Working Group on Deep-water Ecology

2016/2/ACOM26 The **Working Group on Deep-water Ecology** (WGDEC), chaired by Neil Golding, UK, will meet at ICES HQ in Copenhagen, Denmark, 20-24 March 2017 to:

a) Provide all available new information on distribution of VMEs in the North Atlantic with a view to identifying potential new closures to bottom fisheries or revision of existing closures to bottom fisheries. In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters;

b) Begin to explore how to best define Good Environmental Status (GES) for deep-sea habitats; in particular, commence a review on progress with indicator development for the deep sea;

c) Develop a flow chart capturing how and when different information layers (including but not exclusively geomorphology, bathymetry, VME indicator/habitat layers and buffer zones) are used in order to delineate bottom fishing closures used to manage impacts of fisheries on sensitive areas;

d) Explore the development of the ICES VME Database in order to better capture 'survey effort', particularly from those trawl records where no VME indicators were recorded (absence records);

e) Review our current understanding and knowledge of the connectivity of deep-sea populations, with a view to the management of deep-sea ecosystems.

f) Review and report on the distribution of VMEs (VME Indicators and Habitats) within the Rockall Bank Haddock Box

g) Review the appropriateness of NEAFC bottom fishing closures as defined in Annex 2 of NEAFC Recommendation 19:2014, and whether significant adverse impacts on VME are still considered likely in these areas.

WGDEC will report by 5 May 2017 to the attention of the ACOM Committee.

Supporting Information

Priority:	High as a Joint group with NAFO and is essential to providing information to help answer external requests
Scientific justification and relation to action plan:	a) This information and associated maps are required to meet the NEAFC request " to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats." as well as part of the European Commission MoU request to "provide any new information regarding the impact of fisheries on. sensitive habitats. The location of newly discovered/mapped sensitive habitats is critical to these requests. It is essential that ICES/WG chair asks its Member Countries etc. to supply as much relevant information as they may have by one month in advance of the WGDEC meeting. Completion of this ToR will also be facilitated by the completion of a VME Data Call by the ICES Data Centre during 2016; b) Understanding and defining Good Environmental Status is a core concept of the Marine Strategy Framework Directive. While much effort has been concentrated on shelf seas, including indicator development, further work on deep-sea ecosystems is required. In particular, this ToR will focus on reviewing the progress made to date with deep-sea indicator development – the focus of a number of European funded projects. c) Continuing on from work undertaken in WGDEC 2016 (ToR (b)), additional work is required to demonstrate a clear process for delineating bottom fishing closures to manage sensitive areas, such as through a flow chart. The importance of this clear process was highlighted by the VME review group and Advice Drafting Group. d) The ICES VME database, as it currently stands, provides an effective mechanism for storing records of VME indicator and *bona fide* VME habitat. However, WGDEC has not yet developed an effective way to store VME absence records. These absence records may be from trawl track records submitted by Working Group members, where no VME bycatch was recorded. Potential development of the VME database is required, or other mechanisms explored, to allow these VME absence records to be stored, so they can be utilised effectively in future. e) Research projects, with objectives focused on developing a better understanding of the connectivity of deep-sea populations, are currently in progress. The aim of this ToR is to review current literature and understanding (including new knowledge being generated through this research) to allow a better understanding of the connectivity of deep-sea ecosystems. This understanding is essential when considering areas of the deep sea (containing VMEs for example) to be being managed from potentially damaging activities. f) In 2015, evidence was found that bottom-towed gears were being used inside the area on Rockall Bank closed to fishing (https://www.neafc.org/system/files/Rec2_Haddock.pdf). ICES has previously noted that this area contains VMEs/VME indicators but no boundary within the haddock box has ever been proposed to cover an area that might be closed for habitat reasons. This ToR will enable ICES to advise the EU and NEAFC on the location of VMEs/VME indicators in this area. g) TOR g will assist NEAFC in 2017 to review the appropriateness of bottom fishing closures. The NEAFC Recommendation 19:2014 on the protection of vulnerable marine ecosystems in the NEAFC Regulatory Area includes regulations prohibiting bottom fishing activities in the following areas according to Article 5, within the coordinates as defined in Annex 2 of that Recommendation: (a) Northern MAR Area;

