UNITED NATIONS

EP

UNEP/MED WG.626/4/Rev.1

UN environment programme | Mediterranean Action Plan Barcelona Convention

09 May 2025
Original: English

Joint Meeting of the Ecosystem Approach Correspondence Groups on Pollution and Marine Litter Monitoring

Anavyssos, Greece, 27 - 28 May 2025

Agenda item 4: Guidance Factsheets for IMAP Pollution Indicators

Updated Guidance Factsheets for IMAP Common Indicators 13, 14, 17, 18, 20 and 21

UNEP/MAP
Athens, 2025

Note by the Secretariat

At the 19th Meeting of the Contracting Parties (COP 19) held in February 2016, the Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria was adopted through Decision IG.22/7. This decision established regionally agreed descriptions of Good Environmental Status (GES), common indicators, targets, and a timeline for implementation.

In alignment with IMAP, Guidance Factsheets for the IMAP Pollution Common Indicators were developed, reviewed, and endorsed by the Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring (CorMon on Pollution Monitoring) in Marseille, France (October 2016), and the Meeting of the MED POL Focal Points in Rome, Italy (May 2017). Subsequently, these Guidance Factsheets were approved by the 6th Meeting of the Ecosystem Approach Coordination Group in Athens, Greece (September 2017), and utilized in the preparation of the 2017 Mediterranean Quality Status Report (2017 MED QSR).

Pursuant to Decision IG.22/7 (COP 19, 2016), and Decision IG.23/6 (COP 20, 2017) concerning the 2017 Mediterranean Quality Status Report (MED QSR), the Guidance Factsheets were updated in 2019 for Common Indicators 13, 14, 17, 18, 20, and 21, which pertain to Ecological Objectives 5 (Eutrophication) and 9 (Contaminants). Additionally, initial Guidance Factsheets were developed for Candidate Common Indicators 26 and 27, related to Ecological Objective 11 (Energy, including underwater noise). These updates were approved by the Meeting of MED POL Focal Points (May 2019) and the 7th Meeting of the Ecosystem Approach Coordination Group (September 2019), supporting IMAP Pollution implementation by the Contracting Parties over the past three biennia.

In accordance with Decision IG.24/4 on Assessment Studies, monitoring and assessment tools, practices, and standards were developed as outlined in the 2023 Mediterranean Quality Status Report (2023 MED QSR) roadmap and needs assessment. The significant progress achieved since 2019 culminated in the preparation of the 2023 MED QSR adopted by Decision IG.26/3 (COP 23, 2023) concerning the 2023 MED QSR and a Renewed Ecosystem Approach Policy in the Mediterranean.

Furthering this progress, Decision IG.26/14 on the Programme of Work and Budget for 2024–2025, (COP 23, 2023), mandated MED POL to deliver “e) IMAP pollution and marine Cluster CIs Guidance” under activity 6.2.2. This activity focuses on upgrading the assessment component of IMAP, including potential integrated assessments for all IMAP clusters, with an emphasis on assessment criteria and thresholds for indicators CI 1, 2, 6, 13, 14, 16, 17, 18, 21, 22, 23, and Candidate Common Indicator 25. This falls under Outcome 6.2: Science-based IMAP, foresight, and other assessments and assessment tools for a strengthened science-policy interface and decision-making.

Building upon the achievements as of 2019, the present document outlines the revision of the Guidance Factsheets for Common Indicators 13, 14, 17, 18, 20, and 21, incorporating achievements in monitoring and assessment practices, methodologies, and environmental criteria as approved for the preparation of the 2023 MED QSR by the Meetings of the Ecosystem Approach Correspondence Group on Pollution, MED POL Focal Points, and Ecosystem Approach Coordination Groups held in 2020, 2021, 2022 and 2023. The present document does not include targets for IMAP Common Indicators 13, 14, 17, 18, 20, and 21, as their minor adjustments are included in working document UNEP/MED WG.262/3 for further consideration at the current meeting. Following the decisions to be taken in this regard, the revised GES targets will be included in the revised IMAP Pollution Indicators Factsheets outline in this document.

This document is submitted for review and endorsement to the current Joint Meeting of the Ecosystem Approach Correspondence Group on Pollution and Marine Litter Monitoring. Following the expected endorsement, it will be submitted to the Meeting of MED POL Focal Points, scheduled to take place in Athens, Greece, on 17–18 June 2025.

