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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

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ICES Headquarters, Denmark



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## Executive summary

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More than 70% of the Earth's surface is seafloor and this vast area accommodates an abundance of different habitats and associated species. Given the pending threats upon the critical goods and services the seafloor provides, the Marine Strategy Framework Directive (MSFD) addresses seafloor integrity in its Descriptor 6. Good environmental status (GES) will be achieved when seafloor 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.

A Workshop to review the 2010 Commission Decision on criteria and methodological standards on good environmental status (GES) of marine waters in what concerns Descriptor 6 Seafloor Integrity was held in Copenhagen on 2–3 September 2014. This report presents the result of this workshop, which was attended by experts in MSFD implementation and/or scientists specialising in assessing seafloor integrity. The workshop was planned by a “core team” of 5 scientists. Participants came from across the ICES area and from other non-ICES EU countries (NE Atlantic, Baltic and Mediterranean MSFD regions). Those from ICES countries were nominated by ICES Delegates and ACOM, and those from non-ICES countries by invitation from DGENV to the national marine directors. To conform to best practice and ICES policy, NGOs and stakeholders were permitted to attend the workshop. A total of 27 participants from 15 nationalities were represented in the workshop. All participants were reminded that this was a scientific meeting where stating or lobbying for institutional policy objectives was not endorsed.

The topics addressed by the workshop were:

- Scoping of seafloor integrity attributes;
- How to ensure seafloor integrity: setting GES boundaries;
- Indicators for proposed criteria: functionality and recoverability;
- Relation with other descriptors;
- Gauging impact: pressure/sensitivity.

The workshop was run largely in plenary and also made use of three parallel sub-groups on (i) scoping of seafloor attributes, (ii) setting reference levels for GES, and (iii) indicators, which discussed and synthesized information and regularly reported back to a plenary.

The workshop concluded that the Decision 2010/477/EU D6 criteria (6.1 *Physical damage, having regard to substrate characteristics* and 6.2 *Condition of benthic communities*) are insufficient and risk compromising our ability to assess seafloor integrity. The present criteria should be revised into new criteria 6.1 *Functionality* and 6.2 *Recoverability* that are more closely related to resilience and recovery potential of the seafloor. This would simplify the existing Decision and may not require any additional monitoring from Member States. 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 perturbation 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. 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.

Scientific guidance will be required in prioritizing functions to be assessed under each criteria, as well as choosing indicators and establishing GES boundaries for seafloor integrity (with reference points and targets). This will be required in any potential revisions of Decision 2010/477/EU and in its implementation by Regional Sea Conventions (RSCs) and Member States. A substantial body of scientific knowledge that can serve as the basis for this guidance has already been consolidated in the ICES/JRC 2010 Task Group 6 report. Appropriate experts building on this foundation can make rapid progress on finalizing the necessary guidance. 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.

## 1 Scoping

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### 1.1 The Descriptor

“Good Environmental Status” for Descriptor 6, *Sea-floor 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”.

### 1.2 Definitions relevant to the Descriptor and this report

**Seafloor** is defined as a key compartment for marine life. It includes both the physical and chemical parameters of seabed (e.g. bathymetry, roughness (rugosity), substratum type, oxygen supply, etc.) as well as the biotic composition of the benthic community. Different kinds of habitats for sedentary and mobile marine species are formed inside and above the seabed.

**Integrity** is interpreted as comprehending both (i) natural spatial connectivity (avoiding unnatural habitat fragmentation or connectivity), and natural ecosystem processes functioning in their characteristic ways.

**Not adversely affected** means that the cumulative effect of pressures associated with human activity are at a level that ensures the ecosystem maintains its respective components (structure) along with its natural levels of diversity, productivity, and dynamic ecological processes (functioning). Levels of disturbance (intensity, frequency, and spatial extent) must be at a level that ensures a dynamic recovery potential is maintained.

**Recovery** means that the impacted seafloor attributes show a clear trend towards their pre-perturbation conditions, and the trend is expected to continue (if pressures continue to be managed) until the attributes lie within their range of historical natural variation. Benthic communities are not static entities, and thus recovery does not require that the ecosystem attributes return to their exact prior state.

**Rapid** must be interpreted in the context of the life histories of the species and natural rates of change in the community properties being perturbed. For some seafloor habitats and communities, recovery dynamics from perturbation would require multiple decades or more, and in such cases management should strive to prevent perturbations.

**Impairment of an ecological component** occurs if the ecological consequences of the direct or indirect perturbations extend widely through the ecosystem in space and/or time, or if the normal ecological linkages among species act to extend and amplify the effects of a perturbation rather than to dampen its effects.

### 1.3 Important considerations

Although D6 is largely discussed in its own right in the 2010 ICES-JCR D6 Task Group Report (Rice *et al.*, 2010), in the MSFD context all descriptors will be assessed.

This has several implications that are discussed in various places in the current report, but particularly in Section 1.5 “Criteria and Attributes of Sea-floor Integrity”.

There are no points of significant disagreement among experts regarding key terms or what constitutes gradients of degradation in environmental status. However, serious problems of sampling and measurement and high scientific uncertainty about aspects of benthic ecology (e.g. dispersal scales) and tolerances of benthic ecosystems to perturbations pose challenges to the application of the GES concept. Sound assessments of GES are possible, but they require integration of results from local scales, where both natural benthic ecosystems and pressures may be very patchy, into much larger regional or subregional scales.

### **The importance of habitat heterogeneity**

A key to defining whether or not overall “Good Environmental Status” (GES) has been achieved for D6 is if habitat/environmental heterogeneity is maintained allowing representative species to also maintain viable populations across a region. Habitat heterogeneity per unit area can thus ensure representative community types are maintained in a region (beta diversity) and with subsequent dispersal (larval, post-larval and adults) over relatively shorter distances can ensure recovery is rapid (source-sink dynamics) when natural or anthropogenic disturbances impact specific subpopulations in the region.

### **Community composition(s) and the importance of scale**

Both environmental conditions and dispersal potential vary among different systems and spatial scales ranging from small local scales to large biogeographic scales. Many processes also vary in temporal scales that potentially affect both the realized benthic community composition (e.g. species abundance and richness), as well as the recovery potential (e.g. seasonal peaks in recruitment).

This patchiness extends to anthropogenic disturbances to the seafloor, which result from an increasingly number of activities carried out not only in the marine environment but also in more or less distant on-land locations and reaching the coasts more or less concentrated.

As discussed in the 2010 ICES–JCR D6 Task Group Report, delineating scales for assessing GES of the seafloor is particularly challenging because:

- Benthic ecosystem features are patchy on many scales.
- A wide range of human activities inducing pressures on the seafloor operate also at patchy spatial scales.
- Direct and indirect ecological consequences of human activities may be spread out considerably by physical and biotic processes although initial impacts are often local and patchy.
- Monitoring of the seafloor is also patchy and often local.

Addressing this patchiness will require tackling serious challenges with sampling and measurement, along with aspects of benthic ecology (e.g. dispersal scales and tolerances of benthic ecosystems to perturbations) for which high scientific uncertainty persists. Monitoring will not only have to be adapted to local conditions but also expanded both in terms of seafloor area covered and types of Attributes measured.

Assessing GES for D6 will be possible but it will require integration of results from local scales, where both natural benthic ecosystems and pressures may be very patchy, to broader (sub-) regional scales. Developing one single algorithm for combining indicator values will be particularly challenging for evaluating GES or providing a meaningful index of GES for seafloor integrity. Although it might be possible to integrate indicators for individual attributes on a local scale, this is considerably more challenging across attributes and scales. No single scale will be the “right” one and logically indicators for D6 and their reference levels will also vary across the scale being considered. Expert assessments will be required for evaluating GES of seafloor integrity.

#### 1.4 Conclusion on how to approach seafloor Integrity

Consensus was achieved during the Workshop (WKGMSFDD6) that all attributes proposed by the D6 Task Group Report in 2010 should be considered when developing indicators, and emphasis should be on the functions they provide to ensure seafloor integrity in the ecosystem. “Structure” is not irrelevant to D6, but may be captured in D1 assessments, whereas “Function” (of the seafloor integrity) would not be addressed in other descriptors. In addition, the Attribute of the “Habitat/environmental heterogeneity and regional connectivity” was included in as much as its contribution was considered important in assessing (i) recovery potential and (ii) describing the maintenance of natural linkages between the seafloor biotic and/or habitat components (see “e” below).