	(b) Middle MAR Area (Charlie-Gibbs Fracture Zone and subpolar Frontal Region); (c) Southern MAR Area; (d) Altair Seamount; (e) Antialtair Seamount; (f) Hatton Bank 1; (g) Rockall Bank; (h) Logachev Mounds; (i) West Rockall Mounds; (j) Edora's bank; (k) Southwest Rockall Bank; (l) Hatton-Rockall Basin; and (m) Hatton Bank 2. ICES has been requested to consider whether significant adverse impacts on VME are still considered likely in the closed subareas (a) – (i) and (k) – (m). According to Article 10, second paragraph the closures (a) – (i) and (k) – (m) shall be in force until 31 December 2017. Before that time, the measure shall be reviewed by NEAFC with the intention of extending the period that the closures are in force, unless the conclusion of the review is that the continued application of the measure or parts of the measure is not required. It is noted that the closures to be reviewed were implemented on the basis of previous ICES advice confirming that they would be appropriate and protect VMEs from significant adverse impacts. It is assumed that any new advice on modifications or advice on additional closures relevant to Rec. 19:2014 will be provided as responses to the recurrent request for scientific advice.
Resource requirements:	Support will be required from the Secretariat and the ICES Data Centre (with respect to maintenance of the ICES VME Database and VME Data Call)
Participants:	The Group is normally attended by some 15–20 members and guests.
Secretariat facilities:	None, apart from the SharePoint site
Financial:	No financial implications.
Linkages to ACOM and its expert groups	ACOM is parent group. WGDEEP and WGSFD is related, but no explicit overlap in work this year.
Linkages to SCICOM and its expert groups	No direct linkages, though in 2017, better linkages with WGMHM and BEWG will be explored
Linkages to other organisations:	OSPAR, NEAFC

4 Begin to explore how to best define Good Environmental Status (GES) for deep-sea habitats; in particular, commence a review on progress with indicator development for the deep sea – ToR [b]

4.1 Background

Understanding and defining Good Environmental Status is a core concept of the European Union (EU) Marine Strategy Framework Directive (MSFD). While much effort has been concentrated on shelf seas, including indicator development, further work on deep-sea ecosystems is required. In particular, this ToR will focus on reviewing the progress made to date with deep-sea indicator development; the focus of a number of European funded projects.

The EU Marine Strategy Framework Directive (MSFD) defines the marine environment as "a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing oceans which are clean, healthy and productive (EU Directive 2008/56/EC)." The MSFD requires member states to adopt an ecosystem approach to the management of human activities that puts emphasis on the health of the ecosystem alongside the sustainable use of marine goods and services. The Directive aims to achieve Good Environmental Status (GES) of most European marine waters by 2020. To help Member States (MS) interpret what GES means in practice, the Directive sets out, in Annex I, eleven qualitative descriptors which describe what the environment will look like when GES has been achieved.

Within this context, the European Commission has adopted criteria for assessing GES of marine waters (Commission Decision 2010/477/EU), in relation to the 11 descriptors of the MSFD. Although a great effort has been put into developing methodological standards for assessing GES in a coherent manner to support the ecosystem-based approach to management, there is still a substantial need to develop additional scientific understanding to determine appropriate ecosystem metrics, and in particular those that could be applied to the deep sea. The relationship between descriptors, criteria and potential indicators is summarised in Table 4.1.

The ICES scientific community and associated partners have worked towards providing scientific guidance to define GES indicators and standards. ICES and the Joint Research Centre (JRC) has established Task Groups for each of the qualitative Descriptors with the aim of developing criteria and methodological standards for each. A Management Group has been established to provide information on a number of issues that are common to all of the Descriptors (cf. Cardoso *et al*., 2010; also sections below for more recent information). More recently, ICES suggested some revisions to the MSFD to consider humans impacts on the functioning of ecosystems (ICES, 2015). The OSPAR Commission has also worked on developing methodologies and guidelines relevant to determining 'Good Environmental Status', in particularly for the descriptors addressing biodiversity, foodwebs, eutrophication, contaminants, litter and noise.

