Descriptor 5: Eutrophication

Definition of Eutrophication: 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.

Definition of GES: "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".

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. 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.

Based on the conclusions and proposals of the MSFD TG5 **„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"**.

Criteria and indicators for Descriptor 5: Eutrophication (Commission decision, 2010/477/EU):

Criteria	Indicator
5.1. Nutrients levels	5.1.1. Nutrients concentration in the water column
	5.1.2. Nutrient ratios (silica, nitrogen and phosphorus), where appropriate
5.2. Direct effects of nutrient enrichment	5.2.1. Chlorophyll *a* concentration in the water column
	5.2.2. Water transparency related to increase in suspended algae, where relevant
	5.2.3. Abundance of opportunistic macroalgae
	5.2.4. Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities
5.3. Indirect effects of nutrient enrichment	5.3.1. Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency
	5.3.2. Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned

The legal framework

The legal framework on which GES evaluation for descriptor 5: Eutrophication is based:

National level
Regulation of water quality standards (OG 73/13)

EU level
Water Frame Directive (WFD, 2000/60/EC)

Regional sea level
Barcelona convention
HELCOM Baltic Sea Action Plan
OSPAR Quality Status Report 2010 (OSPAR, 2010)

Descriptor state based on Initial assessment

According to the initial assessment, eutrophication in the Croatian part of the Adriatic Sea is mainly manifested at the local level. The ecological status of this part of the Adriatic is in its most part very good that is of the highest quality. Initial assessment agrees with the condition that was found during the implementation of the WFD. This is primarily because most of the coastal waters defined under WFD coincides with the ones defined in MSFD, due to indented coastline and notable insular system. Good condition of the ecosystem, from the standpoint of eutrophication, was observed only in the Limski kanal, Pula, Rijeka and Split harbour and the Bakar Bay. The worst situation was observed in the area of Šibenik bay where it is close to moderate. These are all areas under significant anthropogenic influence, mainly because of unresolved urban waste water drainage system. Although in all these areas these systems are under construction or are newly constructed, a significant reduction in the degree of eutrophication is expected in the coming years. Particularly interesting areas are Limski kanal and Bakar Bay, which are partly under the influence of natural eutrophication and its anthropogenic component.

Any imbalance in the marine ecosystem is primarily reflected at the first trophic level, and the monitoring of phytoplankton biomass can gain a good insight into the overall state of the marine ecosystem. The increase in phytoplankton biomass, usually is caused by the increased availability of nutrients, and to a certain degree, this process has a positive effect on secondary production and the entire ecosystem. From this point of view the northern Adriatic, which is one of the most productive parts of the Mediterranean Sea, and which is under the direct influence of the Po River, the third by river flow (1540 m^3 s^{-1}) in the Mediterranean, demand particular attention. If we consider that data collected over a period of more than 40 years at the station SJ107 (13 Nm off Rovinj) may represents what is happening in the northern Adriatic open waters (Figure 5.1) it arises that the concentration of chlorophyll *a* is characteristic of an uneutrophied coastal sea and show a significant interannual variability. The variability can be attributed to natural and anthropogenic components of eutrophication (Mozetič *et al.*, 2010). An important assumption, derived from the analysis of all available data on the eutrophication of the Adriatic, is that the regional component of the problem is significant compared to most of the Croatian coast.

