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Task Group 5 Report

Eutrophication

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PREFACE

The Marine Strategy Framework Directive (2008/56/EC) (MSFD) requires that the European Commission (by 15 July 2010) should lay down criteria and methodological standards to allow consistency in approach in evaluating the extent to which Good Environmental Status (GES) is being achieved. ICES and JRC were contracted to provide scientific support for the Commission in meeting this obligation.

A total of 10 reports have been prepared relating to the descriptors of GES listed in Annex I of the Directive. Eight reports have been prepared by groups of independent experts coordinated by JRC and ICES in response to this contract. In addition, reports for two descriptors (Contaminants in fish and other seafood and Marine Litter) were written by expert groups coordinated by DG SANCO and IFREMER respectively.

A Task Group was established for each of the qualitative Descriptors. Each Task Group consisted of selected experts providing experience related to the four marine regions (the Baltic Sea, the North-east Atlantic, the Mediterranean Sea and the Black Sea) and an appropriate scope of relevant scientific expertise. Observers from the Regional Seas Conventions were also invited to each Task Group to help ensure the inclusion of relevant work by those Conventions. A Management Group consisting of the Chairs of the Task Groups including those from DG SANCO and IFREMER and a Steering Group from JRC and ICES joined by those in the JRC responsible for the technical/scientific work for the Task Groups coordinated by JRC, coordinated the work. The conclusions in the reports of the Task Groups and Management Group are not necessarily those of the coordinating organisations.

Readers of this report are urged to also read the report of the above mentioned Management Group since it provides the proper context for the individual Task Group reports as well as a discussion of a number of important overarching issues.

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Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

2. Definition of terms in Descriptor and understanding of the key concepts

Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of nutrients causing changes to the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services. These changes may occur due to natural processes; management concern begins when they are attributed to anthropogenic sources. Additionally, although these shifts may not be harmful in themselves, the main worry concerns 'undesirable disturbance': the potential effects of increased production, and changes of the balance of organisms on ecosystem structure and function and on ecosystem goods and services.
TG5 arrived at the following definition as the basis for interpreting the MSFD descriptor:

Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.

3. What is "Good Environmental Status" of the descriptor?

GES with regard to eutrophication has been achieved when the biological community remains well-balanced and retains all necessary functions in the absence of undesirable disturbance associated with eutrophication (e.g. excessive algal blooms, low dissolved oxygen, declines in seagrasses, kills of benthic organisms and/or fish) and/or where there are no nutrient-related impacts on sustainable use of ecosystem goods and services.

4. How should "scale" be addressed with the Descriptor?

Due to the wide extent of eutrophic zones in some places, the sampling effort at sea necessary to assess algal biomass with reliability/confidence will increase in some countries relatively to WFD needs. Systematic use of additional tools such as remote sensing of surface chlorophyll, ferry boxes, and smart buoys is recommended.

Further breakdown into sub-units is expected. These smallest divisions should be defined according to oceanographic characteristics aiming for spatially homogeneous areas.
Eutrophication indices must consider temporally appropriate datasets, which may:
(i) favour seasonal datasets (e.g. the productive period, and/or winter nutrients), or
(ii) an annual cycle, which may be more adequate for marine areas with a less well defined seasonality.
In order to detect acute effects, which often pose serious threats to the ecosystem, monitoring and modelling must be temporally adjusted to rapidly developing events, such as the sudden and sharp peaks of oxygen depletion in bottom waters or harmful algal blooms. Numerical models that integrate data assimilation may provide short-term predictive capacity for such events, which are by nature unpredictable on a longer time scale.

5. Key Attributes of the Descriptor

a. Description of attribute and why it is important

Attribute	Why it is important
Water clarity	Related to phytoplankton biomass and important for growth of benthic plants
Primary production	Associated with the loading of nutrients to marine waters
Organic decomposition	Registers fate of ungrazed production and potential for oxygen consumption. Potentially leads to oxygen depletion (hypoxia/anoxia)
Algal community structure	Reflects the ecological balance of primary producers. Undesirable shifts in balance can include the appearance of harmful algal blooms (HAB)

b. Criteria: characteristics of the attribute with respect to GES and degradation gradient(s)

- Compliant with GES target conditions (all)
- Decreased water clarity
- Increased primary production
- Increased organic decomposition
- Undesirable changes in algal community structure

c. What are the pressures that act upon the attribute

Nutrient loads, especially nitrogen and phosphorus. Physical processes (i.e. climate, upwelling, ocean circulation and currents, water column stratification) may act to modify the response to nutrients.
Nutrient sources and loads should be included so that loads can be associated with impairment and successful management measures can be developed.

d. What are the indicators or classes of indicators that cover the properties of the attribute and linkages to the pressures?

Indicator class	Indicator[1]	Linkage to pressure increase
Physico-chemical	Nutrient load	Increase
	Nutrient concentration	Increase
	Nutrient ratios (Si:N:P)	Deviate from normal proportions (e.g. Si is reduced in relation to other nutrients)
	Water transparency	Decrease due to increase in suspended algae
	Dissolved oxygen	Decrease due to increased organic decomposition
Biological	Chlorophyll	Increase due to increased nutrient availability
	Opportunistic macroalgae	Increase (e.g. can form blankets over the natural flora and suffocate benthic animals)
	Floristic composition	Species shifts (e.g. diatom: flagellate ratio, benthic to pelagic shifts, indicator species, HAB)
	Perennial seaweeds and seagrasses	Decrease (e.g. fucoids and wracks, eelgrass and Neptune grass, that are adversely impacted by decreases in water transparency

[1]Not all indicators in this list may be relevant in particular systems/regions.

6. How are the indicators aggregated to assess GES for the descriptor?

The question of aggregation was discussed at two levels: (i) the integration of different indicators into attributes for the descriptor; and (ii) A range of tools was reviewed. No specific method (i.e. tool) is recommended to be used for GES, but those used must be robust, integrated, sufficiently sensitive, comparable, and with recognized scientific merit.

7. Emergent messages about monitoring and research and final Synthesis

Monitoring

Monitoring is addressed under Art. 5 of the MSFD, in the context of the elaboration of the Initial Assessment. Its main objective is to characterize present state and trends as well as to identify the environmental impact of human activities as possible causes for observed environmental impairments. The design of Monitoring Programmes must take into account scientific questions and policy/management issues.

The General Guidelines to develop Monitoring Programmes include the definition of spatial domain and location of sampling stations, the frequency and timing for measurements, and the list of variables and sampling methodology. Consideration shall also be given to those pressures and impacts relevant for Human Induced Eutrophication. An inventory of national programmes, assessment of available methodological standards and definition of associated requirements must be carried out.

The monitoring of open waters at stations well offshore requires the use of methodologies of ocean observation systems, including satellite remote sensing. The measured data may provide ocean boundary conditions for the WFD coastal area, and help establish the cause of violation of quality thresholds for some indicators.

Member States must determine to what extent data needs are covered by national monitoring programmes, and what aspects of the descriptor are not or are poorly covered. The framework for a monitoring program should also be guided by existing programs, such as the OSPAR Comprehensive Procedure. On this basis it will be possible to optimize existing monitoring information, and identify where improvements may be made through targeted and focused additional monitoring.

On an EU level, the importance of infrastructure improvements is highlighted, in order to provide long-term datasets and information to help avoid misdiagnosis of new events/changes, improve interpretation of trends, and facilitate development of management measures.

Quality Assurance guidelines for the descriptor are an essential requirement for successful monitoring, allowing for appropriate intercalibration and comparative assessment.

Research

Coupled atmosphere-river-coastal sea models need to be developed at the regional scale for the estimate of critical nutrient loads from terrestrial sources, in relation to transitional/ coastal retention, and chemical and biological target indicators (Cat. I); natural background nutrient enrichment (e.g. import by upwelling; import from pristine/ good status rivers) for determination of unimpacted state and separation of naturally productive status from anthropogenically eutrophic status; climate change impacts on availability and transformation of nutrients and organic matter from land to the sea.

Nutrient regulation for algal biomass production; selection of dominant species, functional groups, and community structure, nutrient competition and needs (nutrient stoichiometry);

Impact of top-down (e.g. shellfish filtration, zooplankton grazing) control, grazing-resistant species, and other food-web interactions (viral infections, parasitism…) on fate/ sinks of algal biomass and transmitted/ amplified effects; regulation of harmful algal blooms (HABs); the link to land-based inputs is not always well established: blooms may be linked to upwelling relaxation events, cyst formation etc; research is needed to categorize to what extent events are manageable; Setting the GES targets (with safety margins) for algal production/ biomass ensuring none or minor undesired secondary effects on zoobenthic or fish communities;

Research on factors that govern the occurrence and extension of hypoxic/ anoxic sediment surface: there is a need to distinguish between natural range and increase of spatial extension of anoxic sediments due to anthropogenic organic loading; ecoregion and/ or habitat-specific relationships between the indicators/ parameters and proxies for nutrient loading pressures; identification of critical nutrient loading thresholds beyond which the whole system is changing into an alternative steady state; recovery pathways and the outcome of the restoration.

Development of phytoplankton assessment tools that account for shifts in species composition and frequency of blooms in the scoring; Development of monitoring tools that account for rapid changes in algal communities, allowing detection of bloom peaks (continuous measurements, ships-of-opportunity, remote sensing tools, algorithm development, real-time monitoring, etc.).

1. Introduction

Eutrophication in marine waters has been a management concern in Europe for the last decades. This has resulted in action taken by the contracting parties of OSPAR, HELCOM, Barcelona (MEDPOL) and other international conventions, and in a body of legislation enacted by the European Union, ranging from directives such as the Urban Wastewater Treatment Directive (UWWTD) to the more recent, and far more comprehensive Water Framework Directive (WFD), and the Marine Strategy Framework Directive (MSFD).

As a result of this concern, important steps have been taken over the past thirty years to understand, assess and combat marine eutrophication:

(i) Systematic collection of datasets for European regional seas, in order to allow for a robust assessment of state and detection of trends;
(ii) Development and testing of assessment methods focusing on the particular conditions that exist in marine systems;
(iii) Building of numerical models to relate nutrient loading, physical processes and biogeochemical cycles to state (eutrophication status), thus providing decision-makers with appropriate tools to test the outcome of management options;
(iv) Implementation of management measures which include the reduction in nutrient loading to coastal waters.

The starting point for the work of TG5 is the guidance already developed for the WFD, in particular (i) the CIS WG2.4 (COAST) report on typology, classification, and reference conditions for transitional and coastal waters published in 2003, and (ii) the Guidance Document on Eutrophication Assessment (Eutrophication assessment in the context of European water policies) published in 2009. The EEA-EMMA work on the 'Indicator Comparison process' was also reviewed.

Table 1 highlights some general features of the MSFD vis-à-vis the WFD and other legislative instruments.

Table 1. Some key features of the MSFD

MSFD requirement	Notes
Marine waters: from the seaward side of the baseline from which territorial waters are measured to the outmost reach of MS jurisdiction	Much larger area and volume than the WFD (depth increases offshore, often significantly e.g. the west Iberian coast or the Adriatic)
Ecosystem-based approach to management of human activities, enabling a sustainable use of ecosystem goods and services	Again, focused on the ecological component, using the chemical criteria only for support
Exceptions: natural causes/force majeure (e.g. HAB Western Iberia) and transboundary problems (Baltic, southern North Sea...)	Recognises that some quality issues are due to natural causes and therefore not manageable in the sense of resolving them
No explicit typology like WFD, but MS should define Good threshold by marine regions/subregions. Only two classes (Environmental Status)	Recognises that the WFD system with five quality classes is challenging re: meaningful type-specific thresholds, and that the focus on two classes is a more practical approach. However, progress in the insufficient class cannot be demonstrated to managers and public by one class alone.
Biological diversity is maintained Population distribution = healthy stock Balanced marine food webs Human-induced eutrophication	All these points are horizontal with respect to the TG5 descriptor, i.e. eutrophication

The document presented in the following pages is designed to provide guidance for the interpretation and application of the *Eutrophication Quality Descriptor (QD5)*, one of eleven quality descriptors required for evaluation of Good Environmental Status (GES) in the Marine Strategy Framework Directive.