The following aspects are essential considerations in the process when amending the Decision (EU/477/2010) to ensure seafloor integrity:

- a) Although it is indirectly suggested by the Decision text that some of the attributes should be completely left to other descriptors, such as D1 and D4, it is their interpretation in assessing biodiversity and ecosystem functioning which makes them actually different and necessary for D6. In particular, the same proposed classes of indicators may be applied under different hypotheses in Descriptors 1 and 6 with their results being, accordingly, interpreted in a different way. For example, a species rarity indicator such as the level of curvilinearity of a species dominance curve can be used to (i) assess rare species presence (which is a biodiversity feature assessed under D1) and, at the same time, (ii) analyse the way species fill ecological space (which by relating to the way ecosystem functions are served may be part of a D6 assessment).
- b) Oxygen, Contaminants and Hazardous substances, including litter: despite different components of this Attribute are already measured under Descriptors like D5, D7 and D8, oxygen availability in the pore water or variables in reduced sediments are still not measured in any of them. A comprehensive and credible environmental status assessment of seafloor integrity will always require the integration and interpretation of information on oxygen depletion and contaminant levels. Such information is instrumental in (i) interpreting, for instance, degraded biotic seafloor integrity indicators such as community composition or (ii) providing pressure indicators under the existing Criterion 6.1 “*Physical damage, having regard to substrate characteristics*”.
- c) Another key, and possibly specific, issue in assessing D6 is the inherent importance of the patchiness of both substrate and benthic biological communities. This mosaic nature of the seafloor can be degraded if the consequence of

management is homogeneity of the environment. The assessments of D1, D4, and D5 might not take loss of heterogeneity into account as long as the pieces are still present. However the heterogeneity itself may be important for seafloor integrity, as this habitat heterogeneity may be vital for certain biological populations to remain viable in a region. This, in turn, could be necessary for essential functions to be served and for a range of goods and services to be provided.

- d) Spatial and time-scales are crucial. Multiple anthropogenic pressures, acting in isolation or in concert on the seafloor have important impacts on its integrity.
- e) Measurability and uncertainty. The nature of seafloor integrity needs to take into account several aspects such as: the scarcity of data, the occurrence of natural disturbance, and high natural variability. This should be incorporated as a strength not a weakness in identifying a GES boundary and when operationalizing indicators (see GES section 2).

### 1.5 Attributes of seafloor integrity

The Decision implies that only two criteria need to be used in order to propose or develop the appropriate indicators in the context of D6: (a) *“Physical damage, having regard to substrate characteristics”* and, (b) *“Condition of benthic community”*. However, this view ignores the most important aspect of the very definition of D6: *“integrity”*. The suggested new criteria functioning and recoverability, would place the provision of ecosystem goods and services more centrally within D6. When selecting indicators and setting appropriate reference point and targets for Functionality and Recoverability reflecting GES for seafloor integrity D6 (see section 2) the following seafloor attributes need to be considered:

- a) **Substrate:** By definition, the seafloor is at the core of the benthic ecosystem, encompassing both its abiotic and biotic components. This is particularly mentioned in the definition. In addition, substrate/substratum is linked to processes taking place in the water column, such as hydrodynamics, and may be expressed as spatial and possibly temporal variation in several components of biological organization from microbes to macrofauna. In addition, the natural disturbance regime must be considered as part of the process that shapes the benthic substrata and community composition.
- b) **Bioengineers:** Bioengineers provide crucial functions that help ensure seafloor integrity. Bioengineers create habitat (both directly and indirectly) that communities depend on. In addition, they will influence physical processes such as deposition and re suspension rates of sediments, bioengineering organisms should thus also be part of assessment of physical substrate.
- c) **Species composition, size composition, trophodynamics and life-history traits.** There are many ways to measure species composition, size composition and life-history traits, and the exact *“taxonomy”* used doesn't always matter that much. What does matter is our ability to interpret *“integrity”*, according to the definition, responsible for preserving the function and structure of the seafloor. Therefore, it is not possible to make a sound assessment on the seafloor integrity without measuring the status of the parts of the biotic component of the benthic ecosystem. The parts to measure are exactly those relating to the functions, and to the extent they may not be

picked up in D1, D3, and D4 assessments, (these functions are provided by benthic community and are thus associated with critical goods and services that the seafloor ecosystem provides). In that context, trophodynamic functions could be covered at least in part (and that part might be substantial) by D4. However, explicit guidance should be given to specifically estimate indicators of benthic foodweb relationships (as well as benthic-pelagic), so as to ensure integrated indicators can be developed. Indicators and benchmarks based on foodweb relationships will need to ensure benthic seafloor integrity (D6) and appropriate assessment of it. Finally, recent progress in molecular biology will make it necessary to develop indicators of genetic structure of benthic species and their populations (e.g. for measuring connectivity), as well as the composition of the microbial communities in sediments.

d) **Habitat/environmental heterogeneity and regional connectivity:** It was mentioned several times by workshop participants that an important consideration for the seafloor is habitat heterogeneity. Heterogeneity may exist at many scales and in combination with dispersal or connectivity will facilitate recovery following a disturbance. It should be, therefore, ensured that heterogeneity and connectivity are maintained in order to host viable populations which, in turn, facilitate the ecosystem's function. However, heterogeneity-driven management may also serve to eliminate biogeographic barriers and establish unnatural connectivity in areas where it did not naturally exist. This can also facilitate range expansion of “unwanted” species (D2). As the sensitivity and specificity of any indicators of heterogeneity and connectedness are poorly known, the issue can be tackled by risk assessment approaches. The description of this additional Attribute is provided below:

- High habitat heterogeneity per unit area will increase the number of source locations of different species that are available within short dispersal distances from each other. This connectivity may promote higher local species richness and functional diversity. Hence heterogeneity and connectivity should be enhanced (where previously depleted) or already sufficient then, maintained in order to host viable populations which, in turn, facilitate community persistence (resilience) and recovery potential. This criteria is also key to effective Marine Spatial Planning (MSP), including the development of a coherent network of marine protected areas, which are both tools for achieving seafloor integrity.
- Several disturbances to the seafloor can either have a homogenizing (eutrophication) or heterogenizing effect (frequent small-scale physical damage) on the seafloor, directly or indirectly by changing underlying habitat/environmental conditions over large-scales. Habitat fragmentation can increase dispersal distances and thus impair source-sink dynamics and local population persistence, affecting overall recovery potential within the region. This will occur as populations in the degraded habitat will tend towards birth rates that are insufficient to offset mortality, thus also lowering potential for the export of any surplus individuals. Communities within these degraded habitats will have greater dependence on immigration from non-degraded habitats.

## 1.6 Proposals for Revision to the Criteria

At present for D6 under the 2010/477/EU Decision only two criteria are covered, one relating to Substrates and the other to Benthic communities. This was considered insufficient and may compromise our ability to assess seafloor integrity. Rather, alternate criteria that better reflect a healthy functioning benthic ecosystem and its ability to recover from perturbations should be adopted to provide clearer guidance in the development of indicators to assess seafloor *integrity*. Thus for D6 the Criteria Functionality and Recoverability is proposed for identifying GES boundaries. Both Criteria would require taking account of both *Physical damage, having regard to substrate characteristics / Condition of benthic community* (the two Criteria in the existing Decision). Substrate impacts would be assessed relative to their consequences for ecosystem function under Functionality, and for the ability to recover from the changes to substrate under Recoverability. Thus, in less well known systems, reductions of three-dimensional structure or spatial heterogeneity in substrate alone could be cause to conclude GES is not achieved, unless recovery of the reduced structure or heterogeneity was expected to be rapid and secure for benthic communities. Changes to community composition known from local studies or generalized from studies of other relevant ecosystems to have consequences for functions important to seafloor integrity would be evaluated under Functionality. Again, in systems where the functional consequences of changes in benthic communities are poorly known, Recoverability allows GES assessments to be done on the basis of how well the communities is expected to recover from perturbation.

There is not full certainty in some experts that all changes captured in the original Criteria are also captured in assessments used in Functionality and Recoverability. Therefore an option would be to keep the original Criteria (Physical damage, having regard to substrate characteristics), as well as Functionality and Recoverability until there is some experience with the actual performance of these new Criteria in assessments of seafloor integrity.

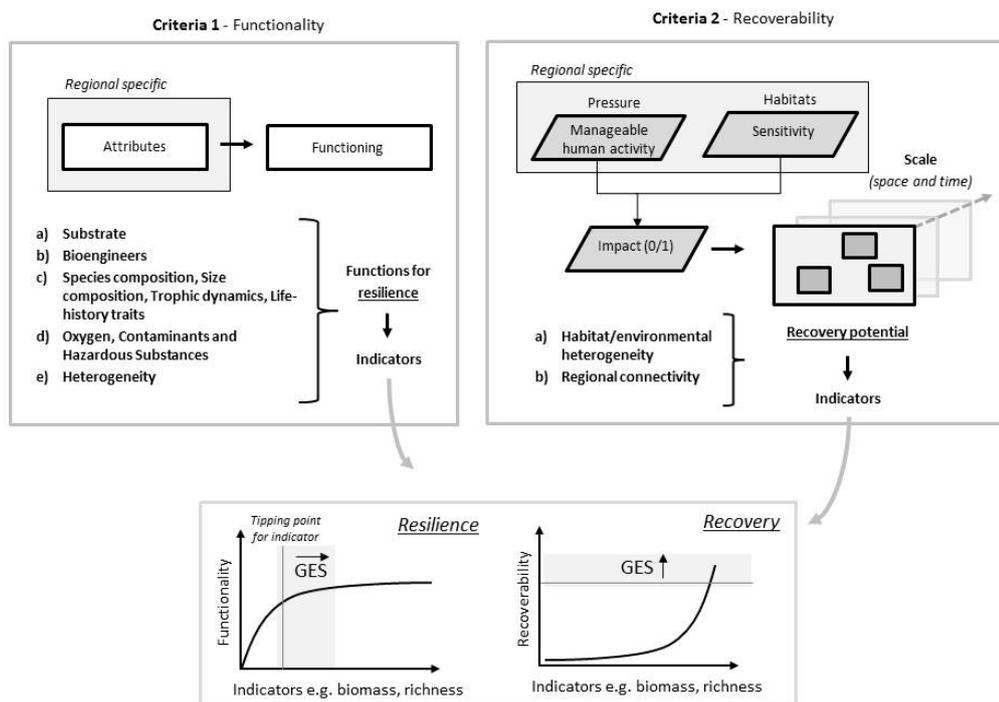


Figure 1. Conceptual diagram showing how the expert group viewed the revision of criteria to best address seafloor integrity.