To further facilitate implementation, the European Union 7th Framework Programme (FP) project DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status) has built a catalogue of models and their derived indicators to assess which models provide information about indicators outlined in the MSFD, particularly for the biodiversity, foodweb, non-indigenous species and seabed integrity descriptors (Piroddi *et al*., 2015). Another important output from DEVOTES is the software package NEAT (The Nested Environmental status Assessment Tool), which has been developed to support the integrated assessment of the status of marine waters (Uusitalo *et al*., 2016). Other projects which address MSFD implementation include the IndiSeas project (funded by IOC/UNESCO, EUROCEANS), the FRB project EMIBIOS, and the 7th FP project MEECE. They have analysed indicators of the status of different ecosystems (Shin and Shannon, 2010).

To explore how best to define Good Environmental Status (GES) for deep-sea habitats, WGDEC 2017 undertook a review of progress with indicator development for the deep sea. A summary of the outcome of discussions made by the European Horizon 2020 project ATLAS towards these goals during its kick-off meeting in June 2016 is presented here.

Table 1. The relationship between descriptors, criteria and potential indicators.

DESCRIPTOR	CRITERIA	INDICATOR
1. Biological diversity	1.1. Species distribution	1.1.1. Distributional range 1.1.2. Distributional pattern within the latter 1.1.3. Area covered by the species (for sessile/benthic species)
	1.2. Population size	1.2.1. Population abundance and/or biomass
	1.3. Population condition	1.3.1. Population demographic characteristics 1.3.2. Population genetic structure
	1.4. Habitat distribution	1.4.1. Distributional range 1.4.2. Distributional pattern
	1.5. Habitat extent	1.5.1. Habitat area 1.5.2. Habitat volume, where relevant
	1.6. Habitat condition	1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate 1.6.3. Physical, hydrological and chemical conditions
	1.7. Ecosystem structure	1.7.1. Composition and relative proportions of ecosystem components (habitats, species)
3. Exploited fish and shellfish	3.1. Level of pressure of the fishing activity	3.1.1. Fishing mortality (F) 3.1.2. Catch/biomass ratio
	3.2. Reproductive capacity of the stock	3.2.1. Spawning–Stock Biomass (SSB) 3.2.2. Biomass indices (if 3.2.1 not possible)
	3.3. Population age and size distribution	3.3.1. Proportion of fish larger than the mean size of first sexual maturation 3.3.2. Mean maximum length across all species found in research vessel surveys 3.3.3. 95% percentile of the fish length distribution observed in research vessel surveys 3.3.4. Size at first sexual maturation
4. Foodwebs	4.1. Productivity of key species or trophic groups	4.1.1. Performance of key predator species using their production per unit biomass

Descriptor	Criteria	Indicator
	4.2. Prop. of selected species at the top of foodweb	4.2.1. Large fish (by weight)
	4.3. Abundance/distribution of key trophic groups	4.3.1. Abundance trends of functionally important selected groups/species
5. Human-induced eutrophication	5.1. Nutrient levels	5.1.1. Nutrient concentration in the water column 5.1.2. Nutrient ratios (silica, nitrogen and phosphorus)
	5.2. Direct effects of nutrient enrichment	5.2.1. Chlorophyll concentration in the water column 5.2.2. Water transparency related to increase in suspended algae 5.2.3. Abundance of opportunistic macroalgae 5.2.4. Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms caused by human activities
	5.3. Indirect effects of nutrient enrichment	5.3.1. Abundance of perennial seaweeds and seagrasses impacted by decrease in water transparency 5.3.2. Dissolved oxygen changes and size of the area concerned
6. Seabed integrity	6.1. Physical damage, having regard to substrate characteristics	6.1.1. Type, abundance, biomass and areal extent of relevant biogenic substrate 6.1.2. Extent of the seabed significantly affected by human activities for the different substrate types
	6.2. Condition of benthic community	6.2.1. Presence of particularly sensitive and/or tolerant species 6.2.2. Multimetric indices assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species 6.2.3. Proportion of biomass or number of individuals in the macrobenthos above specified length/size 6.2.4. Parameters describing the characteristics of the size spectrum of the benthic community