QD5, addressed by Task Group 5 (see Annex II), is defined as follows:

QD5: Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

2. Initial interpretation of the descriptor

In its original use and etymology, 'eutrophic' meant 'good nourishment', and eutrophication meant the process by which water bodies grew more productive. By the end of the 20th Century, however, the terms had acquired a scientific and legal meaning enshrined in several European Directives, a decision by the European Court of Justice in 2004, and OSPAR's 1998 definition that:

" 'Eutrophication'' means the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned, and therefore refers to the undesirable effects resulting from anthropogenic enrichment by nutrients ... ."

Starting from this, and taking account of recent developments in the scientific understanding of eutrophication, TG5 arrived at the following definition (see notes in

Table 6 in annex) as the basis for interpreting the MSFD descriptor:

Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.

Nutrients naturally present in the sea include compounds of silicon (Si) as well as those of nitrogen (N) and phosphorus (P). Concentrations of the main nutrients vary seasonally, as a result of natural processes in the sea. Eutrophication is the result of import-driven enrichment of the 'pristine' seasonal cycle, increasing the stock of nutrient- nitrogen and/or phosphorus in a water body and thus allowing a greater annual primary production of organic material and a greater standing stock of algae.

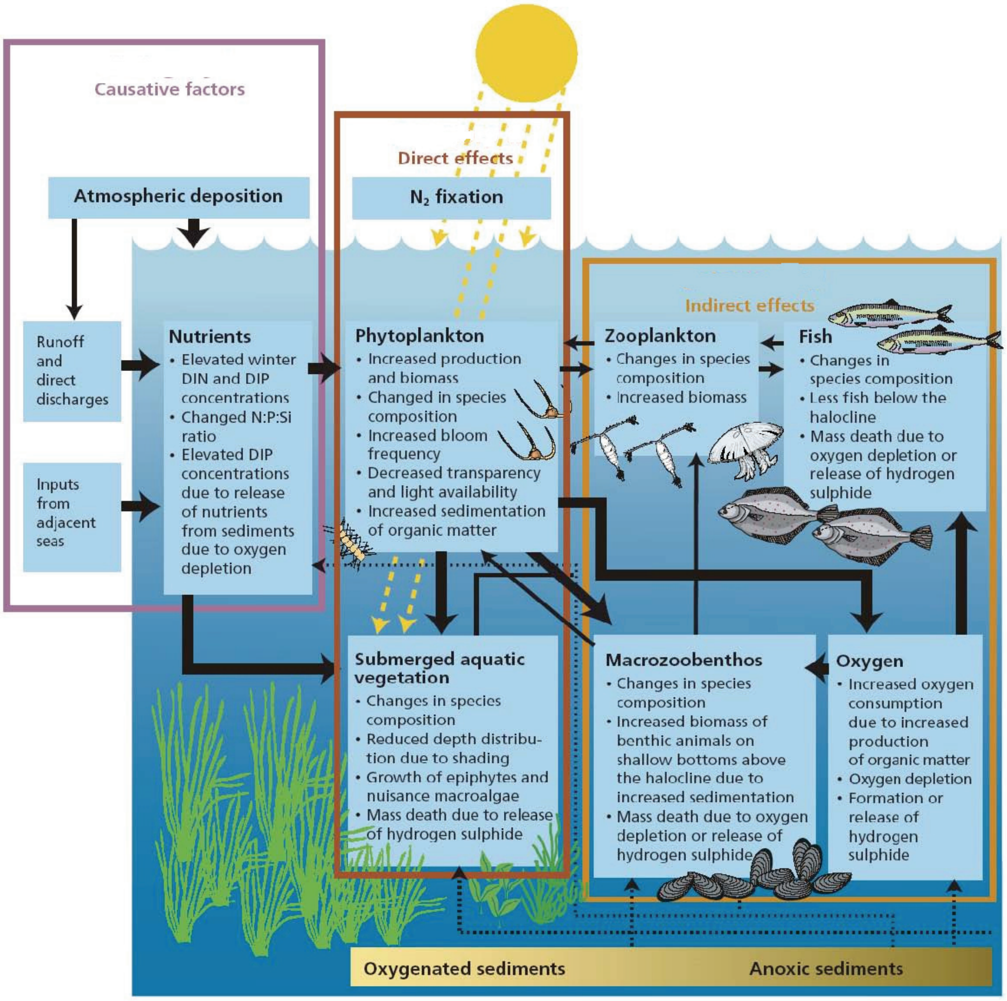

Figure 1. Conceptual model of eutrophication. The arrows indicate the interactions between different ecological compartments. A balanced marine ecosystem is characterised by: (1) a pelagic food chain (phytoplankton ►zooplankton/zoobenthos ►fish), which effectively couples production to consumption and minimises the potential for excess decomposition (2) natural species composition of plankton and benthic organisms, and (3) if appropriate, a natural distribution of submerged aquatic vegetation. Nutrient enrichment results in changes in the structure and function of marine ecosystems, as indicated with bold lines. Dashed lines indicate the release of hydrogen sulphide (H_2S) and phosphorus, under anoxic conditions at the sediment-water interface, which is positively related to oxygen depletion. In addition, nitrogen is eliminated by denitrification in anoxic sediment.

This enrichment can occur naturally (see Table 6 in annex). Management concern should focus on the extent to which anthropogenic nutrients may cause increases in primary production, and/or changes in N:P:Si ratios that shift the balance of primary producers from silicon-requiring diatoms towards non-siliceous algae[1].

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[1] In this context, algae include cyanobacteria.

Because these shifts may not be harmful in themselves, the main worry concerns 'undesirable disturbance': the potential effects of the increased production, and the direct and indirect changes in the balance of organisms, on ecosystem structure and function and on the ecosystem goods and services used by humans. However, such effects do not always follow from nutrient enrichment, and can result from other causes, including climate change, the removal of top predators by fishing, enrichment by allochthonous organic matter, and contamination by harmful substances. A final cause for concern is that these pressures may combine to produce larger effects. Thus, it is important that MSFD descriptors not be considered in isolation.

*QD*5 refers to the adverse effects of eutrophication as including *"losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters." (Figure 1)*

Oxygen deficiency can result from the sinking and decomposition of the excess organic matter produced as a result of eutrophication. It can also come about from other causes, including discharges of allochthonous organics and from decreases in the ventilation of deep water caused for example by climate change. Ecosystem degradation is understood by TG5 as undesirable disturbance to the structure, vigour in function, resistance to change and resilience in recovery, of ecosystems, i.e. to ecosystem health. Because food webs provide part of ecosystem structure, and trophic exchange contributes to ecosystem vigour, there is, clearly, an overlap with *QD4 concerning marine food webs.* Damage to ecosystem structure can include loss of biodiversity, and changes in the '"balance of organisms" certainly implies a shift in relative abundances of species' populations. Thus there is an overlap with *QD1 concerning biological diversity.*

Harmful algal bloom (HAB) is a broad term that embraces many phenomena. We will distinguish three types of harmful bloom: (i) those due to toxic algae (e.g. *Alexandrium*, *Dinophysis* and *Pseudonitzschia*) which can poison shellfish even at low algal abundance; (ii) potentially toxic algae (e.g. *Pseudonitzschia*); and (iii) high-biomass blooms (e.g. *Karenia, Phaeocystis*, *Noctiluca*) that cause problems mainly because of the high biomass itself. High-biomass blooms are sometimes called "red tides" but may in fact be brown, green or white discolourations of the sea. Some organisms (e.g. *Alexandrium*) occur in more than one category. Links between HABs and nutrient enrichment have been much debated. HABs should be treated as part of the undesirable consequences of eutrophication only if their frequency or amplitude increases in correspondence with increased nutrient input. By way of algal toxins, there is an overlap with *QD (9) concerning contaminants in fish and other seafood.*

3. Review of scientific literature and existing methods

There is extensive literature on the use of phytoplankton as an indicator of eutrophication in inshore and offshore waters. All methods include Chlorophyll *a* (Chl a) as an indicator of phytoplankton biomass though the metrics are different (Table 2). There are several ways of determining the status of Chl a dependent upon the timeframe and spatial scales of sampling, the statistical measure used to determine the representative concentration (e.g. mean annual, index period mean and/or maximum), and the reference concentration or condition (RC) and scale that determines the final status. Some methods use only water column measures (i.e. Chlorophyll *a* (Chl a), dissolved oxygen and nutrients; e.g. TRIX, EPA NCA), while others combine additional indicators such as occurrence of Harmful Algal Blooms (HAB), macroalgal abundance and changes in seagrass distribution. Additionally, some methods use combinations of concentration only (e.g. TRIX, EPA NCA) while others include the duration and spatial coverage of bloom concentrations (e.g. ASSETS), or weighting factors that represent the relative contribution to overall water quality (e.g. TWQI/LWQI; see Table 4).

While all the Chl a indices (Table 2) are included in a multi-parameter index, TRIX is the only one for which the Chl a indicator cannot stand alone since it is integrated with three other variables that make up the index (Table 2). The EPA uses comparison of samples from an annual index period (June through September) to the RC determined from national studies (poor >20 µg l^{-1}, fair 5-20 µg l^{-1}, good 0-5 µg l^{-1}) to determine the rating. The samples are taken one time per year based on a random statistical design and provide 90% confidence in the rating for a region.

The TWQI/LWQI method uses non-linear functions to transform annual average Chl a concentrations from sites representative of the system into a Quality Value (QV 0 = worst, 100 = best) which is then multiplied by a weighting factor (here, 15% of total water quality is attributed to Chl a) that accounts for the relative contribution to the overall index. The Chl a QV scores range from optimal conditions (6 µgl^{-1}, for a QV of 100), to a low QV (0 at concentration of 30 µg l^{-1} or greater).

Table 2. Methods of eutrophication assessment, and examples of biological and physico-chemical indicators used, and integration capabilities (pressure-state, and overall)

Method Name	Biological indicators	Physico-chemical indicators	Nutrient load related to impairments	Integrated final rating
TRIX	Chl	DO, DIN, TP	no	yes
EPA NCA Water Quality Index	Chl	Water clarity, DO, DIN, DIP	no	yes
ASSETS	Chl, macroalgae, seagrass, HAB	DO	yes	yes
LWQI/TWQI	Chl, macroalgae, seagrass	DO, DIN, DIP	no	yes
OSPAR COMPP	Chl, macroalgae, seagrass, phytoplankton indicator species	DO, TP, TN, DIN, DIP	yes	yes
WFD	Phytoplankton, Chl, macroalgae, benthic invertebrates, seagrass,	DO, TP, TN, DIN, DIP, water clarity	no	yes
HEAT	Chl, primary production, seagrass, benthic invertebrates, HAB, macroalgae	DIN, DIP, TN, TP, DO, C, water clarity	no	yes
IFREMER	Chl, seagrass, macrobenthos, HAB	DO water clarity, SRP, TP, TN, DIN, sediment organic matter, sediment TN, TP	no	yes
STI	Chl, Primary Production	DIN, DIP	no	no

HEAT uses summertime or annual mean concentrations of samples that are spatially representative of a water body combined with RCs, determined from historical data, empirical modelling or ecological modelling for pristine conditions. The boundary for good/moderate status is the RC +50% which is equal to an Ecological Quality Ratio (EQR) of 0.67.