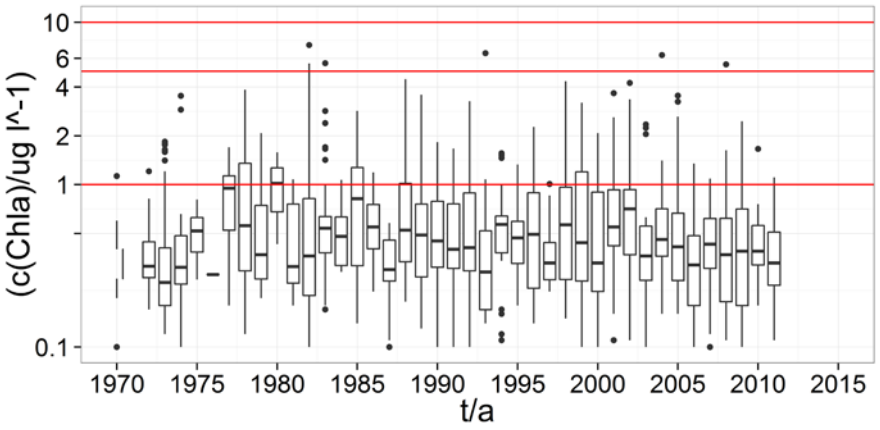

Figure 5.1. Box and Whisker representation of concentration (c) of chlorophyll *a* for the period 1970-2011 at station SJ107 (13 Nm W off Rovinj). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

The main pressures and impacts

Over the past century in the area of Croatian waters along the eastern coast of the Adriatic, there was an increase in human activities, as their intensity as influenced area. This resulted in an increase in various types of pressures on the marine environment, especially the load of nutrients to the marine ecosystem. The main pressures that directly affect the eutrophication in Croatian waters are described in detail in the Initial assessment.

GES assessment and objectives

Assessment of GES for eutrophication in the Croatian part of the Adriatic Sea is based on the conclusions and proposals of the MSFD TG5.

Assessment of GES for indicator 5.2.1 (Concentration of chlorophyll *a* in the water column) is based on the work of a group of Italian, Slovenian and Croatian experts as a common approach to the assessment of the condition of the Biological Quality Element (BQE) - Phytoplankton for WFD and an effort to develop common criteria at the Adriatic level. For this purpose all the available data for the period 2007-2009 were combined and a model relating pressure (as total phosphorus) and state (as chlorophyll *a* concentration, Figure 5.2) developed.

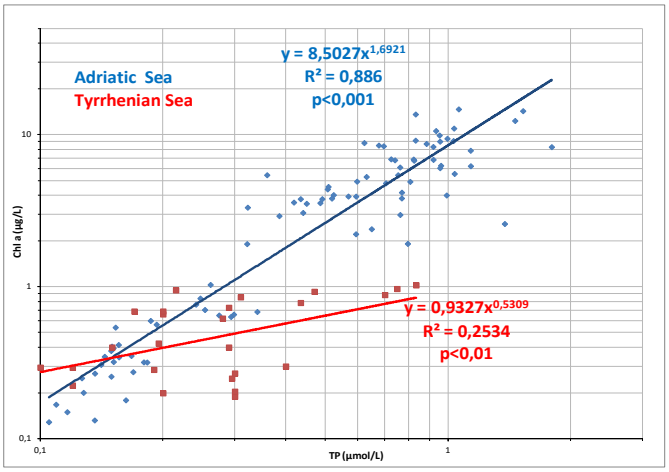

Figure 5.2. The mean annual (geometric mean) concentrations of chlorophyll *a* (Chl a) and total phosphorus (TP) for the Adriatic and Tyrrhenian Sea.

Based on the model a classification of BQE - Phytoplankton was developed, which is summarily shown for different types of water (defined for the WFD intercalibration by EC in 2008 and confirmed in 2013; EU/2013/266) in Table 5.1. Boundaries between good (G) and moderate condition (M) were used to assess GES. Classification according to the Regulation on water quality standards (OG 73/13) for the WFD is expected to align with the future decision of the EC on the results of intercalibration.

Table 5.1. Boundaries for TRIX, Chl a (g. mean and 90th per.), Total Phosphorous (TP) and EQR (real and normalized) by Type. Different metrics (geom. mean and 90th percentile) are shown for comparison with the Italian and Slovenian definition of GES.