## 2 Reference levels for GES of seafloor integrity

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### 2.1 Criteria to Consider

In assessing whether a system is inside or outside GES for seafloor integrity, it is proposed that two criteria must be considered. Neither alone is sufficient to cover all cases for evaluation of GES. For GES evaluations it is necessary to consider both:

**Criteria 1: *Functionality*** - if benthic **FUNCTIONS** are occurring within the bounds of natural variability

**AND**

**Criteria 2: *Recoverability*** - if an area were degraded by impacts of past uses, would **RECOVERY** of the benthos from perturbation expected to be rapid (taking into account life histories) and secure.

Depending on both the nature of the benthic system and the past and present pressures on it sometimes only one of those criteria will be needed in environmental assessments of local habitats. However at (sub-) regional scale assessment of the environmental status has to capture both. Resilience is fostered through connectivity of habitats and thus resilience to and recovery from perturbations is facilitated by spatial heterogeneity of seafloor habitats. Consequently loss of heterogeneity can itself lead to reduced environmental status. However the science to include this directly in GES assessments is incomplete.

For criteria 1 *Functionality*, what actually constitutes full recovery is not straightforward, and expert assessment will be required in assessment.

Depending on both the nature of the benthic system and the past and present pressures on it, sometimes one of those factors will more readily detect changes in environmental status, sometimes the other. If an area is not in GES, both factors are important in choosing and applying measures. If an area is within GES, both factors are still relevant to choosing management measures to maintain GES. Consequently any assessment of environmental status relative to GES has to capture both.

For Criteria 2 *Recoverability*, what actually constitutes full recovery is not straightforward but determinations of expected recovery rate should focus on speed and security of movement in the desired direction, if the pressures are managed effectively. OSPAR (OSPAR, 2008) and the FAO Deep-Sea Fisheries Guidelines (FAO, 2009) provide information on the types of habitats appropriate to evaluate this factor, and the FAO Guidelines provide quantitative criteria for what might be considered “rapid” recovery.

### 2.2 Relationships of criteria in assessing GES

The differences between the two factors in assessing environmental status is partly in how pressure, state and impact indicators may be used in the assessments, but largely where reference point and targets for GES boundaries may be set on indicators for assessment purposes. A loss in functionality that leads to a conclusion that a system is not within GES is a biological feature and is at the heart of seafloor *integrity*. If an assessment concludes that functions are not being degraded, then the system is within GES, whatever its recovery potential. However, if indicators suggest that there

may be some reduction in functionality then recoverability will be an important criteria in determining when a system is no longer in GES.

### 2.3 Roles of indicator types

The types of indicators likely to be important in assessing GES for functionality are discussed as “Type 2 habitats” in Section 3.2. For habitats expected to have slow recovery from perturbation, the indicators and assessment considerations of “Type 1 habitats” will be particularly relevant (see section 3.1).

Pressure indicators will have an important role in assessing environmental status within the functionality criteria, but indicators closely tied to specific functions, which often but not always may be abundance of species or functional groups, also have a central role in assessing GES. Modelling usually will have a role in evaluating if functions are being degraded, and in identifying species or species groups that may be informative indicators of reduction in functionality. Whatever roles models may have in assessing ES for this type of habitats, monitoring will remain an important part of assessing GES. The reliability with which either models or monitoring indicators link measurable ecosystem properties to functions important to seafloor integrity has to be established.

In initial assessments of environmental status against GES benchmarks, *State and Impact* indicators may provide useful information for management, for habitats with all rates of potential recovery, taking account of the differences in appropriate indicator thresholds (see section 2.4). In subsequent assessments of habitats with low likelihood of rapid recovery that have been assessed as not in GES the ecological response to appropriate measures will take time. Consequently pressure indicators will be important in assessing GES, and can be used without additional *State and Impact* indicators (if none are available) because the desired value of major pressures (very low or absent) can be specified.

### 2.4 Placing GES benchmarks on indicators

A decision-tree approach should be followed when in assessment for estimating GES boundaries for change in a function (Figure 2).

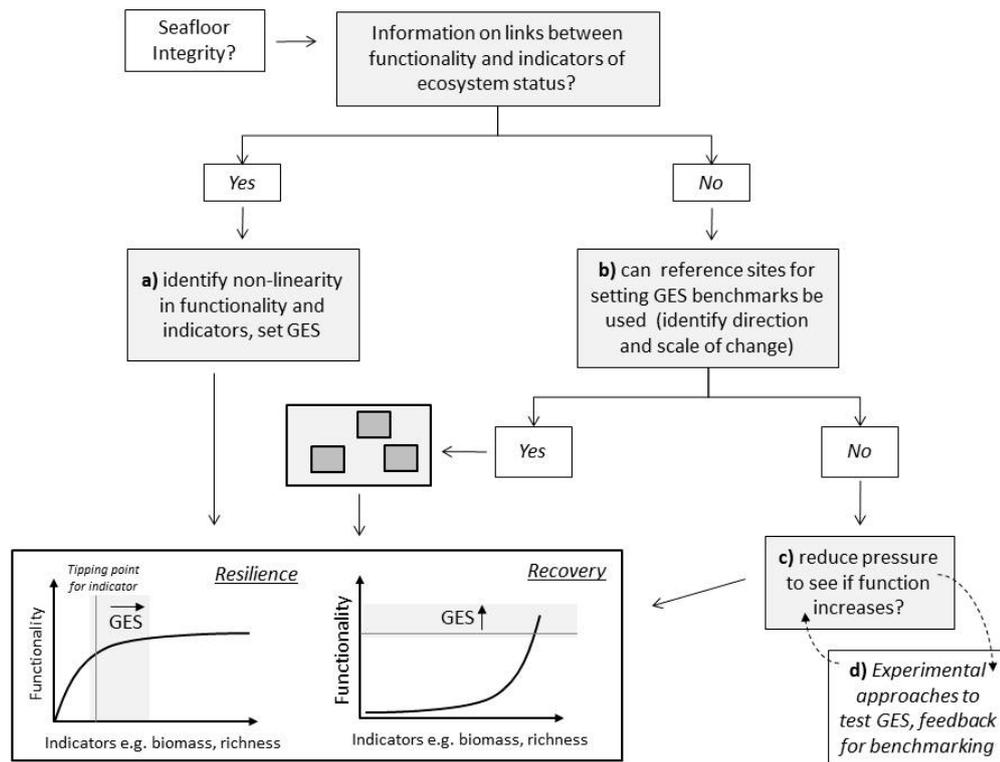


Figure 2. Decision-tree for GES assessment of seafloor integrity.

- a) Where there is information on functionality and indicators of ecosystem status, analyses should look for tipping points (non-linearities) in ecosystem state-function relationship. Such non-linearities will provide a defensible estimate of a GES boundary reference point and target. Local studies, supported by models of the functional relationships can inform where the non-linearities may be on larger scales.
- b) In cases where there is not sufficient information to even look for non-linearities in the relationship between function and indicators of ecosystem status, any loss of functionality will constitute a degradation of environmental status. However, absolute boundaries for GES of functions (or traits linked to functions) will be hard to identify biologically. It may be possible to locate areas in the region or subregion of the assessment that have been less perturbed than most other areas, or historically information on periods of less perturbation. Information from those areas, or from historical information, should be reviewed to see if they can provide information on at least levels of functions observed in the least perturbed areas available. Then if assessments of other areas provide estimates of functionality (or indicators linked to functions) lower than those of these less perturbed areas, at least the direction and scale of change in environmental status has been identified.
- c) Data from most benthic systems come from systems that have already been altered beyond a reference point where un-impacted function levels can no longer be recognized. Modelling may be relevant to estimate such conditions, but for systems that have already been severely perturbed by past activities,

maintaining current levels of functionality is a minimum management target, although insufficient to conclude that GES has per se been achieved. The more perturbed the system is known to be, the greater the rationale to at least reduce pressures to see if the functionality will increase.

- d) If experimental or opportunistic reduction in pressures is possible and can be accompanied by appropriate monitoring, then information can be gained on whether or not GES may be higher than the current status. Feedback from such designed or natural experiments should be used to revise GES boundaries for future assessments.

For habitats that have low recoverability (Criteria 2) the likelihood of rapid and secure recovery from perturbation will be low. Thus the functions the habitat provides will also degrade more quickly than for habitats with higher resilience to perturbation. Therefore, for low recovery potential habitats, GES reference point and targets should be set higher (greater ability to provide related functions). If no information is available, pressure indicators alone may provide the basis for assessing GES for low recovery potential habitats.