ASSETS uses the 90^{th} percentile of annual values for Chl a combined with the spatial coverage of high values and the frequency of occurrence of blooms to determine the Chl a condition within each salinity zone (Tidal Fresh 0-0.5 psu, Mixing Zone 0.5-25 psu, Seawater Zone >25 psu) in a system. The 90^{th} percentile Chl concentration is compared to the RC (see EPA values mentioned above). Spatial coverage can be high (>50%), moderate (25-50%), low (10-25%) or very low (< 10%) corresponding to the water body area over which high concentrations are observed. Frequency of occurrence is periodic, persistent or episodic. The ratings are area-weighted to determine the final Chl a rating for the system.

The Statistical Trophic Index (STI) assesses the trophic status of sea water using data of the two major phytoplanktonic measures: chlorophyll a and primary production. The data are determined seasonally and their levels are scaled statistically by the analysis of probabilistic parameters. This analysis estimates the limits of average concentrations in the relationship eutrophic>mesotrophic>oligotrophic for chlorophyll a, primary production, and physico-chemical parameters by defining thresholds among inshore, offshore, and open ocean waters. It has been used for the estimation of the eutrophication status of the Aegean Sea, Eastern Mediterranean.

The Chl a assessment under WFD guidance and OSPAR are similar, they both use mean summertime/ growing season concentrations for samples that are spatially representative of the water body, and OSPAR also uses the maximum Chl a concentration.

In the setting of the classification boundaries for WFD assessment, both 90th percentile of the chlorophyll a concentrations (NE Atlantic coast and Mediterranean) and the mean of Chl a for the vegetative growth period (May-September; Baltic Sea) were used as indicators of phytoplantkon biomass. WFD assessment requires determination of RC's for establishment of the EQR-values. The WFD classification results in ratings of high, good, moderate, poor, and bad for which thresholds between high-good and good-moderate were developed during WFD intercalibration exercises.

The IFREMER method compares 90th percentile annual or seasonal data to a fixed scale to determine status for Chl a. The thresholds and ranges used, determined from studies such as those of the Organization for Economic Cooperation and Development, are consistent with the scales reported for TWQI/LWQI , EPA and ASSETS (Annex 2: Table 9).

To provide a complete picture of eutrophic conditions, other characteristics should be included in addition to Chl a, such as changes in community composition, occurrence of nuisance and toxic species that result from changes in nutrient ratios, and increased duration and frequency of blooms which result from increases in nutrient loads (Annex 2: Table 8). For example, OSPAR monitors for phytoplankton indicator species by looking at changes in specific groups (e.g. dinoflagellates, diatoms). The ASSETS nuisance and toxic bloom index uses a combination of observations of nuisance and toxic blooms and the frequency and duration of the blooms to determine the status.

4. Relevant spatial/temporal scales for the descriptor

4.1 Spatial scale

4.1.1. The effect of increasing the loading of nutrients

The first factor promoting eutrophication is nutrient enrichment. This explains why the main eutrophic areas are to be found primarily not far from the coast, mainly in areas receiving heavy nutrient loadings. However, some natural symptoms of eutrophication can also be found in upwelling areas.

An increase in the amount of nutrients in coastal areas leads to increased phytoplankton biomass during the spring bloom, but also to the emergence of additional episodic blooms during summer and autumn. For Europe and adjacent seas, the primary production map computed in summer from satellite data shows the very heterogeneous distribution of highly productive areas along the European shores: while the whole shallow south and eastern North Sea, as well as a significant part of the Baltic Sea, and the Black Sea are highly productive, the Atlantic and Mediterranean shores exhibit only a strip of high production along the coast. No extensively eutrophic area seems to be noticeable in the Mediterranean area, except the north-western Adriatic Sea. It should, however, be noted that current algorithms for processing remotely sensed sea colour may overestimate chlorophyll in waters (e.g. the Baltic) containing much coloured dissolved organic matter or much suspended sediment (e.g. the North Sea). Improved algorithms are being developed.

The EUTRISK index developed by the EU-JRC shows where there is a risk of eutrophication during the summer. Extensive areas at risk include Baltic coastal waters except the northernmost areas, the Kattegat and coastal water in the Skagerrak, the central and southern North Sea and the coastal waters west of Jutland, the Azov Sea and western coastal belt of the Black Sea, the Northern Adriatic Sea, and the northern French coast of the Bay of Biscay. In the case of the Baltic Sea, these areas largely correspond to those identified by the HELCOM thematic assessment as 'eutrophic'. In the case of north-western European waters, they largely correspond to those identified by the OSPAR comprehensive procedure as 'problem areas'.

4.1.2. The role of bathymetry and hydrodynamics

Additionally, the risk of eutrophication is linked to the capacity of the marine environment to confine growing algae in the well-lighted surface layer. The geographical extent of potentially eutrophic waters along European coasts may vary widely, depending on:

(i) the extent of shallow areas, i.e. with depth ≤ 20 m;

(ii) the extent of stratified river plumes, which can create a shallow surface layer separated by a halocline from the bottom layer, whatever its depth. The potential for eutrophication is high where nutrients are introduced into the superficial layers of semi-enclosed water bodies (e.g. fjords, rias) that have long periods of water column stratification due to river discharge and/or the deep intrusion of dense coastal water. The risk increases with increasing water residence time;

(iii) extended water residence times in enclosed seas leading to blooms triggered to a large degree by internal and external nutrient pools; and

(iv) upwelling phenomena leading to autochthonous nutrient supply and high nutrient concentrations from deep water nutrient pools, which can be of natural or human origin.

A good example of combining features (i) and (ii) is provided by the southern and eastern part of the North Sea: this shallow (<50 m deep) and tidally mixed region receives, in a cumulative way from SW to NE, the majority of the riverine nutrient loads to the North Sea (Seine, Thames, Scheldt, Rhine, Ems, Weser, Elbe).

4.2. Temporal scale: the effect of changing the nutrient balance

Except in permanently stratified, deep areas, such as the central Baltic Sea, the acute quantitative symptom of eutrophication, i.e. severe hypoxia, is a seasonal feature, which occurs only after strong primary production episodes, mainly in late spring and in summer, when calm weather and seasonal formation of a pycnocline prevent the atmospheric oxygen from being brought to deep water layers.

At the qualitative level, eutrophication may alter the natural succession of species during the year. The terrestrial waterborne loadings on the European coastal shelf have varied during the last century in a nearly independent way for the three main nutrients N, P and Si. Whereas Si remained quasi-constant or slightly declined due to partial trapping by settling freshwater diatoms upstream of dams, P increased until the 1990's, and then decreased due to the polyphosphate ban in detergents and phosphate removal in sewage plants; N increased continuously during the second half of the 20th century, but began to slightly decrease during the last decade due to European legislation. Changing the N/P/Si balance has induced some shifts in the phytoplanktonic flora, both in the abundance of diatoms relative to other groups, and in the relative importance of (regional) indicator species.

In the Greater North Sea, for instance, undesirable blooms of two haptophytes have been recorded. *Phaeocystis globosa*, which forms spherical colonies with foam as by-product, invades the coastal strip off France, Belgium, the Netherlands and Germany every spring (April-May). The toxin-producer *Chrysochromulina spp.*, which blooms between April and August in the Kattegat and Skagerrak, was responsible in May-June 1988 for an extensive episode of toxicity decimating farmed fish. These haptophytes are known to follow the classical early-spring diatom bloom when a remaining excess of nitrate allows their rapid growth, even if phosphate conditions are low, because both species are able to use organic forms of phosphorus. In the Baltic, the decrease of Si levels and concurrent increase of nitrogen and phosphorus inputs have lead to a flagellate-dominance in some areas of the Baltic and an elevated production and sedimentation. A similar situation was observed in the NW Black Sea in the mid 1970s where the nearly simultaneous increase of N and P and decrease in Si led to the dominance of *Prorocentrum Cordatum* over diatoms. In the Black Sea, the N:P:Si imbalance was however exacerbated by Si retention in reservoirs in the Danube. Presently, however, all three nutrients have decreased for different reasons allowing a better balance in Si:N:P stoichiometry.

Along the Atlantic and English Channel coasts, several harmful species of phytoplankton have been recorded, producing diseases in human consumers of shellfish. Some of them are dinoflagellates, and may have been triggered by summer excess nutrient in the coastal plumes.

In the Baltic Sea, the increased magnitude and frequency of cyanobacterial blooms (including toxic species like *Nodularia spumigena*) has been related to increased nutrient levels (both N and P) during the last decades. Elevated nutrient inputs, maintaining increased phytoplankton spring bloom production and sedimentation, leading to an extension of anoxic bottoms and triggering regeneration of P from sediments, are maintaining a vicious circle where external nutrient loading (both N and P) enhances the occurrence of cyanobacterial blooms in the Baltic.

The coastal waters of the western Aegean Sea (E. Mediterranean) have not been prone to seasonal blooms of the invader species *Alexandrium minutum* because the local nutritional status did not support its N:P ratio requirements and the phytoplankton communities were dominated by diatoms that were strong competitors of this species.

4.3. Policy scales

As a result of the WFD, EU Member States have delineated coastal water bodies. In most cases, the ”one nautical mile from baseline” rule missed the largest part of wide eutrophic plumes. Turbidity near the coast and in transitional waters is often too high to allow strong primary production, whereas enriched surface waters more offshore can host very productive communities when suspended inorganic particles have settled.

Presently, as the “ecological status” has to be monitored on the whole shelf, there are a few huge areas where a MSFD eutrophication assessment must clearly delineate the areas potentially subject to detrimental effects. Furthermore, Good Environmental Status (GES) has to be set for these areas based on eutrophication parameters that will be part of the monitoring programmes. Such areal delineation should be based on oceanographic characteristics, such as the Physically Sensitive Area (PSA), the EUTRISK indices developed by the JRC, and the subdivision used by HELCOM and OSPAR.

Some improvement in these existing indices would probably be gained by using new techniques of revealing the dynamically confined areas in the open coastal ocean, as well as tracking the far-field impact of national river loadings, to assess the trans-boundary effects. Modelling may provide a new insight in long-range effects, which are difficult to measure by field sampling techniques. Enclosed sea areas, like the Baltic, where eutrophication is impacting almost the whole sea area, require a regional approach, where delineation of areas and the related GES targets are based on evaluation of long term development and on-going modelling work of the expected impacts of nutrient loading reductions, e.g. as planned by the Baltic Sea Action Plan. The next step will be to set clear GES criteria for eutrophication parameters for these areas. Lessons may be learned from the Baltic Sea where visions and goals have been agreed via the Baltic Sea Action Plan and a process of setting targets has been started. A similar process has been initiated by OSPAR.

Due to the wide extent of eutrophic zones in some places, the sampling effort at sea necessary to assess algal biomass with some reliability will increase in some countries relatively to WFD needs. Hence, a systematic use of remote sensing of the surface chlorophyll content and other techniques has to be encouraged, and regularly improved by comparison to ground-truth samples. This approach, associated to the use of models, has allowed a systematic cover in time and space of the national WFD water bodies.