4.2 Road map

Since evaluating GES for the deep sea has not been discussed in detail, it was agreed at WGDEC to start developing a road map to outline the process and explore the concepts necessary (Figure 4.1). As described in Prins *et al*. (2014), the first question that needs to be addressed is "What is the appropriate ecosystem component level (species, habitat and ecosystem) and spatial scales for the assessment of GES in the deep sea?" This topic needs thorough debate before moving on to discussing criteria and indicators. However during the ATLAS kick-off meeting (June 2016, Edinburgh), it was agreed that addressing GES for habitat and ecosystems (rather than species) would be more appropriate to the deep sea, due to sampling and taxonomic constrains.

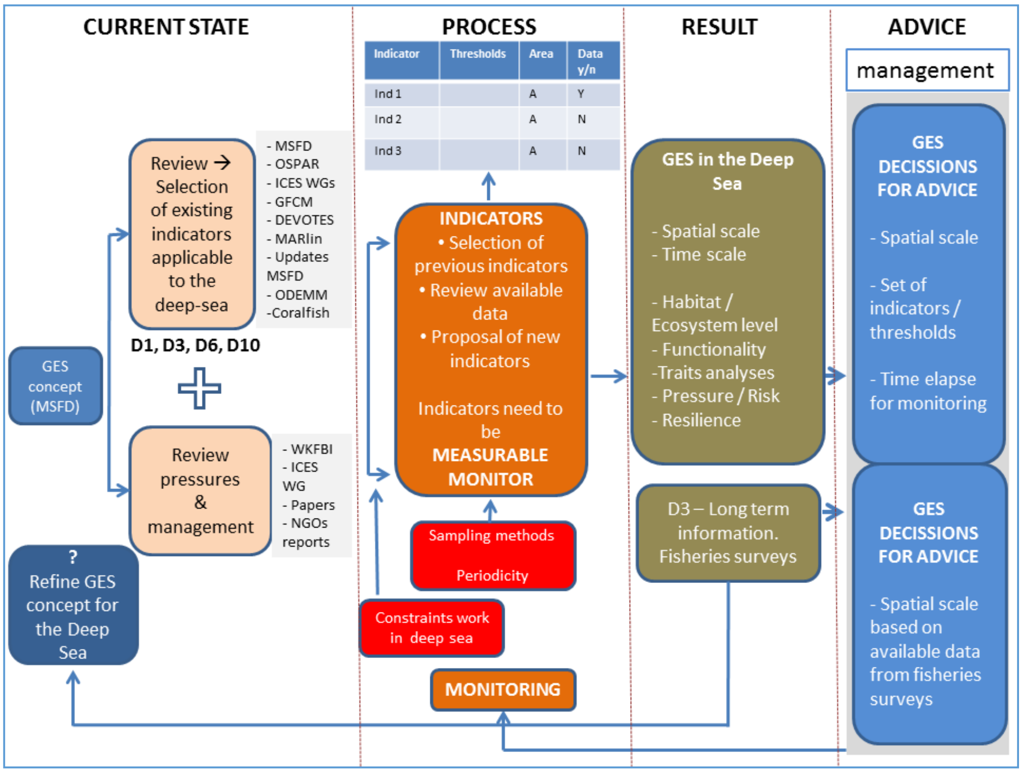

Figure 4.1. Preliminary concepts and road map to best address GES in the deep sea.