## 2.5 Relationship with other Descriptors and Frameworks

For habitats assessed under *Criteria 1 - Functionality*, some data or model-based rationale linking structure and function are needed for a conclusion on whether or not some ecosystem function(s) is (are) being degraded. This will also provide the context for how assessments of D6 may interact with assessments of other descriptors, such as D1. If no function can be identified as degrading as a species (or group of species) abundance is declining, then the decline in abundance is a D1 issue – biodiversity is changing and D1 considerations will determine if this reduces GES. On the other hand, if the assessment concludes that a seafloor function is being degraded as a species (or species group) is declining, then this is a D6 issue even if the populations are consistent with D1 boundaries for GES.

This approach is likely to lead to GES boundaries that differ from reference point and targets for other policies, such as Favourable Conservation Status (FCS) under the Habitats Directive. FCS is for habitats specifically identified by managers as in need of enhanced risk aversion because of their specific ecological properties. There is no inherent contradiction if the Habitats Directive sets higher standards than are set for Recoverability in D6, since most habitats represented in the Habitats Directive will be assessed more stringently under this criteria.

### 3 Indicators

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Following the GES discussions, it was decided that state indicators are always informative and are required for more resilient habitats. Pressure indicators are most often cheaper to acquire and update, however, and can have roles in assessment of GES. For habitats that have moderate or high potential for rapid and secure recovery, GES boundaries can only be identified by demonstrating non-linearities between pressures and metrics of ecosystem function (Section 2.4) so they rarely can be used without state indicators as well. For habitats with low likelihood of rapid and secure recovery, however, there is an implied reference point of no impacts (Section 2.4), so pressure indicators alone can be used in identifying the GES boundary, particularly during the recovery phase.

To make this operational in practice, habitats are proposed to be categorized and monitored as follows:

#### 3.1 Type 1 habitats

These include habitats with a low resilience to human pressures and long recovery times, and which require a high level of protection. Some of the MSFD Annex III “special habitats” (defined as habitats protected under EU, regional or national legislation) and Vulnerable Marine Ecosystems (VMEs) are type 1 habitats, but any habitats defined by their low resilience and long recovery times in relation to pressures are also candidates to be categorized type 1 habitats.

Once areal extent is established either with existing *in situ* data or habitat suitability modelling followed by targeted ground-truthing, pressure indicators are sufficient to monitor appropriate management measure and track progress towards a GES reference point and target. For these habitats with low likelihood of rapid and secure recovery, there is an implied benchmark of no impacts (Section 2.4), which is why pressure indicators alone can be used in assessing GES, particularly during the recovery phase.

#### 3.2 Type 2 habitats

These are habitats referred to in the preceding section with medium to high resilience and where recovery is rapid and secure, taking into account the life histories of the dominant species.

Pressure indicators alone would give incomplete assessment of environmental status of these habitats. State indicators, particularly, some that measure the natural range of variability and the possible tipping point at what level of perturbation the system loses its functionality, will add important information to the assessment of environmental status. This is because GES reference points can only be set through demonstrating non-linearities between pressures and metrics of ecosystem function (Section 2.4) so pressure indicators can rarely be used without state indicators. A risk-based approach might be feasible to select type 2 habitats that are exposed to an elevated level of pressure, which could alter their functionality. For this purpose, the areal extent of type 2 habitats (e.g. defined as EUNIS level 3 habitats) with level of pressure can be used to calculate the percentage of area potentially impacted per habitat type. Meaningful and habitat-specific thresholds on level of impact (e.g. numbers of times trawled per year) would need to be set taking resilience and recoverability into ac-

count. For risk-based models to be reliable, they will often need to be spatially resolved. This may include using expert judgments to determine what the maximum amount of impact and/or fragmentation in an area can sustain before recoverability is compromised so that targets can be set above this limit.

Once the relative risk to habitats are identified, a number of indicators need to be selected to measure the level of their main functions that best reflect resilient communities. These can be specific to different habitat types or seafloor attributes (Table 1).

There are many other functions that are not listed in Table 1 e.g. remineralization, benthic-pelagic coupling. Sets of relevant functions and associated indicators should be selected at (sub-)regional scale. Relevant function should reflect important and to perturbations sensitive functions the main functions of seafloor attributes in habitats occurring in the (sub-) region.

In the time available, the expert group did not evaluate indicator species of the function listed. This requires further work by (sub-)region but it was recognized that some function might be measured using indicator species abundance in some cases.

The group discussed the effect of invasive species on seafloor functions. It was acknowledged that invasive species may replace native species in serving some functions, alter functions or completely replace some functions by others. Occurrence, abundance and ecosystem effect of invasive species are addressed in D1 and D2. The effect on seafloor integrity will be addressed through changes in function (replacement of seafloor function or change of functions levels).

As some pressures may result in homogenization of some properties, for some indicators, both an average level and a variance is needed (or have an indicator of the mean and one of the range).

### **3.3 Selecting indicators for *Recoverability***

Reference points and targets based on impact indicators may be used to measure the maximum amount of impact and/or fragmentation that an area can sustain before recoverability is compromised. High turnover in community composition in an area (beta diversity) can be expected if environmental conditions vary among different patches and different species are favoured under different environments (Kneitel and Chase 2014). Quantitative or trend-based indicators, together with average local species richness can be used to gauge changes in environmental/ habitat heterogeneity that are due to changes in disturbance regimes (frequency, spatial extent, and intensity) and that will affect the recovery potential of an area (i.e. recoverability).

**Table 1. Examples of functions of the seafloor, related attributes and indicators to assess function level.**

<b>Function</b>	<b>Seafloor attribute</b>	<b>Example indicator of the function</b>
Primary productivity	Species composition	Remote sensing on benthic productivity (only in intertidal zone)
	Size composition	
	Trophodynamics	In situ (subtidal)
	Life-history traits	
Secondary production	Bioengineers	Abundance/production of grazers, filter-feeders, deposit-feeders, detritivores, meiofauna Secondary production P/B ratios Growth rate
	Trophodynamics	
	Life-history traits	
Provision of spawning area	Substrate	Occurrence/density of spawning (fish and other mobile organisms)
	Bioengineers	
	Oxygen	
	Habitat/environmental heterogeneity and regional connectivity	
Provision of feeding ground	Substrate	Seasonal occurrence/abundance of mobile organisms
	Bioengineers	
Production of food To infauna To epifauna To demersal/pelagic communities/species	Species composition	
	Size composition	
	Trophodynamics	
	Life-history traits	
Energy flow Changes in functional traits	All	Abundance/biomass of dominant benthic feeding guilds Ratio of functional traits, e.g. filters/scavengers biomass ratio
Sediment reworking	Bioengineers	Bioturbation index (e.g. from video surveys)
		Bioengineer abundance/biomass
Sediment stabilization	Substrate	Abundance/ composition of bioengineer species
	Bioengineers	
Provision of emergent three-dimensional structure Permanent	Bioengineers	Area extent of three-dimensional structure
Seasonal	Bioengineers (e.g. kelps)	Area extent of three-dimensional structure
Connectivity	Habitat/environmental heterogeneity and regional connectivity	Changes in turnover of community composition (beta-diversity) and average species richness (alpha-diversity)

## 4 Conclusion and Recommendations:

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- 1) The Decision 2010/477/EU D6 criteria (6.1 *Physical damage, having regard to substrate characteristics* and 6.2 *Condition of benthic communities*) are insufficient and risk compromising our ability to assess seafloor integrity.
- 2) The present criteria should be revised into new criteria 6.1 *Functionality* and 6.2 *Recoverability* that are more closely related to resilience and recovery potential of the seafloor. This would simplify the existing Decision and may not require any additional monitoring from Member State.
- 3) 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 perturbation at which the decline of the system functionality begins to accelerate.
- 4) 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).
- 5) For both criteria (*Functionality* and *Recoverability*), information on sensitivity and pressures need to be considered together to evaluate overall impact. Pressure indicators alone will result in an incomplete assessment.
- 6) 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.
- 7) Scientific guidance will be required in prioritizing functions to be assessed under each criterion, as well as choosing indicators and establishing GES boundaries for seafloor integrity (with reference points and targets). This will be required in any potential revisions of Decision 2010/477/EU and in its implementation by Regional Sea Conventions (RSCs) and Member States.
- 8) A substantial body of scientific knowledge that can serve as the basis for this guidance has already been consolidated in the ICES/JRC 2010 Task Group 6 report. Appropriate experts building on this foundation can make rapid progress on finalizing the necessary guidance. 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.

## 5 References

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## Annex 1: Term of Reference

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2013/2/ACOM61      The **Workshop on guidance for the review of MSFD decision descriptor 6 seafloor integrity** (WKGMSFDD6), chaired by Jake Rice, Canada, will meet in Copenhagen, Denmark, 2–3 September 2014 to:

- a) Consider the issues raised by the ICES science team on the scientific challenges associated with the implementation of the MSFD decision.
- b) Provide guidance for the finalization of the review
- c) Report on additional scientific challenges to the implementation of the MSFD decision (D6) criteria. WKGMSFD-D6 will report by 15 September for the attention of ACOM.