Eutrophication indices based on monitoring and/or modelling must consider temporally appropriate datasets, which may (i) favour seasonal datasets (e.g. the productive period and/or winter nutrients); or (ii) an annual cycle, which may be more adequate for marine areas with less well defined seasonality. In order to detect acute effects, which often pose serious threats to the ecosystem, monitoring and modelling must be temporally adjusted to rapidly developing events, such as the sudden and sharp peaks of oxygen depletion in bottom waters. This requires use of several approaches combining studies onboard research vessels with high-frequency automated sampling onboard of ships-of-opportunity, satellite imagery, models, automatic high frequency buoy recordings, and traditional sampling in marine areas that are impacted or at risk of being impacted by eutrophication.

5. General framework for describing environmental status

Methods developed to evaluate eutrophic condition should include biological and physico-chemical indicators of eutrophication that will provide information at an appropriate level of confidence, in order to form the basis for management decisions. Indicators selected should show a gradient that reflects the level of human-induced impairment where an increase in nutrient loads leads to increased water quality problems. Ideally, an assessment will provide results showing the level of impairment and the concurrent load and dominant source(s) of nutrients that have caused observed impairment so that management measures can be targeted for maximum effectiveness.

5.1. Methods and Indicators

Most eutrophication assessment methods (Table 2) recognize that the immediate biological response is increased primary production reflected as chlorophyll a and/or macroalgal abundance. These are 'direct effects or 'primary symptoms' and indicate the first stages of eutrophication. 'Indirect effects' or 'secondary symptoms' such as low dissolved oxygen, losses of submerged aquatic vegetation, and occurrences of nuisance and toxic blooms indicate more well developed problems.

Most pressures resulting in eutrophication come from coastal areas, producing a strong gradient across coast-offshore waters; consequently it is recommended that the WFD assesses the status in coastal waters using all elements (biological and physico-chemical) affected by eutrophication. This must be complemented, within the MSFD, using phytoplankton and physico-chemical (e.g. nutrients, Secchi disc, etc.) indicators, in offshore and open marine waters.

In offshore coastal waters nutrient concentrations (i.e. DIN, DIP, etc) are a useful indicator, although this may not be the case in all coastal waters. Monitoring may (i) favour seasonal datasets (e.g. the productive period and/or winter nutrients, which may condition the level of the phytoplankton bloom); or (ii) an annual cycle, which may be more adequate for marine areas with less well defined seasonality.

It is fundamental to include nutrient sources and loads (e.g. terrestrial, airborne) so the load can be associated with impairment and successful management measures can be developed from that relationship. One potential tool is the ICEP indicator, which estimates the eutrophication potential of nutrient river loads on basis of their N:P:Si ratios.

5.2. Spatial and Temporal Representativeness

This in an important issue in the determination of final results, e.g. the EPA NCA method uses a probabilistic sampling framework that provides 90% confidence in results for US regions on a spatial basis, but is not capable of addressing individual estuaries. Alternatively, both natural characteristics and the human dimension can be used to divide a water body into management units where morphology as well as appropriate indicators of pressure and state would determine zone boundaries.

Sampling must consider temporally appropriate datasets, which may (i) favour seasonal datasets (e.g. the productive period and/or winter nutrients); or (ii) an annual cycle, which may be more adequate for marine areas with less well defined seasonality.

The benefit to this approach is that in cases where there is a particularly impacted zone or area, special monitoring and management can be implemented.

The EEA-EMMA reports on the 'Indicator Comparison process' suggest that the identification of temporal trends in Chl a concentration is important for all marine regions, but the sampling resolution in time (e.g. once a year for the NE Atlantic) and space (very limited station network in some regions) may make trend analysis difficult. As suggested above, the use of remote sensing for wider marine areas, which can provide a much finer resolution in time and space, might be considered to fill this gap.

The conclusion in these reports that “nutrient concentrations when used jointly with Chl a are a closer step toward a eutrophication assessment” needs further research in marine waters. The linkage of eutrophication symptoms to nutrient *loading*, underwater light climate and susceptibility (e.g. mixing and residence time) is more straightforward.

In open ocean waters which fall under the scope of the MSFD, remote sensing methods are among those that show the most promise as a tool for eutrophication assessment, through the detection of algal pigments and water clarity.

5.3. Recommended Indicators for Monitoring and Assessment

The eutrophication indicators that should be monitored in marine waters can be developed from the list of indicators derived from previous studies (Table 4), though there may be others that are more relevant and submerged aquatic vegetation may not be appropriate in deeper waters.

The framework for a monitoring program should also be guided by established assessment procedures, such as the OSPAR Comprehensive Procedure. For example, to maximize efficiency of monitoring as well as resource use a screening process might be used whereby only water bodies showing impairment or risk from anthropogenic nutrient loads in an initial assessment would be the focus of a more intensive monitoring and assessment program. The initial screening should be done periodically to ensure that any creeping eutrophication would be detected.

6. Monitoring compliance to GES under the descriptor

6.1. Background concepts and MSFD context

Monitoring is a set of coordinated observations of a list of variables, in pre-defined places and temporal occasions, and is addressed under Art. 5 of the MSFD, in the context of the elaboration of the Initial Assessment. Its main objective is to characterize present state and trends as well as to identify the environmental impact of human activities as possible causes for observed environmental impairments.
The design of Monitoring Programmes must take into account scientific questions and policy/management issues.

The General Guidelines to develop Monitoring Programmes are presented in the box opposite. They include the definition of spatial domain and location of sampling stations, the frequency and timing for measurements, and the list of variables and sampling methodology. Consideration shall also be given to those pressures and impacts relevant for Human Induced Eutrophication presented in Table 3.

To comply with TG5 objectives, an inventory of national programmes, assessment of available methodological standards and definition of associated requirements must be carried out.

General guidelines

☐ **Objectives**:
Aims, management, core and research objectives

☐ **Methods**
Methodology for sampling, analysis, and data integration, descriptors, indicators and indices

☐ **Domain and scales**
Spatial domain and sampling resolution
Frequency and timing for sampling

☐ **Quality assurance**
Intercalibration and comparative assessment

☐ **Reporting**
Standard forms

☐ **Monitoring success**
Verification of outputs and outcomes

Table 3 - Pressures and impacts to be considered for QD5, as defined in Tables 1 and 2 of Annex III of the MSFD

	Characteristics		Pressures and impacts
Physical and chemical features	Spatial and temporal distribution of nutrients (DIN, TN, DIP, TP, TOC) and oxygen, pH, pCO2 profiles or equivalent information used to measure marine acidification[2]	Nutrient and organic matter enrichment	Inputs of fertilizers and other nitrogen and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition), Inputs of organic matter (e.g. sewers, mariculture, riverine inputs)

[2] Under the slightly more alkaline conditions associated with eutrophication a reduction in pCO2 and increase in pH would be expected.

Biological features	A description of the biological communities associated with the predominant seabed and water column habitats. This would include information on the phytoplankton and zooplankton communities, including the species and seasonal and geographical variability	Nutrient and organic matter enrichment	Changes in production
	Information on angiosperms, macro-algae and invertebrate bottom fauna, including species composition, biomass and annual/seasonal variability	Nutrient and organic matter enrichment Physical alteration	Changes in production, changes in spatial coverage of bottom flora and fauna

6.2. Spatial and temporal scales

The spatial coverage of Monitoring Programmes to comply with the MSFD may be divided into (a) a coastal strip where the WFD is also enacted; and (b) a more extended marine area (Figure 2). In the former, the combination of surveillance, operational and investigative monitoring put in place by Member States for WFD compliance is also appropriate for MSFD compliance with respect to the eutrophication descriptor. In the design of Monitoring Programmes for open marine water, the strong diversity of EU regional seas must be taken into consideration.

Figure 2. Maritime boundaries for EU Member States (source: JRC)

In some cases, such as the Baltic, the whole marine area is bounded by limits of territorial waters, and in others, such as the Eastern Mediterranean or NE Atlantic, there are marine areas which are international waters. Nevertheless, most of the offshore areas subject to the MSFD generally show limited eutrophication symptoms. Indirect eutrophication effects such as hypoxia are not observed, except in the Black Sea where this has been a naturally occurring oceanographic phenomenon for much longer than the time-scale of human influence on water quality.

A critical issue is that of Harmful Algal Blooms (HAB) which form part of the eutrophication qualitative descriptor, but which we wish to qualify: "*HABs should be treated as part of the undesirable consequences of eutrophication only if their frequency or amplitude increases in correspondence with increased nutrient input*."

Frequency and timing for sampling must consider the temporal/seasonal variability of the eutrophication process. The rationale for selecting sampling occasions in Monitoring Programmes is provided in the previous chapter on ***"Spatial and Temporal Representativeness***".

6.3. Potential indicators

The indicative list of elements and the "*terms of reference for the Monitoring Programmes"* are set out in Annexes III and V of the MSFD that further define what questions are to be answered by its implementation and by reference to the environmental targets established pursuant Art. 10.
Table 4 summarizes a proposal of the indicators to be monitored, including the associated timeframe and some explanations on units, methods and associated statistics.

Table 4 - Tentative list of eutrophication indicators and timeframes for marine waters assuming samples are taken on a spatially representative basis (see above for alternative approaches)

Indicator Type	Indicator	Sampling timeframe[1]	Statistics
Pressure	Nutrient load (Nitrogen, Phosphorus)	Annual estimate to match timeframe of eutrophication condition assessment	Tons/year can be calculated from riverine and direct inputs adjusted to the inflow, industrial and urban water treatment plant loads. OSPAR RID Programme and HELCOM Pollution Load Compilations (PLCs) could be used for guidance.
State or Condition	Increase in primary production	Estimates at some periodicity over the annual cycle	Can use chlorophyll and other algal components as a proxy or use remote sensing plus modelling as appropriate and as resources allow
	Chlorophyll	Monthly, or more frequent as appropriate and as possible especially for dynamic areas	90th percentile concentration, spatial area of high concentrations
	Dissolved Oxygen	Monthly, or more frequent as appropriate and as possible especially for dynamic areas	10th percentile concentration, spatial area of low concentrations

	Opportunistic macroalgae	Annual sampling in spring – summer when blooms are more probable	Blooms that cause detriment to living resources, duration of blooms, approximate spatial coverage of blooms
	Nuisance/toxic algal blooms	Annual Bloom events Annual to multi-year changes in frequency and/or duration of blooms	Blooms that cause detriment to living resources
	Changes in algal community structure	Annual to multi-year changes from fucoids/kelp to opportunistic green/brown algae and/or changes in balance of diatoms/flagellates/cyanobacteria	Change from diverse natural community to one dominated by opportunistic and/or nuisance and/or toxic species
	Submerged Aquatic Vegetation	Annual surveys	Changes in: spatial coverage, density of beds
	Benthos	Annual	Changes in diversity and proportion of sensitive vs non-sensitive spp
	Nutrient concentrations	Monthly or fortnightly, or more frequent as appropriate and as possible especially for dynamic areas	Annual means or maxima, Seasonal means or maxima, others as appropriate
Other	Benthos/fish	Observations/irregular – take note of kills	Massive mortality, benthos/fish kills

[1]More frequent sampling on a temporal basis and more samples spatially for better areal representation may be appropriate and justified (e.g. surveillance monitoring of WFD), particularly for problem areas and those at risk, but it must be balanced with consideration of resources available for monitoring.

6.4. Monitoring methods

The monitoring of open waters at stations well offshore requires the use of methodologies of ocean observation systems, including satellite remote sensing. The measured data may provide ocean boundary conditions for the WFD coastal area, and help establish the cause of violation of quality thresholds for some indicators.

In the case of high biomass HAB, remote sensing of chlorophyll will probably pick up the signal, with the caveat that when the bloom is not superficial (e.g. when present in thin layers as in the English Channel), this will be a problem for satellite detection. A different problem is faced in the case of toxic blooms without significant biomass increase. HAB monitoring programmes usually take into account the regional differences in the temporal patterns and spatial scales.