Current state of the assessment of GES in the deep sea

To appropriately address GES in the deep sea, a review of the work done previously on the development of indicators should be performed. A number of EU and national projects have been developing indicators to address GES in different ecosystems (e.g. DEVOTES, Options for Delivering Ecosystem-Based Marine Management (ODEMM) and MarLIN[4]) together with work done in ICES Working Groups (e.g. Working Group on Marine Habitat Mapping (WGMHM)). As most indicators have been developed for coastal and shallow-water ecosystems, it is necessary to review existing information and evaluate which indicators can be applied to assessing GES in the

[4] http://www.marlin.ac.uk/

deep sea. The descriptors considered useful to start the evaluation process of GES in the deep sea are:

Descriptor 1, Biodiversity

"Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions." Criteria used to evaluate Descriptor 1 should work on different ecosystem components (species, habitat and ecosystem) and at spatial scales. Due to the lack of information for most parts of the deep sea, evaluation of biological diversity indicators will likely remain at a habitat and ecosystem level and at a broad scale.

Descriptor 3, Commercial fish and shellfish

"Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock." Criteria for evaluating Descriptor 3 should be developed in collaboration with existing ICES working groups such as WGDEEP and may consider the level of pressure of the fishing activity, the life history of the considered species and the population structure of the fishing stocks.

Descriptor 6, Seabed integrity

"Seabed integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected." Criteria to evaluate Descriptor 6 should also be developed in collaboration with existing ICES working groups (e.g. WGMHM) or workshops such WKFBI or WKBENTH and may address both the level of physical damage to the seabed as well as the status, focusing mostly on the functionality of the benthic community.

Descriptor 10, Litter

"Properties and quantities of marine litter do not cause harm to the coastal and marine environment". A number of peer reviewed papers have begun to address litter in the deep sea (e.g. Ramirez-Llodra *et al.*, 2011; Pham *et al.*, 2014; van den Beld *et al.*, 2016).

Additionally, a further review of the past, current and future pressures in the deep sea as well as management measures is needed. Previous work on this subject should be included in the revision (e.g. reports from ICES WGs).

Process of developing indicators

After a careful and comprehensive review of the existing information, a selection of existing indicators should be conducted. Furthermore, a review of the available data to apply these indicators has to be performed. New indicators may also need to be proposed considering the specific constraints of working in the deep sea (e.g. remoteness, difficulties conducting scientific surveys and sampling in deep-sea areas, lack of baseline data) and the main characteristics of these ecosystems.

The selection of indicators should ensure they are SMART (**S**pecific, (Re-) **M**easurable, **A**ttainable, **R**ealistic and **T**imely). Furthermore, the selection of indicators for the deep sea needs to take into account:

- The sampling methods used in deep-sea scientific surveys (e.g. towed cameras, ROVs);
- The often low periodicity of the surveys (impacting opportunities for monitoring).

Once the indicator list exists, we suggest developing a matrix (see Table 4.1), for the different indicators, indicating applicable habitat type and area, thresholds indicating degraded habitat (whenever possible) and whether data are available or has to be collected. Indicators for Descriptor 3 may be straightforward to define as the information gathered from the fisheries surveys is standardised.

Table 4.1. Data matrix for indicators for GES in the deep sea (DS), habitat, area, thresholds, data available (yes/no).

INDICATOR	HABITAT TYPE	AREA	THRESHOLD	DATA (Y/N)
Ind 1	a	A		Y
Ind 2	b	A		N
Ind 3	c	A		Y
Ind 1	a	B		N
Ind 2	b	B		N
Ind 3	c	B		Y

Results of the application of GES deep-sea (DS) indicators

As a result of the selection and development of indicators, a set of GES-DS indicators will be applied to delineated areas, remembering that not all indicators will be applicable to all areas. Considering the spatial scale on which GES should be assessed is an important consideration in the deep sea. In Europe, the MSFD provides a means of setting boundaries for spatially managed areas. The FP7 project Monitoring and Evaluation of Spatially Managed Areas (MESMA) has developed a generic framework to facilitate marine spatial plans. The MESMA framework comprises a series of steps that can be completed, to a greater or lesser extent, to evaluate/propose an existing or new management plan for a given spatially managed area (Figure 4.2).