### Supporting information

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Priority	High. This workshop is part of a process to respond to a request to ICES from DGENV for a technical service to review the descriptors for the MSFD 2010/477 Decision.
Scientific justification	The 2010 Decision of the MSFD raised many challenges. Many of these are concerned with the scientific interpretation of the ideas and concepts of the Decision. This workshop will focus on the scientific challenges for D6- seafloor integrity with a view to clarify the text and make the Decision more understandable. Recent relevant ICES Advice should be taken into account in the review.
Resource requirements	None
Participants	Experts with expertise in MSFD implementations or scientific issues regarding the descriptor are encouraged to participate. Each country can send 1–2 participants. If nominations exceed the meeting space available ICES reserves the right to reject participants. This will be done based on the experts' relevant qualifications for the Workshop and geographical coverage. National participants join the workshop at national expense. The Workshop will be open to stakeholders.
Secretariat facilities	Secretariat support and meeting room
Financial	No financial implications.
Linkages to advisory committees	Direct link to ACOM.
Linkages to other committees or groups	Direct link to the CSGMSFD
Linkages to other organizations	Links to DGENV and the EU GES/MSCG

## Annex 2: List of participants

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## **Annex 3: WKGMSFDD6 Agenda**

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### **2 September 2014**

#### **9 ) Introductions and welcome**

Participants will be welcomed to the workshop.

#### **10 ) Aim of the workshop**

The agenda, aims of the workshop, and expected outcomes will be reviewed. Participants will be invited to provide initial feedback on the proposed agenda and process.

#### **11 ) Issues relevant to revision**

- Revision of “seabed integrity” concept: scope of D6 criteria, other criteria in other descriptors that relate to seafloor integrity (i.e. D1, D4, D5, D7, D8)?
- Setting a reference point for seafloor integrity: disturbance and recovery dynamics
- Measuring seafloor integrity within a DPSIR framework: how many indicators are needed?

### **3 September 2014**

#### **12 ) Criteria for GES for D4**

- Identify essential seafloor integrity elements that ensure Good Environmental Status (GES)
- Review of MSFD (2010/477/EU) that relate to identified seafloor integrity attributes
- Standardized methods for indices, reference level setting and monitoring
- Additional concerns with regards to D6

#### **13 ) Conclusion**

The main conclusions of the workshop will be reviewed and summarized.

## **Annex 4: Workshop background document**

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**ICES**

International Council for  
the Exploration of the Sea

**CIEM**

Conseil International pour  
l'Exploration de la Mer

Descriptor 6

2–3 September 2014

Workshop Background Document

Revised on 27 August 2014

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**Overarching aims of workshop:** to review elements of seafloor integrity in the Decision (2010/477/EU) and suggest ways to improve the scientific guidance to help achieve GES by making it more clear and simple. To do this, the workshop is invited to especially discuss the following:

- Revision of “seabed integrity” concept: scope of D6, other elements in other descriptors that relate to seafloor integrity (i.e. D1, D4, D5, D7, D8)?
- Setting appropriate benchmarks for seafloor integrity: disturbance and recovery dynamics
- Measuring seafloor integrity within a DPSIR framework: how many indicators are needed, and role of State vs Pressure indicators?

**Core ICES D6 science team:** Jake Rice (Canada, Chair); Pascal Lorance (France), Christos Arvanitidis (Greece), Fernando Tempera (JRC), Sebastian Valanko (ICES)

### **Outline of D6 WK background document:**

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- 1 Definitions**  
Sea-floor, Integrity, Not adversely affected, Recovery, Dynamic, Impairment of ecological attributes
- 2 Important consideration**  
Scale and habitat heterogeneity
- 3 Revision of concept “seabed integrity”**  
Essential attributes of seafloor integrity  
Overlap and gaps between descriptors
- 4 Benchmarks for GES: disturbance and recovery dynamics**
- 5 The DPSIR framework: how many indicators are needed?**  
Pressure, State, Impact  
Way forward – simple and clear

**Appendix:** Policy context and linkages to Regional Seas Conventions (RSCs)

## 1 Definitions – GES for descriptor 6

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### Title of Descriptor

Good Environmental Status for Descriptor 6: “Sea-floor 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”

### Definition of the Descriptor

**Sea-floor** is defined as key compartment for marine life. It includes both the physical and chemical parameters of seabed - bathymetry, roughness (rugosity), substrate type, oxygen supply etc., and biotic composition of the benthic community. Different kinds of habitats for sedentary and mobile marine species are formed inside and above the sea bottom.

**Integrity** is interpreted as including both spatial connectedness, (avoiding unnatural habitat fragmentation), and natural ecosystem processes functioning in their characteristic ways.

**Not adversely affected** means that the cumulative effect of pressures associated with human activity are at a level that ensures the ecosystem maintains its respective components (structure) along with its natural levels of diversity, productivity, and dynamic ecological processes (functioning). Levels of disturbance (intensity, frequency, and spatial extent) must be at a level that ensures a dynamic recovery potential is maintained.

**Recovery** means that respective seafloor attributes show a clear trend towards their pre-perturbation conditions, and the trend is expected to continue (if pressures continue to be managed) until the attributes lie within their range of historical natural variation. Benthic communities are not static entities, and thus recovery does not require that the ecosystem attributes return to their exact prior state.

**Dynamic** must be interpreted in the context of the life histories of the species and natural rates of change in the community properties being perturbed. For some seafloor habitats and communities, recovery dynamics from perturbation would require multiple decades or more, and in such cases management should strive to prevent perturbations.

**Impairment of an ecological component** occurs if the ecological consequences of the direct or indirect perturbations spread widely through the ecosystem in space and/or persist particularly long in time, or if the normal ecological linkages among species act to extend and amplify the effects of a perturbation rather than to dampen the effects.

### **Important considerations**

A key to defining whether or not overall GES has been achieved for D6 is if habitat/environmental heterogeneity is maintained allowing representative species to also maintain viable populations. Regional connectivity will allow dispersal of species and different life-stages between habitats and support recovery dynamics (source-sink) when faced with natural and anthropogenic disturbances (i.e. integrity).

### **Scale and Habitat heterogeneity**

There are no points of significant disagreement among experts regarding key terms or what constitutes gradients of degradation in environmental status. However, serious problems of sampling and measurement and high scientific uncertainty about aspects of benthic ecology (e.g. dispersal scales) and tolerances of benthic ecosystems to perturbations pose challenges to application of —“good environmental status”. Sound assessments of GES are possible, but they require integration of results from local scales where both natural benthic ecosystems and pressures may be very patchy, into much larger regional and subregional scales.

Both environmental conditions (habitats) and dispersal potential varies among different systems and spatial scales (small local scale to large biogeographic scales). There may also be variation in temporal scales of many processes, which affects both the realized benthic species composition (abundance, species richness), as well as recovery potential (e.g. seasonal peaks in recruitment).

Anthropogenic disturbances to the seafloor may be the result of either activities in the sea or inland activities such as agriculture and industries resulting in chemicals, nutrients or other pressures that are carried by river, have their initial inputs concentrated at river mouths and plume in the coastal waters. Initial impacts may therefore be patchy and/or at some distance from the source(s) of the pressure(s).

Delineating scales for assessing GES of the sea floor is thus particularly challenging, due to the following:

- Benthic ecosystem features are patchy on many scales.
- A wide range of human activities cause pressures on the seafloor, and they usually operate at patchy spatial scales.
- Although initial impacts of human activities are often local and patchy their direct and indirect ecological consequences may be transported widely by physical and biotic processes.
- Monitoring of the seafloor is also patchy and often local.

Thus indicators for D6 and their reference levels will also vary across the scale being considered. This means that monitoring must be adapted to local conditions, and expanded for the seafloor – both in terms of area covered and types of attributes measured. It also means that developing one single algorithm for combining indicator values will be particularly challenging for evaluating GES or providing a meaningful —index of GES for seafloor integrity. Even though it might be possible to conduct analytical syntheses of indicators for individual attributes on a local scale, it is considerably more challenging across attributes and scales. Expert assessments may be required for evaluation of GES of seafloor integrity.

### Setting benchmarks for Seafloor integrity

The Decision (EU/477/2010) is a document about both sustainable use of marine ecosystems and protection of their components in good environmental status. Given the reference to “sustainable use” the standards for GES cannot be pristine. Pristine conditions may be used for anchoring the upper end of a continuum of environmental status. But many aspects of the seafloor are necessarily affected by certain uses (such as benthic invertebrates affected by harvesting for human consumption), and to require pristine conditions to be maintained is to require that all benefits from such uses be forgone. Consequently, just as the threshold for GES of Descriptor 3 (commercially-exploited fish and shellfish) must reflect levels of harvesting that are sustainable, so must the thresholds and standards for Descriptor 6. To make this concept operational, indicators for Descriptor 6 should be able to reflect rapid and secure changes towards improved environmental status, while also being able to demonstrate associated functions have not been adversely affected. Percentages for such thresholds are available in management at the population level for many pressures, including fishing.