Most of the references of this review come from marine coastal areas; there is not as much literature about assessment/management of GES in marine open waters. In the MSFD, we recommend appropriate methodologies for chlorophyll-a observation offshore using tools such as satellite observation, smart buoys, and ferry boxes.

Member States must determine to what extent data needs are covered by national monitoring programmes, and what aspects of the descriptor are not or are poorly covered. The framework for a monitoring programme should also be guided by established programmes, such as the OSPAR Comprehensive Procedure. On this basis it will be possible to optimize existing monitoring information, and identify where improvements may be made through targeted and focused additional monitoring.

6.5. Infrastructure improvements

A long-term monitoring and research infrastructure is needed, including marine/oceanic observation capabilities that include continuous plankton recorders and long-term fixed stations of data collection for model validation.

Maintenance of long-term data series and information is important for prevention of misdiagnosis of new events/changes and will improve interpretation of trends in HAB and facilitate development of management measures.

6.6. Quality Assurance guidelines

Quality Assurance guidelines for the descriptor are an essential requirement for successful monitoring, allowing for appropriate intercalibration and comparative assessment. The procedures aim to ensure that monitoring results meet the required levels of precision and confidence. Those procedures can take the form of standardizing sampling and analytical methods, replicate analyses, ionic balance checks and laboratory accreditation schemes (following the recommended methodologies for the WFD).

7. Research needs

The current understanding of nutrient loading pressure and its consequences to the marine ecosystem, gaps in knowledge, and research needs are considered in relation to the conceptual framework for eutrophication shown in Figure 1. It is important to remember while reviewing the list of research needs that there are basin-related and regional differences in the temporal patterns and spatial scales as well as in the magnitude of nutrient loads, resulting in differences of visible and persistent eutrophication effects. Likewise, there are already regional differences in the availability of tools for assessment and management of eutrophication. The research needs listed here are meant to capture research needs on a broad basis.

The research needs to fill gaps in understanding are grouped according to the framework (Figure 1) as (i) nutrient supply and enrichment; and (ii) eutrophication symptoms.

7.1. Nutrient Supply and Enrichment

Biogeochemical transformation of nutrients along the catchment and through the coastal and open marine waters continuum is currently not sufficiently understood in order to set targets for GES and to allow planning of required management options for reaching GES in marine basins and marine regions. More specifically there is a need to carry out research on:

- Estimates of nutrient loads from terrestrial and atmospheric sources, in relation to transitional/coastal retention, and chemical and biological target indicators;
- Natural background nutrient enrichment (e.g. upwelling, import from pristine/good status rivers) compared to human related sources for determination of unimpacted state and distinction between naturally productive status and anthropogenically eutrophic status for identification of what can and cannot be managed;
- Contribution of transboundary and transnational supply and/or exchange of nutrients compared to terrestrial and atmospheric sources of nutrients and whether/how these can be managed;
- Climate change impacts on availability of nutrients including transportation (e.g. from new circulation patterns, increased rainfall, changes in upwelling/coastal processes that might lead to new or enhanced sources), and transformation of nutrients and organic matter;
- Distinction between climate change and anthropogenic impacts and how best to manage these;
- Relationships between indicators/parameters and proxies for nutrient loading pressures (e.g. change in nutrient concentrations where this can be demonstrated to be an effective proxy) need to be established in order to set ecoregion and/or habitat-specific targets for GES.

7.2. Eutrophication symptoms

It is important to be able to understand the mechanisms of eutrophication and to predict the alternative outcomes of ecosystem status with changes in nutrient pressure, as well as the uncertainty in the anticipated recovery pace and endpoint(s) as a function of reductions in nutrient loading mandated by the EU MSFD as we aim for GES of the European seas by 2020. It is important to set GES targets with safety margins for sustainable maintenance and fostering of marine ecosystems and services.

In order to understand regulation of phytoplankton and macroalgal biomass, and other eutrophication symptoms (e.g. hypoxia, loss of seagrasses) by nutrient pressures, and to set appropriate GES threshold targets and management measures, the following research questions require attention:

Research on primary production and algal biomass regulation

- The relationship among nutrient concentrations, chlorophyll, and primary production, and whether when used jointly they are useful and should be pursued as part of eutrophication assessment, given the stronger linkage of symptoms to nutrient loading, underwater light climate and susceptibility (e.g. mixing and residence time);

- Nutrient regulation and stoichiometry of algal biomass (i.e. phytoplankton and macroalgae) production including nutrient related selection of dominant species, functional groups, and algal community structure;
- New development of phytoplankton assessment tools that account for shifts in species composition and frequency of blooms in the status assessment scoring;
- Relationship between nutrient enrichment and shifts in structure and functioning of the planktonic food web;
- Development of monitoring tools that account for rapid changes in algal communities, allowing detection of bloom peaks (e.g. continuous measurements, ships-of-opportunity, remote sensing tools, algorithm development, etc.);
- Effect of top-down control (e.g. shellfish filtration, zooplankton grazing) and other food-web interactions (viral infections, parasitism, including the role of mixotrophy (ability to use organic sources of N and P) etc) in regulation of algal biomass and transmitted/ amplified effects.

Research on Harmful Algal Blooms

- Identification and understanding of the link between HABs and land-based nutrient inputs;
- Identification of the role of mechanisms such as upwelling relaxation events, cyst formation etc in HAB formation, and the extent to which these events are manageable;

Research on value, resilience and recovery of marine ecosystems

- Marine submerged vegetation (SAV) is valuable for maintenance of biodiversity as it forms habitat for many organisms (invertebrates, fish juveniles, etc.). Research is needed on evaluation of eutrophication impacts including the optimal extent and status of SAV communities for supporting viable and diverse communities; valuation of goods and services provided by such communities and development of tools for marine spatial planning and management of marine protected areas with respect to eutrophication
- Identification of factors that govern the occurrence and extension of the hypoxic/ anoxic events as well as the impacts of such events on resilience and recovery of benthic communities. There is a need to distinguish between the natural range and increases in spatial extent of anoxic sediments and bottom waters due to anthropogenic organic loading;
- Determination of the resilience of marine ecosystems for identification of critical nutrient loading thresholds beyond which the whole system shifts to an alternative steady state. This includes research exploring potential recovery pathways from eutrophic to non-eutrophic states. This is not well established because system functioning and components may have changed and the recovery pathway and restoration outcome may not be identical to rate of deterioration or the original status before impairment (e.g. Figure 3);
- Research on effects of eutrophication on benthic biodiversity and marine food webs is also highlighted, but could best be addressed within the respective TGs (Figure 4).

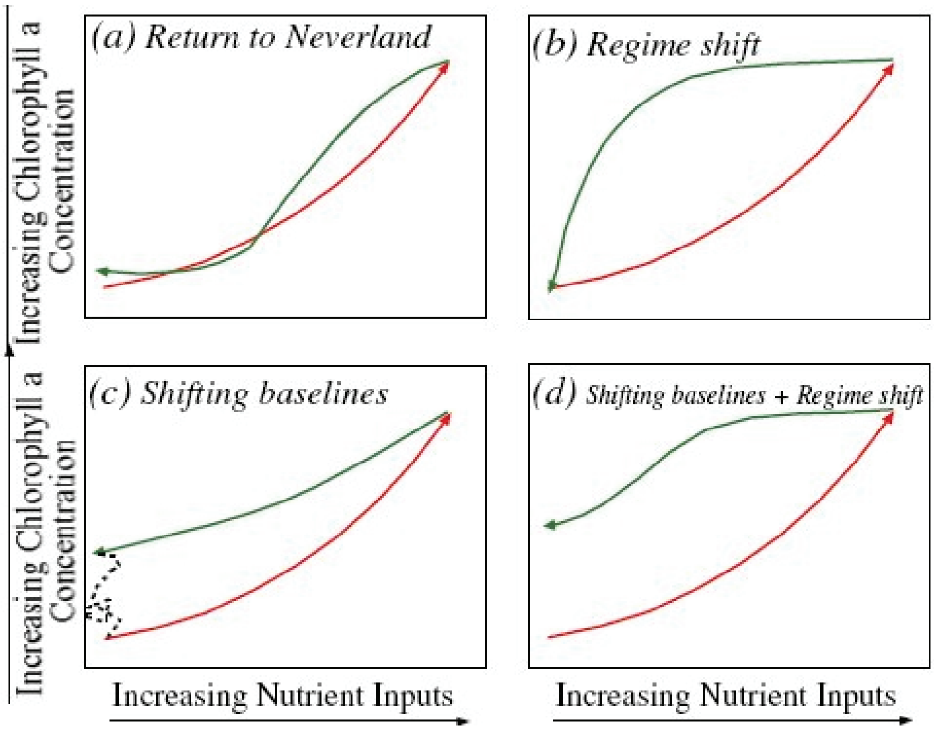

Figure 3. Idealized trajectories of chlorophyll a concentrations with changing nutrient loading (source: Duarte et al., 2009).

8. Relationship with other MSFD descriptors

Figure 4 outlines the relationship between QD5 and other descriptors, using QD1 (biodiversity) as an example.

In the example shown in Figure 4, the tools used to determine eutrophication status, based on the suite of indicators described earlier (which are combined into indices), provide an entry point to other Quality Descriptors such as QD1, Biodiversity.

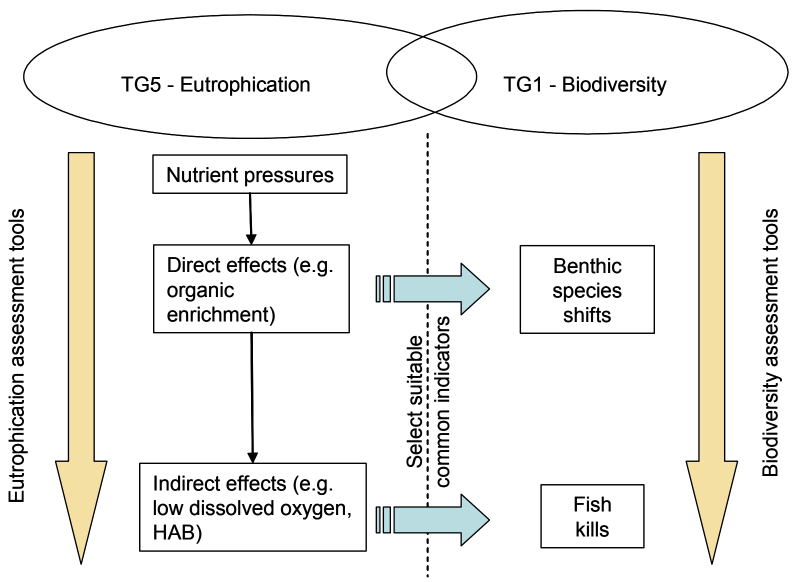

Figure 4. Schematic approach for using elements of the eutrophication descriptor as entry-points to the biodiversity descriptor. The example may be extended to other descriptors

Since QD1 is affected by multiple factors apart from eutrophication (e.g. QD3 - Fisheries, and QD6 – Sea floor integrity), the assessment from QD5 should be combined with others to apportion the relative importance of the different qualitative descriptors which affect QD1.

9. Conclusions

9.1. Findings and Recommendations

Interpretation of the descriptor

Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.