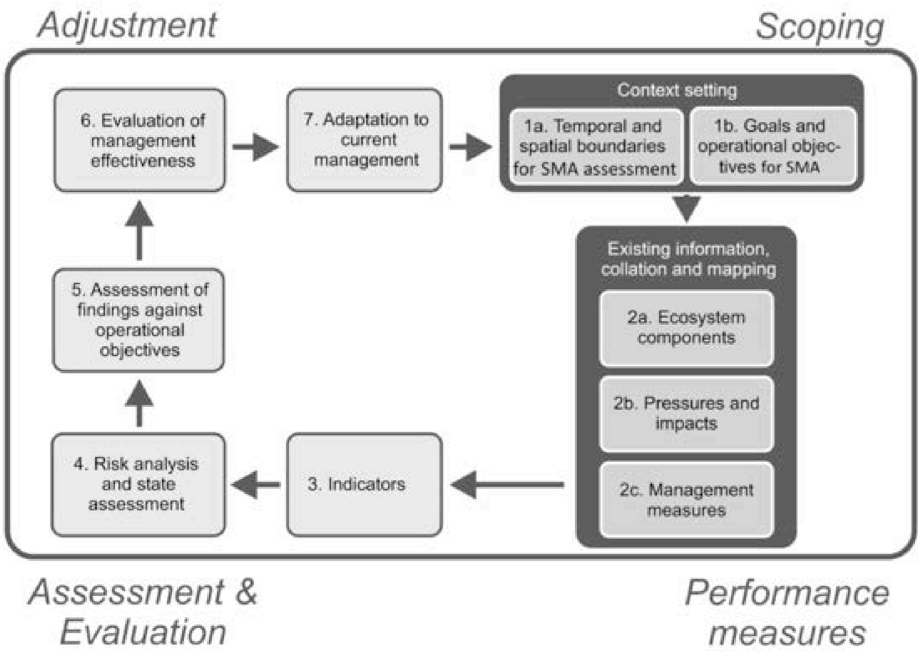

Figure 4.2. Proposed FP7 project *Monitoring and Evaluation of Spatially Managed Areas* (MESMA) framework to facilitate marine spatial planning.

Knowledge of the impact footprint of human activities operating in the deep sea will inform the extent of areas required to manage these activities. This will subsequently inform over what spatial scale GES should be evaluated. The ATLAS project will apply the MESMA framework to develop marine plans to support Blue Growth scenarios in 12 case studies located in different jurisdictions across the Atlantic.

Time-scale is another important issue, especially when thinking about monitoring. Ten years may be an appropriate time-scale, and also realistic, taking into account the probability that a scientific survey will revisit a specific site. This does not apply to Descriptor 3 as fisheries surveys take place at a higher frequency and hence more regular monitoring is expected.

Beside spatial and time-scales, some other aspects were identified during discussions by ATLAS partners and during this meeting of WGDEC. These include that:

- Biodiversity (D1) will generally be addressed at biotope/ habitat / ecosystem except where species determinations are unambiguous, e.g. *Lophelia pertusa*.
- The seabed integrity (D6) will focus on ecosystem functionality due to the lack of a baseline for other indicators and the difficulty of obtaining data in the deep sea for commonly used indicators such as abundance/biomass measurements.

Furthermore during this WGDEC meeting it was agreed to consider:

- Trait analyses;
- Pressure / risk assessment;
- Habitat / ecosystem resilience.

The results of the analyses, could be displayed in a table similar to Table 4.2 below, where the different habitats considered in an area as well as the different indicators will be displayed and the status presented in a general way using a simple traffic light system (red, amber, green). An easy-to-read table will be more useful (even it is of course a large simplification) for managers.

Table 4.2. Example of a potential way to display the environmental status evaluation of an area. Legend: red= good environmental status not achieved; yellow= good environmental status partially achieved; green= good environmental status achieved.