Evaluating the status of single indicators is an important but not final step in assessing overall GES. As explained above, seafloor integrity is inherently an integrative property of the states (structure) of several components of integrity including:

1. **Substrate** (also relevant in D1)
2. **Bioengineers** (also relevant in D1)
3. **Oxygen** (also relevant in D5)
4. **Contaminants and Hazardous Substances** (also relevant in D8)
5. **Species Composition** (also relevant in D1)
6. **Size Composition** (also relevant in D1)
7. **Trophodynamics** (also relevant in D4)
8. **Life History Traits** (also relevant in D1)
9. **Habitat/Environmental heterogeneity and regional connectivity** (also relevant in D1)

Collectively these attributes will allow the ecological processes (functions) of the seafloor and benthic communities to be expressed. The integrated nature of seafloor integrity means that there is no single state that can be defined as “good” for each indicator; seafloor components interact in ways that may synergistically or antagonistically allow functions to be served (or compromised) by a variety of combinations of states of the various indicators of components. Thus the integration of environmental status on whatever suite of indicators is used is a crucial step in assessing GES. Simplistic rules like “one out-all out” can be applied unambiguously, but will rarely lead to reliable or useful assessments of GES. Pathways for more appropriate integration of separate indicators into reliable assessments of seafloor integrity are discussed in the ICES/JRC report of 2010.

Relevant benchmarks for evaluation of GES, with associated metrics will need to be set by management. This management choice of a specific goal and scale will serve to guide the scientific work for operationalizing D6 indicators. For managers, setting such targets can be challenging as they need to be unambiguous and the time taken to derive them should not be underestimated.

This can best be done through an iterative process, among scientists, stakeholders, and policy-makers.

It should also be acknowledged that ecosystems and their attributes have intrinsic value, beyond the uses society may choose to make of an ecosystem. To the extent that such inherent values can be identified, GES also requires that these values are preserved. This may mean that some areas of the seafloor receive a high degree of protection from any human induced perturbations.

## **2 Revision of concept “seafloor integrity”: essential attributes**

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To ensure seafloor integrity human pressures on the seabed should not affect the ability of ecosystem components to retain their natural diversity, productivity, and dynamic ecological processes, all important aspects of ecosystem resilience. Assessment and monitoring needs to be carried out after an initial screening of impacts and threats to biodiversity features and human pressures, as well as an integration of assessment results from smaller to broader scales. One main concern for management is the extent and magnitude of impacts of human activities on seafloor substrates structuring the benthic habitats. Among the substrate types, biogenic substrates, which are often the most sensitive to physical disturbance, provide a range of functions that support benthic habitats and communities. The other main concern of management is extent and magnitude of impacts of human activities on ecosystem functions and processes. Characteristics of the benthic community such as species composition, size composition, and functional traits provide an important indication of the potential of the ecosystem to function well. Information on the structure and dynamics of communities is obtained, as appropriate, by measuring species diversity, productivity (abundance or biomass), tolerant or sensitive taxa and taxocene dominance and size composition of a community, reflected by the proportion of small and large individuals.

The relevance of the overlap issues between similar indicators considered under different descriptors depends largely on the future use of the individual indicator assessments. A key use is as part of composite indicators developed for higher-level assessments. Where similar low-level indicators are used several times in the assessment of GES in different descriptors, double accounting issues may result in unbalanced assessments. However, multiple uses of an indicator may also reflect that a particular component is corner stone to two or several ecosystem processes so that its alteration impacts several dimensions of the ecosystem. For example indicators of the species (D6.2.2) and size (D6.2.4) composition of the benthic community may reflect the status of some functions served by the benthic community (e.g. benthic cover) but also the intrinsic benthic biodiversity assessed under criteria D1.6 and D1.7. The potential for imbalance in assessments from multiple uses of similar indicators can be mitigated if sets of indicators are used to describe the multi-dimensional landscape of GES, such that the relationship of such multi-use indicators to other descriptor-specific indicators is preserved in the assessment instead of just being rolled up with other indicator values into a much less informative composite score.

Indicators with potentially high overlap may be found, for example, under criteria D1.4 habitat distribution, D1.5 habitat extent, D6.1 substrate

characteristics, and indicator D4.3.1/habitat-defining groups/species. In addition, Descriptor 6 has a relation to other pressure-related descriptors (D2, 5, 7, 8, 9 and 10), except for underwater noise (Descriptor 11) where effects on benthic species have yet to be adequately considered.

In choosing a combination of indicators that can be used to measure GES for seafloor integrity it needs to be ensured that all seafloor attributes are covered and to take account of cross-descriptors. In so doing, the complementarity of indicators will need to be considered, as will also the scale at which indicators will respond (e.g. large 100 km, medium 1 km, small scale 1 m).

#### **Attributes of seafloor integrity:**

**Substrate:** The physical properties of the seabed such as grain size, porosity, rugosity, solidity, topography and geometric organization (e.g. three-dimensional habitats). Substrate is a driver of patterns in diversity, function, and integrity of benthic communities. Together with hydrodynamics, substrate is a main factor structuring benthic habitats. Four types of Substrate are considered separately, both because they contribute differently to ecosystem processes and they are affected differently by diverse pressures: soft sediments, gravels, hard substrates, and biogenic substrates. Indirect indicators of functions are often more practical to use in assessing GES than indicators of substrate itself.

**Bioengineers:** Organisms that change the structure of the seafloor environment in ways not done by geophysical processes alone, by reworking the substrate or by providing structures that are used by other species. Bioengineers may serve functions such as providing shelter from predation or substrate for other organisms, reworking of sediments, transporting interstitial pore water, and facilitating material exchange at the sediment-water interface. Bioengineers are sensitive to many pressures, but often prove difficult to monitor directly. Indirect indicators of the functions they serve or indicators from mapping the pressures on bioengineers are often practical alternatives for assessing GES.

**Oxygen:** Concentration of dissolved oxygen in the bottom water and/or in the upper sediment layer of the seafloor. Decreasing oxygen supply of bottom water and/or the upper sediment results in significant changes of the benthic communities and can lead to mass mortality. Oxygen depletion is particularly associated with excessive nutrient and organic enrichment of the seafloor. Important indicators for oxygen concentration include abundance of organisms sensitive or tolerant to oxygen level and the spatial distribution of oxygen/hydrogen sulphide concentrations conducted in critical regions and in critical seasons.

**Contaminants and Hazardous Substances:** Guidance on including these substances in assessments of GES is presented for D8. Particular attention should be given to applying that guidance for seafloor communities and habitats. Sediments may be repositories for many of the more toxic chemicals. Contaminated sediments represent a hazard to aquatic life and human use through direct toxicity as well as through bioaccumulation in the food web.

**Species Composition:** The list of species present in an area, their abundances, and/or their evolutionary and ecological relationships, including their pattern of occurrence in space and time. Species composition captures information on the

biological diversity, structure, and dynamics of communities. It represents a fundamentally valued feature of ecosystem's potential to function well, to resist potential threats, and be resilient. Of the large number of indicators of species composition, those focusing on diversity among samples (space or time) and measures of species/area relationships may be most useful. These must be applied on local scales to account for natural scales of community structure and pressures on them.

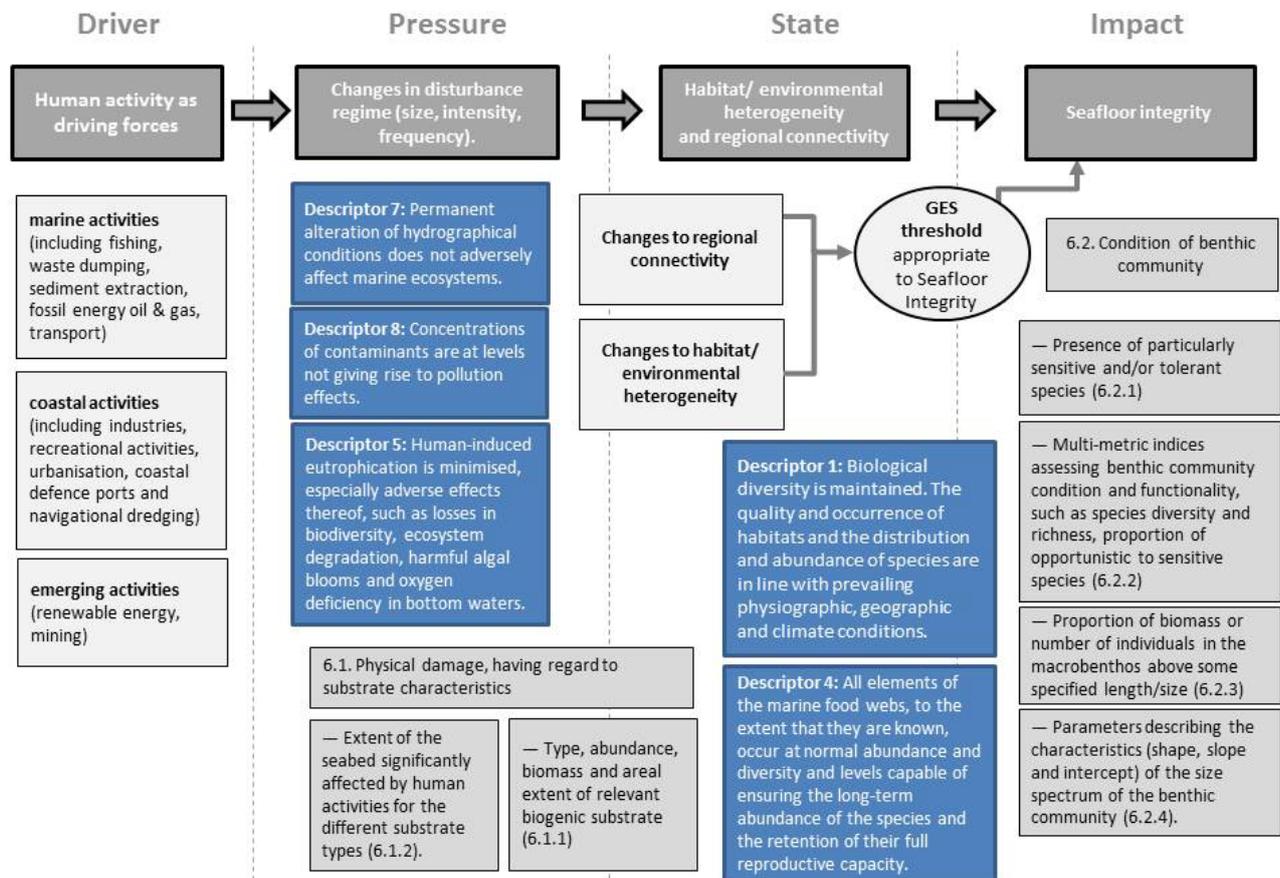
**Size Composition:** Abundance or biomass of individuals of different sizes in the community, with size as either continuous or as categories. The size composition of a community integrates information about productivity, mortality rate, and life histories of the full community. Indicators include the proportion of numbers (or biomass) above some specified length, parameters (slope and intercept) of the size spectrum of the aggregate size composition data, and shape of a cumulative abundance curve of numbers of individuals by size group.