Type I

Boundaries	TRIX	Chl *a* annual g. mean (µg/L)	Chl *a* 90th percentile (µg/L)	EQR real	EQRs normalized	TP annual g. mean (µM/L)
Ref. value	-	0.8	2.3	1	1	0.24
VG/G	5.0	2.5	7.0	0.32	0.78	0.4
G/M	5.7	6.2	17.3	0.13	0.59	0.6
M/P	6.4	15.1	42.5	0.05	0.39	0.9
P/B	7.1	37.1	104.4	0.02	0.20	1.6

Type IIA- Adriatic

Boundaries	TRIX	Chl *a* annual g. mean (µg/L)	Chl *a* 90th percentile (µg/L)	EQR real	EQRs normalized	TP annual g. mean (µM/L)
Ref. value	-	0.15	0.36	1	1	-
VG/G	3.7	0.65	1.58	0.230	0.75	0.23
G/M	4.5	1.57	3.81	0.095	0.58	0.37
M/P	5.3	3.79	9.20	0.040	0.41	0.61
P/B	6.1	9.14	22.17	0.016	0.22	1.01

VG- very good; G – good; M – moderate; P – poor and B – bad

Table 5.2. Criteria, indicators, and proposed objectives and GES definition for descriptor 5: Eutrophication in the Croatian part of the Adriatic Sea.

Criteria	Indicators	Objectives and GES definition
5.1. Nutrients levels	5.1.1. Nutrients concentration in the water column	GES for the indicator concentration of nutrients in the water column is achieved if the average annual value (geometric mean) for individual nutrients is not higher than: total phosphorus (TP) 1.4 µmol/L; total inorganic nitrogen (TIN) 2.4 µmol/L; orthophosphate (PO_4) 0.15 µmol/L.
	5.1.2. Nutrient ratios (silica, nitrogen and phosphorus), where appropriate	Not applicable due to the assumption that phosphorus is a limiting factor.
5.2. Direct effects of nutrient enrichment	5.2.1. Chlorophyll *a* concentration in the water column	GES in the water column is preserved if the biological community remains balanced and retains all the functions in the absence of undesirable disturbances caused by eutrophication particularly excessive algal blooms. The concentration of chlorophyll *a* should not on an annual basis exceed the value of 1.57 µg/L (geometric mean) or 3.81 µg/L (90^{th} percentile) or EQR <0.58 (WFD).
	5.2.2. Water transparency related to increase in suspended algae, where relevant	Not applicable.
	5.2.3. Abundance of opportunistic macroalgae	GES of benthic communities on hard bottoms are not reduced. CARLIT (Cartography of Littoral) method (developed under the WFD); boundaries: EQR > 0.61 Distribution of biocenoses is maintained.
	5.2.4. Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities	GES in the water column is preserved if the biological community remains balanced and retains all the functions in the absence of undesirable disturbances caused by eutrophication particularly excessive algal blooms. This refers to the index of high abundance of phytoplankton I_E, which describes the frequency and extent of phytoplankton blooms and whose value does not exceed 0.2.
5.3. Indirect effects of nutrient enrichment	5.3.1. Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency	GES is preserved if the area occupied by the settlements of *Posidonia oceanica* is not reduced. Mapping of settlements (developed under the Habitats Directive). The environmental quality of the *Posidonia oceanica* settlements is not reduced. POMI (Posidonia Oceanica Multivariate Index, developed under the WFD) EQR value > 0.55; measurement of the upper and lower edge of the settlements; boundaries: under development.
	5.3.2.Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned	The concentration of oxygen in the bottom layer must be sufficient for the survival of marine fauna. Due to anthropogenic activities episodes of decrease of concentration of oxygen (hypoxia) must be temporally and spatially limited not to cause mortality of benthic organisms. It should not occur complete disappearance of oxygen in the bottom layer (anoxia). Indicators are the concentration of dissolved oxygen in the bottom layer, the spatial extent of anoxia or hypoxia, and their duration. GES is preserved when the oxygen concentration is not less than 2 mg/L as a boundary value between anoxia and hypoxia.