Area	Habitat 1	Habitat 2	Habitat 3	Habitat 4
Indicator 1	red	yellow	yellow	green
Indicator 2	yellow	yellow	yellow	yellow
Indicator 3	yellow	yellow	green	green
Indicator 4	red	yellow	red	yellow

For Descriptor 3, the indicators might be similar to the ones already being used in the assessment of GES of assessed stocks in coastal and shelf seas (ICES, 2012; e.g. Spawning–Stock Biomass (SSB), Fishing mortality consistent with achieving Maximum Sustainable Yield (F_{MSY}), Spawning–stock biomass (SSB) that results from fishing at F_{MSY} for a long time (B_{MSY}), fishing activity, the life history of target species, and the population structure of the fishing stocks). The spatial scale for D3 assessment might be limited to the existing fishing grounds, from where most fisheries surveys are conducted. However, D3 should also address non-assessed stocks with alternative techniques (e.g. ROV transects) and indicators, and also on non-fishing grounds. It should be noted that trawling impacts seabed integrity (D6) which may require a broader spatial assessment due to downstream effects of resuspended sediments. Time-scales for evaluating assessed stocks may be defined by fisheries survey periodicity. In the specific case of D3 the lack of baseline information (as it was the case for the benthic ecosystems) is not an issue for assessed stocks, since long-term dataseries may be available allowing to analyse the GES and trends over time. A potential easy-to-read table for summarizing D3 is shown in Table 4.3. Such a table may be prepared for each spatial area including the different analysed fish stocks and a GES status will be added into the table for each analysed indicator.

Table 4.3. Example of a potential way to display the environmental status evaluation of the fish stock in an area. Legend: red= good environmental status not achieved; yellow= good environmental status partially achieved; green= good environmental status achieved.

Area	Fish stock1	Fish stock2	Fish stock3	Fish stock4
Indicator 1				
Indicator 2				
Indicator 3				
Indicator 4				

Advice

Combined analyses of multiple GES descriptors in a spatially managed area should help to identify areas where accumulated impacts of overlapping activity footprints have the potential to lead to environmental degradation, such that GES will no longer be achieved. Mitigation actions will then need to be proposed. A better understanding of the factors leading to accumulated impacts will also be important in this regard.

4.3 Conclusions

The temporal and spatial scale on which GES should be assessed in the deep sea is an important aspect to be considered and which will need further discussion. Due to the data limited situation and challenges posed for monitoring, it may well be the case that GES will have to be assessed at large spatial and temporal scales when compared to the shallower waters of the European Seas. For similar reasons, the type of indicators to be used may have to be simplified and likely be based on high level analyses related to traits, pressures/risks, and habitat /ecosystem resilience. Ultimately, the results of the combined analyse of GES descriptors may lead to a potential refining or redefinition of the GES concept for the deep sea.

Annex II

OSPAR indicators

Code	Common indicator name	Common in OSPAR Region
M3	Seal Abundance and Distribution	II
M4	Abundance and Distribution of marine mammals	II, III, IV
M5	Grey seal pup production	II, III
M6	Marine mammal bycatch	II
B1	Marine bird abundance	II, III, IV
B3	Marine Bird Breeding Success / Failure	II, III, IV
FC1	Recovery in the population abundance of sensitive fish species	II, III
FC2	Proportion of large fish (Large Fish Index)	II, III
BH1	Typical species composition	IV
BH2	Condition of Benthic Habitat Communities	II, III, IV
BH3	Extent of Physical Damage to Predominant and Special Habitats	II, III, IV
PH1/FW5	Changes in plankton functional types (life form) index Ratio	II, III, IV
PH2	Plankton biomass and/or abundance	II, III, IV
PH3	Changes in biodiversity index(s)	III
NIS	Trends in New Records of Non-Indigenous Species (NIS) Introduced by Human Activities	II, III, IV
FW3	Size composition in fish communities	II, III, IV
FW4	Change in average trophic level of marine predators in the Bay of Biscay	IV

Annex III

Table with all indicators for D1, D3 and D6 presented to case study leaders with the aim to select the ones they consider more appropriate for deep-sea areas. This Annex is included as excel table due to the large dimensions it has.

Annex IV

Literature research for quantitative data on different deep-sea benthic organism (mostly deepsea corals and sponges), as well as fish and litter. The aim of this compilation was to facilitate case study leaders the set-up of boundary and target values for the different indicators. This Annex is included as excel table due to the large dimensions it has.