**Trophodynamics:** A complex attribute with many subcomponents. Key ones include Primary and Secondary Production, Carrying Capacity, Energy Flows, and Food Web Relationships. The task-group report on descriptor 4, on Food webs deals thoroughly with primary production, energy, flow and food webs. In the decision (2010/477/EU), these attributes are monitored by indicators of productivity, abundance and/or biomass of key species and/or taxonomic groups. However, even if such indicators are part of the assessment of Descriptor 4, and assessment of GES on Descriptor 6 may also require some indicator(s) of these productivity processes, since benchmarks for *integrity of the seafloor* may not be identical with the benchmarks for foodweb with multiopel trophic pathways, soe of which are pelagic. When evaluating Seafloor Integrity it is important to follow the expert guidance available for the specific context of the benthic community, its food web relations, and benthic-pelagic relationships. Secondary Production and Carrying Capacity are also important to Seafloor Integrity but at this time there are no practical indicators for their assessment.

**Life History Traits:** Life History Traits are the categorization of characteristics of the life cycle that species can exhibit, i.e. growth rates, age or size or maturation, fecundity and the seasonality of life history features such as reproduction. Various combinations of these traits lead to species differing in their natural productivity, natural mortality, colonization rates, etc. They are important to GES as they reflect the status of ecosystem functioning. Their changes are direct measures of the condition of the biota, or may uncover problems not apparent with other attributes, and provide measurements of the progress of restoration efforts. Many synthetic indices based on representation of species with different sensitivities and tolerances for general or species pressures have been used. As with trophodynamics, even if some Life History indicators are used in the assessment of D1 (biodiversity), the assessment of Seafloor Integrity will also require indicators of life history properties of benthic communities, with benchmarks appropriate specifically to processes of benthic communities.

**Habitat/environmental heterogeneity and regional connectivity:** several disturbances to the seafloor can either have a homogenizing (eutrophication) or heterogenizing effect (frequent small scale physical damage) on the seafloor, directly or indirectly by changing underlying habitat/environmental conditions over large scales. This will affect species so that their niche requirements are no longer matched with the prevailing conditions. Furthermore, it can be expected

that species richness at a locality can be higher than expected purely on the habitat and species niche requirements due to high rates of dispersal from other adjacent source populations. Thus regional connectivity will ensure that dispersal is sufficient to maintain populations and also ensure dynamic recovery potential when faced with disturbance. Thus at a larger scale ensuring habitat/environmental heterogeneity and regional connectivity is important to GES as it reflects the status of a functioning ecosystem.



**Figure 1.** Conceptual diagram showing Driver, Pressure, State, Impact divisions for D6 criteria and other descriptors to illustrate how GES in terms of sea floor integrity is maintained.

### 3 The DPSIR framework: how many indicators are needed?

The DPSIR framework (driver, pressure, state, impact, response) can provide clear, simple guidance in D6 considerations. Pressures exerted on the sea floor by anthropogenic activity, the state or sensitivity of the seafloor and its habitats, and resulting impact (Fig. 1). Given the nature of seafloor integrity, there may be large overlap and redundancy with other MSFD descriptors, criteria, and indicator sets. At present D6 "Seafloor integrity" is defined as a combined pressure and state descriptor with subordinate pressure and state criteria and indicators. Furthermore, some ambiguity exists about the relationship between benthic biodiversity and seafloor state and seabed habitat indicators included in different descriptors.

**Pressure** - Pressures are developed by driving forces, which are human activities, policies and environmental changes at regional scales. Inland activities such as agriculture and industries resulting in chemicals, nutrients or other pressures that are carried by river, have their initial inputs concentrated at river mouths and plume in the coastal waters. Activities occurring on the coast and inputting products or pressures directly into the sea are still clustered along the coastline as municipalities, industry sites, recreational centres, etc. Activities occurring in the sea are usually patchily distributed as well. Some marine activities are actually centred in nearshore or coastal areas, such as mariculture, recreation, mechanical energy, ports development, etc. All are also unevenly distributed along the coast on regional scales. Activities that occur offshore are also not evenly distributed in space; fishing, shipping, mining, hydrocarbon production etc are all concentrated in specific habitats, corridors, or sites. Consequently assessments of environmental status are almost always going to be done for areas that are a mosaic of different degrees and types of perturbations by human activities, making general statements of environmental quality difficult. Seafloor integrity can be affected by anthropogenic changes in the natural disturbance regime (size, frequency, and intensity) exerted. Thus D6 has many links to other, especially, eutrophication status (D5), alterations in hydrography (D7), concentration of contaminants (D8) which will need to be incorporated in the overall MSFD GES review process. However, one main goal of the MSFD is to develop proper policies (i.e. response) when GES of a particular descriptor or criterion is not achieved. The DPSIR framework is particularly relevant to this aim to which the overall GES assessment might provide incomplete information for policy development. Other pressures causing physical habitat loss and damage arise from activities such as bottom-trawling fisheries, waste dumping, coastal defence, ports and navigational dredging, and aggregate extraction.

**State** - the seafloor consists of habitats (biotic and abiotic) that support species with different niche requirements. These habitats are often embedded within larger landscapes that collectively represent a continuum of environmental gradients (e.g. oxygen, substrate, pH, depth, organic content), and many habitats may share a suite of common species. In addition to habitat heterogeneity, dispersal between habitats has the potential to influence patterns of marine diversity across multiple spatial and temporal scales. It is also a process that is especially important in response to disturbance and thus in maintaining seafloor integrity. The roles of environmental factors and spatial processes vary with changing scale considered. Depending on the region and habitat, useful state indicators can be the proportion of an area where benthic invertebrate biomass and/or production (P) are above a given percentage of pristine benthic biomass or production.

**Impact** - most impact indicators of human activities on the seafloor descriptors are expected to apply to biological attributes of the seafloor. Changes to the seafloor habitats can have a homogenizing effect (eutrophication, hazardous substances) favouring specific disturbance tolerant species that are able to disperse and colonize more areas. This can be detected by changes in the community structure (dominance). Changes in the connectivity can also change source-sink dynamics, and recovery potential of a disturbed site. Physical habitat loss can increase fragmentation of key habitats that can act as sources of recruitment. Ensuring seafloor integrity can minimize biodiversity loss (closely linked to D1). Depending on the region and habitat, useful state indicators can be

beta-diversity (either the degree of change in species composition along a gradient or the variation between point locations) within pre-defined areas.

### **Way forward – simple and clear**

Layers reflecting both system sensitivity (state) and cumulative pressures (pressures) should be used to determine the distance to GES for seafloor integrity (impact). It is thus recommended that GES for seafloor integrity has three steps.

1. Identify the ecological structures and functions of particular importance (e.g. natural variation in habitat/ environmental heterogeneity and the connectivity across the scales under consideration).
2. Identify the human pressures known or likely to reach levels that degrade environmental status (e.g. type of disturbances that impair the natural functioning).
3. For the ecosystem components and pressures 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. Assessments can start with specific attributes of the seafloor.

For D6 seafloor integrity to determine GES the following aspects should be taken into consideration:

- the intensity or severity of the impact at the specific site being affected;
- the spatial extent of the impact relative to the spatial extent of the habitat type affected;
- the sensitivity/vulnerability vs the resilience of the area to the impact;
- the ability of the area to recover from harm, and the rate of such recovery;
- the extent to which ecosystem functions may be altered by the impact; and
- where relevant, the timing and duration of the impact relative to the time when the area serves particular functions in the ecosystem (shelter, feeding, etc).