Methods

1. To provide a complete picture of eutrophic conditions, other characteristics should be included in addition to Chl a, such as changes in community composition, occurrence of nuisance and toxic species that result from changes in nutrient ratios, and increased duration and frequency of blooms which result from increases in nutrient loads (Annex 2: Table 8). For example, OSPAR monitors for phytoplankton indicator species by looking at changes in specific groups (e.g. dinoflagellates, diatoms). The ASSETS nuisance and toxic bloom index uses a combination of observations of nuisance and toxic blooms and the frequency and duration of the blooms to determine the status.
2. No specific best method is recommended by the group. Methods to be used for GES must be integrated and comparable. It is expected that scientific research will improve these methods, and generate new ones. The criteria for acceptance are integration, sensitivity, comparability and scientific merit.

Scale

1. Due to the wide extent of eutrophic zones in some places, the sampling effort at sea necessary to assess algal biomass with some reliability will increase in dramatic proportions for some countries relatively to WFD needs. Hence, a systematic use of remote sensing of the surface chlorophyll content has to be encouraged, and regularly improved by comparison to some ground-truth samples. This approach has allowed a systematic cover in time and space of the national WFD water bodies.
2. Eutrophication indices based on monitoring and/or modelling must consider temporally appropriate datasets, which may (i) favour seasonal datasets (e.g. the productive period and/or winter nutrients); or (ii) an annual cycle, which may be more adequate for marine areas with less well defined seasonality.

Assessment Framework

1. In offshore coastal waters nutrient concentrations (i.e. DIN, DIP, etc) are a useful indicator, particularly winter concentrations which may condition the level of the phytoplankton bloom, although they may not be useful indicators in all coastal waters;
2. It is fundamental to include nutrient sources and loads (e.g. terrestrial, airborne) so the load can be associated with impairment and successful management measures can be developed from that relationship.
3. Sampling must consider temporally appropriate datasets, which may (i) favour seasonal datasets (e.g. the productive period and/or winter nutrients); or (ii) an annual cycle, which may be more adequate for marine areas with less well defined seasonality.

Monitoring

Monitoring is a set of coordinated observations of a list of variables, in pre-defined places and temporal occasions, and is addressed under Art. 5 of the MSFD, in the context of the elaboration of the Initial Assessment. Its main objective is to characterize present state and trends as well as to identify the environmental impact of human activities as possible causes for observed environmental impairments. The design of Monitoring Programmes must take into account scientific questions and policy/management issues.

The General Guidelines to develop Monitoring Programmes include the definition of spatial domain and location of sampling stations, the frequency and timing for measurements, and the list of variables and sampling methodology. Consideration shall also be given to those pressures and impacts relevant for Human Induced Eutrophication. An inventory of national programmes, assessment of available methodological standards and definition of associated requirements must be carried out.

The monitoring of open waters at stations well offshore requires the use of methodologies of ocean observation systems, including satellite remote sensing. The measured data may provide ocean boundary conditions for the WFD coastal area, and help establish the cause of violation of quality thresholds for some indicators.

Member States must determine to what extent data needs are covered by national monitoring programmes, and what aspects of the descriptor are not or are poorly covered. The framework for a monitoring program should also be guided by existing programs, such as the OSPAR Comprehensive Procedure. On this basis it will be possible to optimize existing monitoring information, and identify where improvements may be made through targeted and focused additional monitoring

The contracting parties of HELCOM have requested the Baltic Sea as the pilot area for testing the MSFD. For QD5, there should be a pilot also in an open water area since the Baltic is an enclosed sea and may not provide results in the pilot that are transferrable to all regions/sub-regions;

On an EU level, the importance of infrastructure improvements is highlighted, in order to provide long-term datasets and information to help avoid misdiagnosis of new events/changes, improve interpretation of trends, and facilitate development of management measures.

Quality Assurance guidelines for the descriptor are an essential requirement for successful monitoring, allowing for appropriate intercalibration and comparative assessment.

Research Needs

Coupled atmosphere-river-coastal sea models need to be developed at the regional scale for the estimate of critical nutrient loads from terrestrial sources, in relation to transitional/ coastal retention, and chemical and biological target indicators (Cat. I); natural background nutrient enrichment (e.g. import by upwelling; import from pristine/ good status rivers) for determination of unimpacted state and separation of naturally productive status from anthropogenically eutrophic status; climate change impacts on availability and transformation of nutrients and organic matter from land to the sea.

Nutrient regulation for algal biomass production; selection of dominant species, functional groups, and community structure, nutrient competition and needs (nutrient stoichiometry);

Impact of top-down (e.g. shellfish filtration, zooplankton grazing) control, grazing-resistant species, and other food-web interactions (viral infections, parasitism…) on fate/ sinks of algal biomass and transmitted/ amplified effects; regulation of harmful algal blooms (HABs); the link to land-based inputs is not always well established: blooms may be linked to upwelling relaxation events, cyst formation etc; research is needed to categorize to what extent events are manageable; Setting the GES targets (with safety margins) for algal production/ biomass ensuring none or minor undesired secondary effects on zoobenthic or fish communities;

Research on factors that govern the occurrence and extension of hypoxic/ anoxic sediment surface: there is a need to distinguish between natural range and increase of spatial extension of anoxic sediments due to anthropogenic organic loading; ecoregion and/ or habitat-specific relationships between the indicators/ parameters and proxies for nutrient loading pressures; identification of critical nutrient loading thresholds beyond which the whole system is changing into an alternative steady state; recovery pathways and the outcome of the restoration.

Development of phytoplankton assessment tools that account for shifts in species composition and frequency of blooms in the scoring; Development of monitoring tools that account for rapid changes in algal communities, allowing detection of bloom peaks (continuous measurements, ships-of-opportunity, remote sensing tools, algorithm development, real-time monitoring, etc.).

9.2. Upscaling

Contrary to the WFD, which defines a “one out-all out” approach in order to classify a waterbody, in the MSFD, GES may be envisaged as an integration (e.g. sum, weighted average, or other approaches) of all/most criteria.

TG5 could therefore provide a number, range (colour) to feed into the overall score. It would be desirable that the various task groups are involved in the process leading to an overall formula for determination of GES, to ensure that the proper balance is maintained across quality descriptors, true to the philosophy of the MSFD.

The various criteria should also provide stand-alone feedback to help managers. For this holistic approach to GES, the eutrophication criterion QD5 should provide a broader range of quality classes than GES/non-GES, to provide more flexibility to the overall GES calculation procedure.

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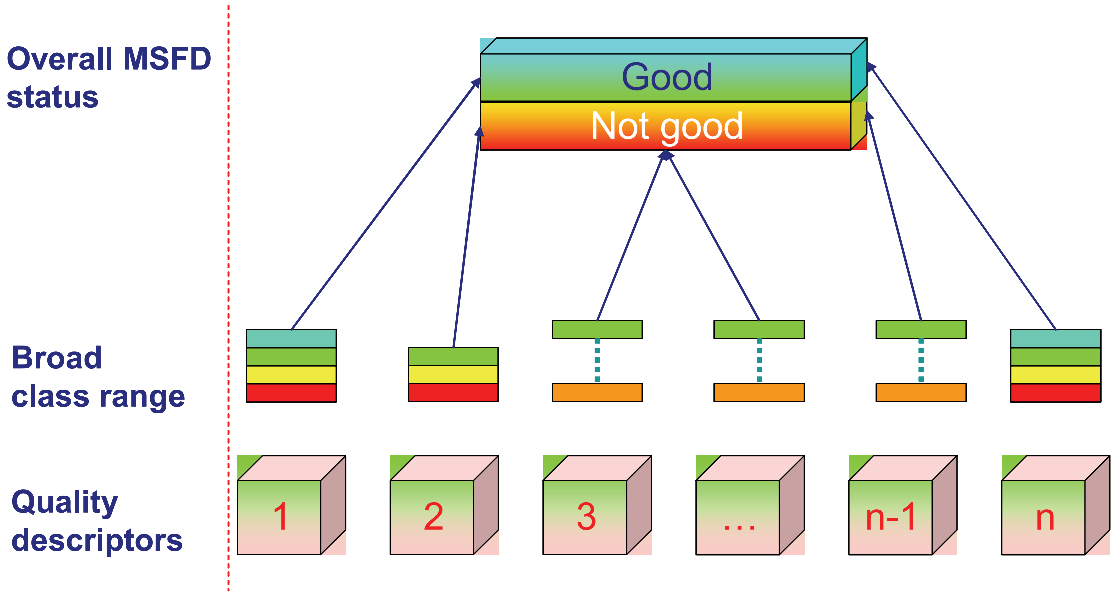

Figure 5. Integration of quality descriptors into MSFD environmental status

This concept is illustrated in Figure 5, where the various Quality Descriptors are individually classified into a range of quality classes, which allow managers to examine trends, particularly for sub-classes in the "not good" class.

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11. Glossary

Table 5. Glossary of acronyms used

Name	*Acronym*
Assessment of Estuarine and Coastal Trophic Status	ASSETS
EU Joint Research Centre	JRC
European Environment Agency	EEA
European Union	EU
Exclusive Economic Zone	EEZ
HELCOM Eutrophication Assessment Tool	HEAT
Helsinki Convention	HELCOM
Indicator of Coastal Eutrophication Potential	ICEP
International Council for Exploration of the Sea	ICES
Marine Strategy Framework Directive	MSFD
MSFD Quality Descriptor	QD
Oslo-Paris Convention	OSPAR
OSPAR Comprehensive Procedure	OSPAR COMPP
Statistical Trophic Index	STI
Urban Wastewater Treatment Directive	UWWTD
Water Framework Directive	WFD

Annexes

Annex 1 – Additional supporting materials

The sections in this annex provide complementary text, tables and figures for the corresponding sections in the main document. In order to condense the core text, the expanded versions of definitions, interpretations, and other aspects of this guidance were collated in annex.

Initial interpretation of the descriptor

*QD*5 refers to the adverse effects of eutrophication as including *"losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters."*