Table 5.3. GES assessment and objectives

Criteria	Indicator	Use of criteria and indicators	GES maintained	Objectives
5.1. Nutrients levels	5.1.1. Nutrients concentration in the water column	**YES**	**YES** In most of the ecosystem the biological community remains balanced and retains all the functions in the absence of undesirable disturbances caused by eutrophication.	Maintain existing levels of nutrients in the water column. Encourage the proper use of fertilizers in agriculture to reduce the input of nutrients in natural streams.
	5.1.2. Nutrient ratios (silica, nitrogen and phosphorus), where appropriate	**NO**	–	–
5.2. Direct effects of nutrient enrichment	5.2.1. Chlorophyll *a* concentration in the water column	**YES**	**YES** In most of the ecosystem the biological community remains balanced and retains all the functions in the absence of undesirable disturbances caused by eutrophication.	Chlorophyll *a* concentrations are not increasing.
	5.2.2. Water transparency related to increase in suspended algae, where relevant	**NO**	–	–
	5.2.3. Abundance of opportunistic macroalgae	**YES**	**YES** GES benthic communities on hard bottoms are not reduced. Distribution of biocenoses is maintained.	Abundance of opportunistic macroalgae is not increasing. Their coverage declines.
	5.2.4. Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities	**NO**	–	–
5.3. Indirect effects of nutrient enrichment	5.3.1. Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency	**NO**	**YES** Condition and functioning of benthic communities are in harmony with natural processes in the ecosystem and are not adversely altered.	Distribution and coverage of the sea bottom with marine algae and seagrasses are within the natural cycles. Distribution of biocenoses is maintained.
	5.3.2. Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned	**YES**	**YES** GES is maintained, values below the limit of hypoxia are not recorded.	Maintain existing or lower the load to the ecosystem from anthropogenic sources. No occurrence of anoxia and mortality of benthic organisms.

Connections/relationships with other descriptors

Descriptor 5 is associated with the first (Biodiversity), 4th (Food web) and 6th (Seabed integrity) descriptor. Considering the eutrophication impact on the ecosystem above descriptors are mainly defined as state ones. Some of the mentioned descriptors are used as direct indicators of eutrophication and are built in the 5th descriptor.

Disadvantages, enhancements, and further research needs

Indicator 5.2.4. (Changes in the floristic composition of species such as the ratio between diatoms and dinoflagellates, changes in the benthic pelagic species, as well as the occurrence of harmful/toxic algal blooms (such as cyanobacteria) caused by human activity) is one of the most important problems for eutrophication since it indicates the environmental dimension of the descriptor. Unfortunately, its complexity, methodological problems and high costs represent a significant limitation in its usability. In this regard, further research is needed to define a usable multimetric index as indicator.

Table 5.4. shows the list of indicators, the most suitable time frame and metric for monitoring the state of eutrophication, as guidelines and instructions for the development of a monitoring and observing system for continuous assessment of the Adriatic Sea.

Table 5.4. List of indicators, the most suitable time frame and metric for monitoring the state of eutrophication.

Indicator type	Indicator	Sampling time frame	Metric	
Pressure	nutrient load (Nitrogen, Phosphorus)	annual estimate	t/a, calculated from river, direct industrial and urban loads. LBA protocol as a basis.	systematic monitoring within the descriptor 5
State and impact	increase in primary production	annual estimate	chlorophyll *a* concentration integrated with satellite observations and modelling.	
	chlorophyll *a* concentration	monthly or more frequently	mean annual values (geometric mean or 90th percentile)	
	dissolved oxygen concentration	monthly or more frequently	mean annual values (10th percentile)	
	undesirable and toxic blooms	annual events	blooms harmful to living resources (frequency, duration and area affected)	
	concentration of nutrients	monthly or more frequently	mean annual values (geometric mean)	
	changes in community structure	annual or multi-year	changes from natural community to one dominated by opportunistic species, changes in the balance between diatoms/dinoflagellates/ cyanobacteria (multimetric index)	under development
	underwater vegetation	annual	changes in spatial coverage and density	together with descriptors 1 and 6
	benthic communities	annual	changes in diversity and relation between sensitive and non-sensitive species (multimetric index – M-AMBI)	
	benthic organisms/fish	irregular systematic observations – mortality records	massive mortality of benthic organisms/fish (event records)	