Annex Va

Excel files corresponding to each case study including the information supplied by CS ledares to perform the NEAT analyses

Annex Vb

Word template given to each CS leader to interpret the results obtained by the NEAT analyses

Template for case study leaders for the interpretation of NEAT assessment results

- In the attached file you have a summary of the NEAT assessment for your case study.
- Neat offer overall values but you, as expert in the area have to interpret the obtained results and discuss how this match with your knowledge and vision of the area.
- This template will try to guide you to complete your interpretation and discussion of the obtained results.
- Once completed, please send this back to us not later than XX of August to allow time to discuss (if needed) the document with you and also to give us (Georgios and I) time to prepare the deliverable.

NEAT assessment results

- As you will be probably not familiar with NEAT, please have a look into the short video you can find here: http://www.devotes-project.eu/neat/, so that you can understand the mechanism of the program.

- We used the default settings from NEAT
- NEAT values range from o (lowest value) to 1 (highest value)

  - High GES is represented by indexes values from 1 to 0.8
  - Good GES is represented by indexes values from 0.8 to 0.6
    - ➔ GES threshold value to GES: 0.6
  - Moderate GES is represented by indexes values from 0.6 to 0.4
  - Poor GES is represented by indexes values from 0.4 to 0.2
  - Bad GES is represented by indexes values from 0.2 to 0

- Values are given for each SAU selected as well as per habitat and ecosystem component. The habitats and ecosystem components were also selected by you in the excel template you sent us.

Summary of results of the NEAT assessment for your case study area:

1. Overall evaluation / comments of the assessment result

- Please comment on the overall result of the NEAT analysis and how this agrees with your knowledge and information from the case study area, giving references when needed.
- In order to allow us to establish comparisons among the results obtained for the different cases studies, please tick or highlight the appropriate answer below:

1) The outcome of NEAT analysis agrees completely with my knowledge/information for the case study
2) The outcome of NEAT analysis agrees well but not completely with my knowledge/information for the case study
3) The outcome of NEAT analysis agrees moderately with my knowledge/information for the case study
4) The outcome of NEAT analysis - agrees little with my knowledge/information for the case study
5) The outcome of NEAT analysis does not agree at all with my knowledge/information for the case study

2. Discussion on the NEAT assessment results

- In general the number of indicators addressed by CS leaders is very short and mostly are related to benthic communities, please considering the information you supplied for the analyses, please discuss the reliability of the results of this analyses. Please for this take into consideration:

    - Amount of supplied data
    - Type supplied data
    - Quality of the supplied data
    - Time frame covered by the data (e.g. long time series, punctual observations?)
    - Spatial extension covered by the data (GES, after the MSFD should be address at Regional level…we know how difficult is this for the Deep-sea, but please, discuss also about that!)
    - The threshold values you supplied for each of the indicators (i.e. values representing the "worst", "moderate/good" and "best" environmental status). **You are also welcome to elaborate in your text about how confident/satisfied you are about the threshold values that you have supplied.**
    - Please think about/include what kind of research activities should take place in your case study in order to improve our understanding for its environmental status? Also please taking into account already existent monitoring activities, which should be enhanced or maybe enlarge covering other areas?

      And any other aspects you consider relevant

- Please for the previously mentioned parameters (e.g. amount of supplied data, quality of supplied data etc.) indicate how satisfied with the information supplied from you:

  - o Completely satisfied
  - o Well satisfied but not completely
  - o Moderately satisfied
  - o Little satisfied
  - o Not all satisfied

- Considering your knowledge of the area, together with the previously mentioned aspects, please discuss the NEAT results, adding references where needed.

3. Final conclusions

- Please elaborate a text where you indicate your opinion (considering your expert opinion) about the final outcomes of NEAT for the GES assessment in your case study. Please also add your comments, suggestions to improve things, criticism etc. about the way that NEAT proceed regarding the selection of boundary values, assessment of areas, habitats, ecosystem components etc.

- For instance, in most cases the scarce data, lack of base line and lack of time series of data will be certainly a handicap, please include these aspects also in the discussion.