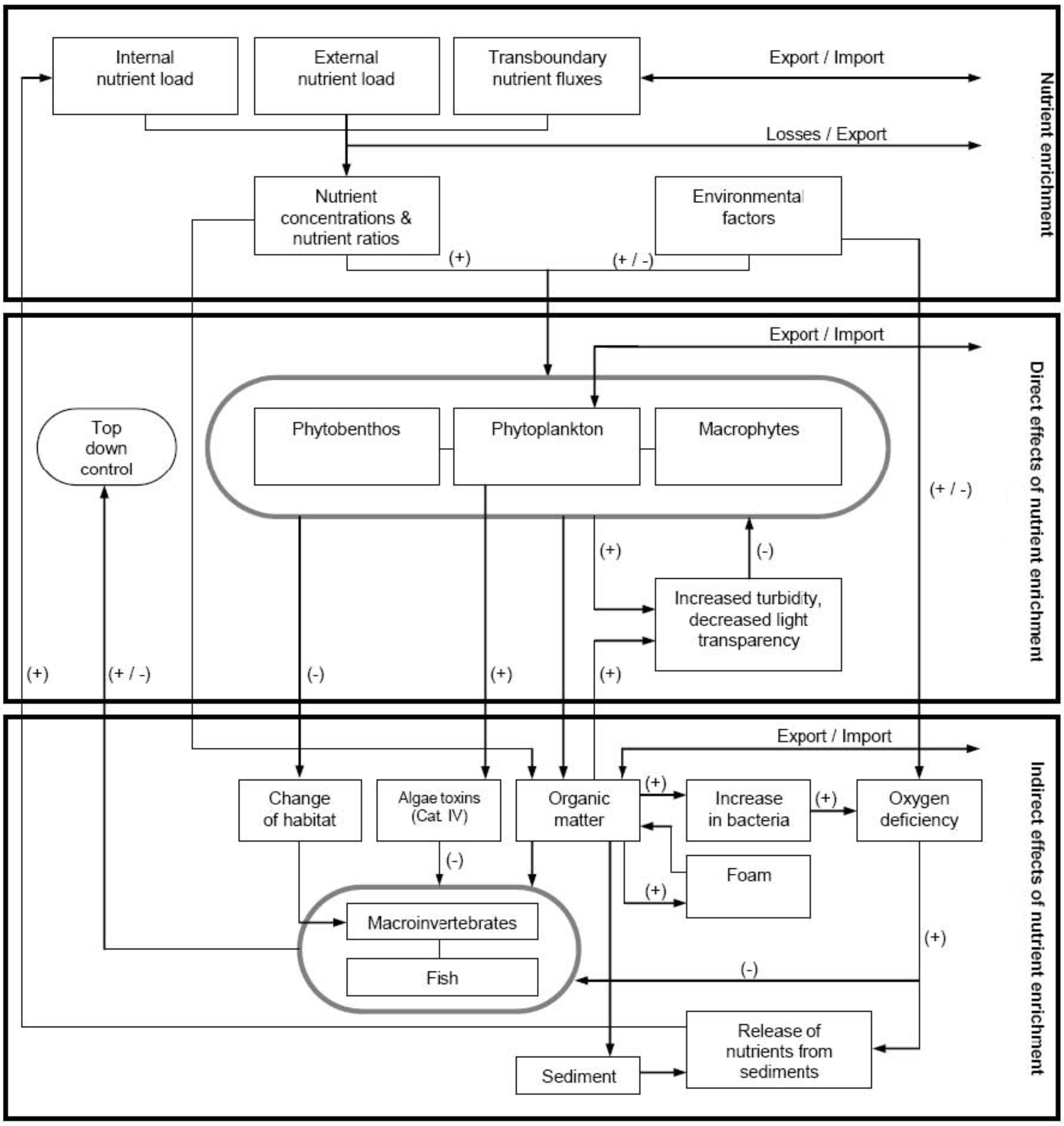

Figure 6. General conceptual model of eutrophication (source: OSPAR Commission, 2005).

Figure 6 is provided in complement to Figure 1. The complexity of these diagrams may vary, and the authors are aware that components which are important in some regions (e.g.

denitrification) could be added, and that in other regions (e.g. deep marine waters) some components (e.g. macrophytes) are not applicable.

Table 6. Definition of eutrophication, with commentary

Definition	*Commentary*
Eutrophication is a process driven by enrichment of water by nutrients,	*The process can be natural or human-driven, or both. Other human pressures on the marine environment can lead to similar changes and impacts, so it is a necessary condition of a diagnosis of eutrophication that the changes are linked to nutrient enrichment.*
especially compounds of nitrogen and/or phosphorus,	*The main compounds are those involving nitrate, ammonium and phosphate, which are needed for algal growth; however, the decay of organic compounds of N and P can release these inorganic nutrients; and recent research has shown that organic forms such as urea can contribute directly to increased growth and may favour some harmful organisms. Attention should also be paid to changes in the ratios of nutrient -N and -P to each other and to dissolved silica, needed by diatoms*
leading to: increased growth, primary production and biomass of algae;	*'Algae' is meant to refer to cyanobacterial and algal members of the phytoplankton and phytobenthos, the latter including macro-algae ('seaweeds'). We omit 'higher forms of plant life' in the present context as seagrasses can be harmed but not stimulated by the eutrophication process. We stress the centrality of 'increased primary production' to the definition, but restrict this to increased autochthonous organic production driven by increased allochthonous nutrient supply.*
changes in the balance of organisms;	*Such changes are likely to take place initially in the phytoplankton and phytobenthos, and then propagate through marine food webs. The primary producer changes, which may in part result from perturbations of natural ratios of nutrient elements, include shifts from diatoms to cyanobacteria or flagellates, and the suppression of fucoid seaweeds, or sea-grasses, by an overgrowth of opportunistic (green or brown) algae.*
and water quality degradation.	*Such degradation includes: 'aesthetic' effects such as the appearance of Red Tides or excessive foam; decreases in water transparency resulting from greater biomass of phytoplankton; and decreases in bottom-water or sediment pore-water oxygen content because of the decay of increased primary production*
The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health	*'Ecosystem health' refers to the homeostatic (self-regulatory) ability and resilience of marine food webs interacting with their non-living environment, and is evident in their 'structure' (which includes functional components of biodiversity) and 'vigour' (which includes food-web function and biogeochemical cycling). Note that change in the balance of organisms is not in itself undesirable, and can occur naturally; we are concerned with nutrient-induced changes that harm ecosystem structure and function, exemplified by loss of seagrass meadows as a result of decreased water transparency, or by increased mortalities of benthic animals because of bottom-water deoxygenation.*
and/or the sustainable provision of goods and services.	*The nutrient-driven increase in primary production that is key to eutrophication can lead to increased harvest of fish or shellfish, as well as to undesirable consequences, such as damage to exploited fish stocks by water deoxygenation or to tourism by the accumulation of algal foam on beaches. Changes in the balance of organisms might (but don't always) include more frequent occurrences of toxic algae.*

Table 7 lists multinational policies and conventions that have a bearing on eutrophication in the seas governed by the Marine Strategy Framework Directive.

Table 7. Laws, policies, and conventions relevant to eutrophication in European waters

Name	***Responsible authority and domain of applicability***	***Aim (relevant to eutrophication)***	***Comments***
Urban Wastewater Treatment Directive (91/271/EEC)	European Commission: European Union	*..to protect the environment from the adverse effects of* [urban waste water and certain industrial] *discharges*	article 2.11 defines eutrophication. Eutrophic waters are 'sensitive' and therefore waste water discharges require 'more stringent treatment'
Nitrates Directive (91/676/EEC)	European Commission: European Union	to reduce, and prevent further, *water pollution caused or induced by nitrates from agricultural sources*	article 2.ii defines eutrophication (in relation to nitrogen compounds only). Lands draining into waters with a high nitrate concentration and that are eutrophic, are 'vulnerable zones' and remedial measures must be taken.
Habitats Directive (92/43/EEC)	European Commission: European Union		
OSPAR's Strategy to Combat Eutrophication (OSPAR, 1998a; 2003)	Convention for the Protection of the Marine Environment of the North-East Atlantic	*..to achieve and maintain by 2010 a healthy marine environment where eutrophication does not occur*	OSPAR (1998b) defines eutrophication. The 'Comprehensive Procedure' of the 'Common Procedure' provides a framework or tool to assess the status of sea-areas in relation to eutrophication (OSPAR, 2005). Nutrient loads to 'Problem Areas' must be reduced. *Correct?*
Water Framework Directive (2000/60/EEC)	European Commission: European Union (freshwaters, transitional waters, and coastal waters to at least 1 nautical mile from baseline)	.. *protects and enhances the status of aquatic ecosystems*, aiming to achieve 'good' water status (or better) by 2015: this includes 'good' ecological status	Good ecological status' (Annex V) requires near-natural transparency and concentrations of oxygen and nutrients, plus biomass and taxonomic make-up of primary producers, and bloom frequency, close to those under 'type-specific reference conditions'. 'Moderate' status is characterized by changes in the composition and abundance of primary producers, which "*may be such as to produce a significant undesirable disturbance in the other biological quality elements and the physico-chemical quality of the water or sediment".* Eutrophication is explicitly mentioned only in Annex VIII, Indicative List of the main pollutants: "*11. Substances which contribute to eutrophication (in particular, nitrates and phosphates)*."

HELCOM's Baltic Sea Action Plan (adopted 2007)	Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area	*The Action Plan aims to solve all major environmental problems affecting the Baltic Sea, the most serious of which is eutrophication arising from excessive inputs of nutrients.*	*"Eutrophication arises when excessive amounts of nutrients, mainly nitrogen (N) and phosphorus (P) but also organic matter (represented by carbon (C)), build up in aquatic ecosystems and cause accelerated growth of algae and plants, often resulting in undesirable effects."* These effects include decreased water transparency and oxygen content, with impacts on sea-bed flora and fauna. The Action plan aims to continue reducing N and P loads from agriculture, urban waste water, and atmospheric transport
Barcelona Convention (1975, 1995)	originally, Barcelona Convention for the Protection of the Mediterranean Sea against Pollution; now, Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean	There is no specific aim relevant to eutrophication. Article 8. POLLUTION FROM LAND-BASED SOURCES, states that: "*The Contracting Parties shall take all appropriate measures to prevent, abate and combat pollution of the Mediterranean Sea area caused by discharges from rivers, coastal establishments or outfalls, or emanating from any other land-based sources within their territories.*"	Some documents released under the convention mention eutrophication as a problem in some parts, but there appears to be no overall strategy to deal with it
Strategic Action Plan for the Environmental Protection & Rehabilitation of the Black Sea (Sofia, 2009): priority 2.1: *Eutrophication/nutrient enrichment*	Bucharest Convention on the Protection of the Black Sea Against Pollution	Policy Actions: 3.2. *EcoQO 3: Reduce eutrophication*	Eutrophication is defined as "*Excessive nutrient concentrations in a waterbody, usually caused by emissions of nutrients (animal waste, fertilizers, sewage, etc.) from land, which cause a dense growth of plant life (phytoplankton and benthic macrophytes/ macroalgae). The decomposition of the plants depletes the supply of oxygen, leading to the death of animal life.*" The Action Plan calls for integrated river basin and coastal zone management of nutrient loads.

Definition of GES

Table 8. Definition of GES, with commentary.

Short definition	*Comments to accompany short definition*
GES exists while:	refers to GES in relation to eutrophication and the undesirable consequences of anthropogenic nutrient enrichment
the biological community remains well-balanced, and retains all necessary functions;	(1) refers especially to balance amongst phytoplankton high-level taxa; other TGs will deal with higher levels in food chain; (2) need comment on function including primary production (which should be adequate but not excessive); (3) where there is substantial anthropogenic nutrient loading, no undesirable disturbance, but water body is deemed to be sensitive on account of hydrography, 'balance' and 'function' should be monitored for precautionary reasons
in the absence of undesirable disturbance associated with eutrophication;	the symptoms of undesirable disturbance include: excessive algal blooms (indicated by: growing season chlorophyll in substantial excess of reference state; more frequent blooms of chlorophyll or of regionally-specific eutrophication indicator species)
	decreased water transparency leading to shrinkage of seagrass meadows or perennial seaweed beds water column or superficial sediment hypoxia or anoxia due to decay of increased primary production, resulting in deaths of benthic invertebrates or fish
and/or where there are no nutrient-related impacts on sustainable use of ecosystem goods and services	such impacts are exemplified by ...
	adverse effects on tourism e.g. due to foam on beaches, fish kills ...
	interruption of shellfish harvest due to HABs (where these are associated with anthropogenic nutrient enrichment)
	harm to fish nurseries in seagrass meadows or to areas where fish reproduce

Review of scientific literature and existing methods

Table 9. Methods to evaluate the status of phytoplankton in coastal and estuarine water bodies (taken from Borja et al., in prep). References: [1]EPA (Environment Protection Agency) (USEPA, 2008). [2]Vollenweider et al., 1998. [3]TWQI/LWQI (Transitional Water Quality Index)Giordani *et al.*, 2009. [4]HELCOM, 2009. [5]Bricker *et al.*, 2003, 2007. [6]WFD (Water Framework Directive) Devlin *et al.*, in prep. [7] European Commission, 2008; [8]OSPAR COMPP (OSPAR Comprehensive Procedure) OSPAR, 2002. [9]Souchu *et al.*, 2000.