If assessments of GES are to address these aspects of seafloor integrity, then the assessments must use suites of indicators reflecting the component attributes of Seafloor Integrity on pages 6-8, and provide information on how the landscape of current status on the indicators coincides with or deviates from the landscape of the GES thresholds on those indicators.

### **General criteria for screening indicators:**

**Specific.** Indicators should respond to the properties they are intended to measure rather than to other factors, and/ or it should be possible to disentangle the effects of other factors from the observed impact.

**Sensitive.** Trends in the indicator should be sensitive to changes in the ecosystem properties or impacts, which the indicator is intended to measure.

**Responsive.** Indicators should be responsive to effective management action and provide rapid and reliable feedback on the consequences of management actions.

**Measurable.** Indicators should be measurable in practice and in theory. They should be measurable using existing instruments, monitoring programmes, and analytical tools available in the regions, and on the time-scales needed to support management. They should have minimum or known bias, and the signal should be distinguishable from noise.

**Cost-effective.** Indicators should be cost-effective because monitoring resources are limited. Monitoring should be allocated in ways that provide the greatest benefits to society and the fastest progress towards GES.

**Concrete.** Indicators which are directly observable and measurable rather than reflecting abstract properties which can only be estimated indirectly are desirable. This is because concrete indicators are more readily interpretable by the diverse stakeholder groups that contribute to management decision-making.

**Annex****Policy context****Linkages with existing relevant EU legal requirements, standards and limit values**

In the way it is articulated in the Directive, sea-floor integrity is a relatively new concept. However, it encompasses aspects of the physical attributes and functioning of seabed habitats and their communities which have a long history of scientific study and environmental assessment, e.g. in the Water Framework Directive (WFD) and Habitats Directives<sup>1</sup>. In general, as identified by JRC (In-Depth Assessment, 2014), the Habitat Directive and the Water Framework Directive do not explicitly define biodiversity. However both pieces of legislation aim to promote the maintenance of biodiversity, in this sense their requirements and specificities relevant to D6 are highlighted below.

Indeed, the overall concepts applied in the WFD and Habitats Directive of defining good status as target values relative to defined baselines are suitable for application for this biodiversity Descriptor. For e.g., the WFD reference conditions, ideally pristine conditions, are representing the values of the biological quality elements at 'high ecological status' (Directive 2000/60/EC). However the WFD allows a deviation from those reference conditions, i.e. the 'high ecological quality status', to a level equivalent to a 'good ecological quality status', where a certain amount of disturbance is accepted. The WFD, minimum acceptable quality level might therefore be linked to the MSFD 'good environmental status'<sup>2</sup>.

**The Water Framework Directive (2000/60/EC)**

In the marine environment, 'coastal waters' covered by the Water Framework Directive (WFD) are also within the scope of the MSFD. The WFD aims to achieve 'good ecological status', which is assessed at the 'water body' scale. The WFD does not explicitly mention biodiversity, but requires the assessment of taxonomic composition of phytoplankton, macrophytes and zoobenthos and their abundance/biomass as indicators of ecological status. For some of the current COM Dec. D6 criteria there is a great overlap with requirements of the WFD, namely for Criterion 6.2 'Condition of the benthic community'. In this sense, many of the assessment tools in place to address WFD could be adopted within the MSFD<sup>3</sup>. Thus, in overlapping areas (i.e. 'coastal areas'), the MS should consider the existing WFD assessments to address equivalent features defined under the MSFD D6. In those cases, it should be ensured that the WFD normative definition for 'good ecological quality status' are in line with what Article 8 GES definition states.

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1 Commission Staff Working Document on the first steps in the implementation of the MSFD - Assessment in accordance with Article 12, 2014.

2 Figures on pages 31 and 36 of the 'Common Understanding of (Initial) Assessment, Determination of Good Environmental Status (GES) & Establishment of Environmental Targets (Articles 8, 9 & 10 MSFD)'. [https://circabc.europa.eu/d/a/workspace/SpacesStore/8af253a4-75d7-454c-8e7d-1354b793bcd9/2014-06-02\\_V2\\_Draft\\_Revision\\_CU\\_tracked\\_changes.pdf](https://circabc.europa.eu/d/a/workspace/SpacesStore/8af253a4-75d7-454c-8e7d-1354b793bcd9/2014-06-02_V2_Draft_Revision_CU_tracked_changes.pdf)

3 Teixeira et al., 2014. Existing biodiversity, non-indigenous species, food-web and seafloor integrity GEnS indicators. Deliverable 3.1 DEVOTES FP7 Project. JRC89170. Available at [http://www.devotes-project.eu/wp-content/uploads/2014/02/D3-1\\_Existing-biodiversity-indicators.pdf](http://www.devotes-project.eu/wp-content/uploads/2014/02/D3-1_Existing-biodiversity-indicators.pdf)

### **The Habitats Directive (92/43/EEC)**

This Directive requires that EU MS take measures to ensure that the species and habitats “of community interest” listed in its annexes are protected so as to be in “favourable conservation status” (FCS). It specifically establishes the network of Special Areas of Conservation (SACs), known as Natura 2000, as an EU-wide network of nature protection areas, including marine areas, as a means to achieving FCS for the listed species and habitats.

In the network each site contributes to the attainment of FCS but this objective is to be attained at the scale of the natural range of species or habitat type. The site level conservation objectives are set upon identification of the contribution of the particular site to the Member States’ achievement of FCS for the habitats and species present on the site. Site objectives should be established for SACs under the Habitats Directive and also for special protected areas (SPAs) under the Birds Directive. The conservation objectives at the site level must take in consideration the elements laid out in the COM Note on establishing conservation objectives for the Natura 2000 sites (23/11/2012), among which is the need to consider the subsequent spatial scaling-up of the assessments, of relevance for D6. Assessment of whether a species or habitat is in FCS is based on specified criteria with threshold values<sup>4</sup>, with failure of any one criterion giving a ‘below-FCS’ outcome (one-out-all-out principle). MS are required to report on the measures taken and their impact on the conservation status of concerned habitats and species every six years.

### **Linkages to Regional Sea Conventions (RSCs)**

In its In-depth Assessment (2014), JRC states that: “There is very low integration between D6 and RSC and this shows a gap in the development of agreed methods for the implementation of D6 on regional level”.

**HELCOM** in the CORESET II project national experts are nominated as Task Managers to single indicators, for example, relating to biodiversity and seabed habitats (including associated communities). Within this on-going process the project has developed a suite of indicators which will form the core of the commonly agreed indicators among the HELCOM Contracting Parties. CORESET II also allows for development of pre-core and candidate indicators relevant for D6. Both state- and pressure-indicators are under development, and the work will build on relevant previous HELCOM products such as the reports from the HELCOM Red List project where a biotope classification was developed and threatened biotopes were identified. In the HELCOM Red List projects, an attempt has also been made to create a hierarchical classification scheme with numeric split rules, to also provide the classification as a tool for mapping and modelling purposes.

The **OSPAR** Ecological Quality Objectives for threatened and/or declining habitats (EcoQOs) identifies a series of seabed habitats and associated communities which are threatened and/or declining and can contribute to the

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<sup>4</sup> Annex C and E of the following report:  
[http://www.bfn.de/fileadmin/MDB/documents/themen/monitoring/Art\\_17\\_Reporting\\_Formats.pdf](http://www.bfn.de/fileadmin/MDB/documents/themen/monitoring/Art_17_Reporting_Formats.pdf)

implementation of D6 of the MSFD. The OSPAR List of Threatened and/or Declining Species and Habitats was adopted in 2004, further updated in 2008 (Agreement 2008-6), and now includes 16 habitat types. Development of a set of common biodiversity indicators by OSPAR includes a number related to assessing seabed habitat quality and one assessing the spatial extent of damage from human activities. Six indicators pertaining D6 are included in the OSPAR list of common indicators: BH1 Typical species composition, BH2 Multi-metric indices, BH3 Physical damage of predominant and special habitats, BH4 Area of habitat loss, BH5 Size-frequency distribution of bivalve or other sensitive/indicator species, PH1 Changes of plankton functional types (life form) index ratio. They encompass several biodiversity components, from Phytoplankton, Zooplankton, Angiosperms, Macroalgae to Benthic invertebrates. Not all of these indicators are yet operational, though.

The **Black Sea** and **Barcelona Conventions** have respectively not agreed or have just started a process to agree on indicators but these are not yet operational.

The **Barcelona Convention** Ecosystem Approach (EcAp), adopted by this RSC Contracting parties, will gradually implement the ecosystem approach to the management of human activities in the Mediterranean, aiming to attain “A healthy Mediterranean with marine and coastal ecosystems that are productive and biologically diverse for the benefit of present and future generations” by May 2015. Indicators and monitoring programmes to support the 11 Ecological Objectives (EOs) of EcAp, including biodiversity objectives similar to those of MSFD, are currently being developed. A list of habitats and species has been proposed (not public yet) for priority monitoring and assessment in relation to EOs 1 (equivalent to MSFD D1). These are likely to influence also monitoring priorities under D6, since this RSC is trying to establish some compromise between EU MS MSFD minimum obligations and the objectives of non-EU contracting parties. Biodiversity descriptors, EOs 6 included, will also be discussed considering EOs3 (i.e., MSFD D3) in order to address links between fisheries and biodiversity monitoring needs.