Method	Area using method	Biomass				Community composition	Abundance	Indicators in Overall Eutrophication Index
		Chl a Thresholds and Ranges (ug l^{-1})	Sample Timeframe	Statistical measure	Other characteristics			
EPA NCA[1]	US	Poor > 20; Fair 5-20, Good 0-5; lower for sensitive systems	Index period (June - Oct)	concentration, % of coastal area in poor, fair and good condition based on probabilistic sampling design for 90% confidence in areal result		No		Chl a, water clarity, DO, DIP, DIN
TRIX [2]	EU	no thresholds, integrated with other index variables		concentration		No		Chl a, DO, DIN, TP
TWQI /LWQI[3]	EU	Good QV100 = 6; Bad QV0 = 30	annual	Chl concentration mean annual or seasonal modified by weighting factor		No		Chl a, seagrasses, macroalgae, DO, DIN, DIP
HEAT[4]	Baltic	Deviation from ref EQR <0.67; No dev from ref EQR >0.67	summer (June - Sept)	mean summer concentration	increases in concentration, frequency and duration	indicator spp	X	Chl a, phytoplankton, nutrients, water transparency, SAV, DO, benthic invertebrates, summertime bloom intensity index
ASSETS[5]	US, EU, Asia, Australia	High >20; Mod 5-20; Low 0-5; lower for sensitive systems	annual	90th percentile Chl concentration of annual data	spatial coverage, frequency occurrence	Nuisance and toxic bloom occurrence, frequency, duration		Chl a, macroalgae, DO, seagrasses, nuisance/toxic blooms

WFD[6]	EU	Cantabrian coast: Bad >14, Poor 10.5-14, Moderate 7-10.5, Good 3.5-7, High 0-3.5	summer	summer Chl concentration mean, max and sometimes 90th percentile annual data	increases in concentration, frequency and duration	indicator spp	X	Chl a, phytoplankton, macroalgae, microphytobenthos, seagrasses, DO, nutrients, algal toxins
WFD[7]	EU	Mediterranean coast (P90th): T2 (34.5<sal <37.5) A: H/G=2.4 (EQR=0.80); G/M 3.6 (EQR=0.53) T3 (sal>37.5) W-Med: H/G=1.1 (EQR=0.80); G/M 1.8 (EQR=0.50). E-Med: H/G=0.1 (EQR= 0.80), G/M 0.4 (EQR= 0.20)	At least 5 years data available, with monthly sampling, in the surface layer	EQR based on Chl concentration mean or 90th percentile	Mean salinity or density	No	No	Biological quality elements (phytoplankton, macroalgae, macroinvertebrates, seagrasses)
OSPAR COMPP[8]	North East Atlantic	Good QV100 = 6, Bad QV0 = 30	growing season	growing season Chl concentration mean, max	increases in concentration, frequency and duration	indicator spp	X	Chl a, phytoplankton, macroalgae, microphytobenthos, seagrasses, DO, nutrients, algal toxins
IFREMER[9] (lagoons)	France	> 30 Red; 10-30 Orange; 7-10 Yellow; 5-7 Green; 0-5 Blue	annual	mean annual Chl concentration		phytoplankton abundance of <2μm, >2μμ	X	Chl a, phytoplankton counts (<2, >2 μm), macrophytes (biomass, diversity), macrobenthos (richness, diversity), water (DO, Chl, Chl/phaeo, turbidity, SRP, TP, TN, NO_2, NO_3, NH_4), sediment (OM, TN, TP)

Monitoring and assessment

Table 10 shows key statistics for the marine areas to which the MSFD applies. The Ratio column expresses the marine area : region (land) area as a percentage. High ratios such as that shown for the Atlantic NE mean that there are few countries bordering the water mass, whereas low ratios such as for the Baltic correspond to marine waters where the area is partitioned among various countries, each of which typically does not have an EEZ extending to the 200 nm limit. This is roughly indicated by the underlined values in the last column, which correspond to the square root of the ratio of marine area (A) to number of countries (C), i.e. where the square root of A/C < 370 km (200 nm).

Table 10. Areal statistics for waters within the MSFD

Marine region[3] (MSFD)	Area[3] (km^2)	Countries[3]	EU Coastal Nº	Region Area[3] (km^2)	Ratio (%)	Length (km)
Baltic Sea	349644	8	19	925337	38	*209*
Atlantic NE Ocean	4673125	10	78	969932	482	684
Mediterranean Sea	1533098	7	45	694200	221	468
Black Sea	55908	2	3	70338	79	*167*
Marine subregion (MSFD)						
West. Mediterranean Sea	693550	3	16	362150	192	481
Ionian Sea	359906	3	10	112502	320	*346*
Aegean Levantine Sea	418819	2	11	118574	353	458
Adriatic Sea	60823	2	8	100973	60	*174*
Biscay & Iberian Coast	821374	3	14	357071	230	523
Celtic Sea	518672	2	14	154414	336	509
Greater North Sea	1359539	7	47	447833	304	441
Baltic Sea	349644	8	19	925337	38	*209*
Black Sea	55098	2	3	70338	78	*166*
Atlantic Ocean	1973540	2	3	10615	18600	993

[3] http://www.eurocean.org/np4/323.html

Annex 2 – Composition and activities of Task Group 5

Group composition

The composition (13 members + JRC focal point) and rationale for the group composition is shown in the table below.

Table 11 – Members of MSFD Task Group 5.

Name	Ecoregion/expertise	Affiliation	Email
Jesper Andersen	Baltic, monitoring, assessment, WFD and MSFD, ecosystem-based management	DHI, Denmark	jha@dhigroup.com
Angel Borja	NE Atlantic, monitoring, management, involved in WFD implementation	AZTI, Spain	aborja@pas.azti.es
Suzanne Bricker	Evaluation, eutrophication assessment methods	NOAA, USA	Suzanne.Bricker@noaa.gov
Jordi Camp	WFD Mediterranean implementation, HAB, blooms, pressures, monitoring and management	Marine Science Institute (CSIC, Barcelona)	esther@cmima.csic.es evaflo@icm.csic.es
Joao G. Ferreira	NE Atlantic, ecological modelling	UNL, Portugal	joao@hoomi.com
Esther Garcés	WFD Mediterranean implementation, HAB, blooms, pressures, monitoring and management	Marine Science Institute (CSIC, Barcelona)	esther@cmima.csic.es
Anna-Stina Heiskanen	Eutrophication assessment, Baltic	Finnish Environment Institute	Anna-Stiina.Heiskanen@ymparisto.fi
Christophe Humborg	Modeling eutrophication. work is mainly centered in the Baltic, also a very good experience in the Black Sea.	Stockholm Resilience Centre, Director of the Baltic Nest Institute	christoph.humborg@itm.su.se
Lydia Ignatiades	Phytoplankton ecology, eutrophication assessment in the Mediterranean	Institute of Biology, Athens	igna@bio.demokritos.gr lyigna@otenet.gr
Christiane Lancelot	Eutrophication modelling, North Sea and Black Sea experience	ULB, Belgium	lancelot@ulb.ac.be
Alain Menesguen	Channel, North Sea, modelling	IFREMER, France	alain.menesguen@ifremer.fr
Margarida Cardoso da Silva	Marine chemistry. Part of negotiation process of MSFD	LNEC, Portugal	mcsilva@lnec.pt
Paul Tett	Irish Sea, Channel, North Sea, eutrophication modelling	SAMS, UK	paul.tett@sams.ac.uk
Nicolas Hoepffner	JRC focal point	EU JRC	nicolas.hoepffner@jrc.it

In addition to the group shown in Table 11, Ulrich Claussen (UBA, ulrich.claussen@uba.de) acted as OSPAR Convention Observer, and made significant contributions to this text.

Workflow

The six topics specified in the Terms of Reference (see Table 12) were addressed by six sub-groups drawn from the 13 person TG5. The respective summaries are provided in the Executive Summary, and the detailed supporting materials are available in the main report and annexes.

Table 12 – TG5 topics and sub-groups

№	Topic	Details
1	Initial interpretation of the descriptor	Definition/interpretation of the key terms used in the descriptor (i) describe what is covered by this descriptor and what falls outside its scope (ii) identification of possible links and overlaps with other descriptors (iii) identification of relevant policies and conventions related to the descriptor
2	Review of scientific literature and existing methods	Review existing scientific literature relevant for the descriptor in question, as well as existing relevant methods for quantifying GES, taking into account existing practices linked to relevant EU legislation and regional seas conventions . The review should address the following questions: (i) is there a common scientific understanding of the key concepts of the descriptor (e.g. 'biodiversity', 'alien species', 'litter', 'healthy stock', 'pollution effect', 'adverse effect on marine ecosystems')? if yes: describe the common understanding; if no: discuss alternative interpretations and open issues (ii) is there a common scientific understanding how to monitor the descriptor? if yes: describe the common understanding; is it useful/practical; if no: discuss alternative interpretations and open issues (iii) what are the existing approaches that can be used for assessing GES with regard to the descriptor? To what extent do they cover the requirements of the descriptor? What aspects of the descriptor are not, or are poorly covered?
3	Identify relevant temporal/ spatial scales for the descriptor	Identify the relevant spatial and temporal scales for the descriptor. This issue should be addressed in a manner that is consistent with the particular descriptor, taking into account the spatial and temporal scales of the relevant physical, biological and ecological systems and also the policy scales in each region. If different approaches are required in different regions, describe what they are, where they should be applied and the rationale for the differences.
4	General framework for describing environmental status	Describe the conceptual framework that should be used for the descriptor: a. identify relevant state and pressure indicators b. describe how the indicators respond to a degradation gradient Identify how to monitor the state and pressure indicators (what to measure, taking into account spatial and temporal scales)
5	Monitoring	What are the data needs for monitoring compliance to GES under the descriptor (i) to what extent are the data needs covered by national monitoring programmes? What aspects of the descriptor are not, or are poorly covered? (ii) are there existing methodological standards that cover these data needs? (iii) recommendations how to make optimal use of existing monitoring information (iv) identify where it is possible to make improvements by targeted and focused additional monitoring List existing Quality Assurance guidelines for the descriptor e.g. regional conventions, CEN, ISO and national guidelines which could be relevant, and assess where further guidelines need to be developed, identifying the appropriate scale (EU, regional, national).
6	Research needs	Assess the level of maturity of our understanding of the descriptor. This is expected to widely vary among descriptors, but also among marine regions. This should be discussed and where relevant, research priorities identified and recommended.

Selected group publications

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European Commission

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Abstract

The Marine Strategy Framework Directive (2008/56/EC) (MSFD) requires that the European Commission (by 15 July 2010) should lay down criteria and methodological standards to allow consistency in approach in evaluating the extent to which Good Environmental Status (GES) is being achieved. ICES and JRC were contracted to provide scientific support for the Commission in meeting this obligation.

A total of 10 reports have been prepared relating to the descriptors of GES listed in Annex I of the Directive. Eight reports have been prepared by groups of independent experts coordinated by JRC and ICES in response to this contract. In addition, reports for two descriptors (Contaminants in fish and other seafood and Marine litter) were written by expert groups coordinated by DG SANCO and IFREMER respectively.

A Task Group was established for each of the qualitative Descriptors. Each Task Group consisted of selected experts providing experience related to the four marine regions (the Baltic Sea, the North-east Atlantic, the Mediterranean Sea and the Black Sea) and an appropriate scope of relevant scientific expertise. Observers from the Regional Seas Conventions were also invited to each Task Group to help ensure the inclusion of relevant work by those Conventions. This is the report of Task Group 5 Eutrophication.

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

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