Table of Contents

1. Introduction

1. This document presents the revised Guidance Factsheets for IMAP Common Indicators 13, 14, 17, 18, 20, and 21, revising the IMAP Pollution Cluster in accordance with Decision IG.26/3 (COP 23, 2023) concerning the 2023 Mediterranean Quality Status Report (MED QSR) and the Renewed Ecosystem Approach Policy in the Mediterranean.

2. The current revision builds upon achievements endorsed for the preparation of the 2023 Mediterranean Quality Status report (2023 MED QSR) by the Ecosystem Approach Correspondence Group on Pollution, MED POL Focal Points, and Ecosystem Approach Coordination Groups during meetings held in 2020, 2021, 2022 and 2023.

3. These foundational achievements determining the revision of the IMAP Pollution Cluster include:

a) **Strengthening the assessment criteria**, including:

i. Updating the Background Criteria (BC) and Background Assessment Criteria (BAC) values for IMAP Common Indicator 17, at both at sub-regional and regional levels, and the Environmental Assessment Criteria (EAC) values for IMAP Common Indicator 20.

ii. Setting reference conditions and Good/Moderate (G/M) boundary values for chlorophyll-a (Chl a), total phosphorus (TP), and dissolved inorganic nitrogen (DIN) in coastal and open (offshore) waters of the Adriatic Sea Sub-region.

iii. Proposing methodologies for the future revision of EAC values for IMAP Common Indicators 17, 18, and 20, set to commence implementation in 2025.

b) **Defining integration and aggregation rules for monitoring and assessment**, including:

i. Developing a methodology to propose assessment spatial scales based on monitoring scales defined in national IMAP Pollution monitoring programmes, while also taking into account the assessment areas established under national MSFD monitoring strategies by EU Member State Contracting Parties.

ii. Establishing rules for the integration of monitoring and assessment areas within the IMAP Pollution and Marine Litter Cluster (Ecological Objectives EO5, EO9, EO10), while considering interrelations with the Coast and Hydrography (EO6, EO7) and Biodiversity (EO1) Clusters.

iii. Setting rules for the aggregation and integration of assessments across specific IMAP Common Indicators and Ecological Objectives, contributing to an integrated Good Environmental Status (GES) assessment for the IMAP Pollution Cluster.

c) **Development, testing, and implementation of GES and alternative environmental assessment methodologies by applying the integration and aggregation rules, alongside the assessment scales, assessment criteria, and the DPSIR approach within the IMAP nested framework**. This work included:

i. the NEAT IMAP GES assessment methodology across the nested assessment areas (CIs 13, 14, and 17);

ii. the CHASE+ assessment methodology (CIs 13, 14, and 17);

iii. the Ecological Quality Ratio (EQR) methodology (CIs 13 and 14);

iv. the simplified EQR methodology (CI 14);

v. the simplified Good/Moderate (G/M) status comparison methodology (CI 14);

vi. the assessment approach for biological effects, based on the use of relevant literature sources;

vii. the assessment approach for contaminants in seafood, using concentration limits for contaminants regulated within the EU;

viii. the assessment approach for bathing water quality, incorporating both the results presented in the European Environment Agency's 2020 Assessment Report on the State of Bathing Water Quality and monitoring data reported under IMAP; and

ix. the adapted exposure index and assessment methodology in line with EU Threshold Values for Impulsive and Continuous Underwater Sound.

4. Despite the limited data reporting by the Contracting Parties, as stipulated in Decisions IG.23/6 and IG.24/4, based on the results outlined above, **seventeen thematic pollution assessments were developed in 2022 and 2023 for the nine Mediterranean Sea areas/sub-divisions**. These assessments provided the foundation for assessing the four Mediterranean sub-regions, as detailed in the 2023 Mediterranean Quality Status Report (2023 MED QSR). They currently serve as a basis for revising the assessment component of the IMAP Guidance Factsheet.

5. The current revision of IMAP Pollution i.e. Common Indicators 13&14, 17, 18, 20 and 21 also builds upon the following achievements:

d) **Monitoring Guidelines**: These are structured around specific 97 technical protocols for IMAP Common Indicators 13, 14, 17, 18, 20, and 21, and were comprehensively developed by the MED POL Programme in cooperation with IAEA/MESL. The guidelines were approved by the MED POL Focal Points Meeting in 2021, and thereafter used to reinforce national monitoring efforts.

e) **Preparation of National IMAPs** and lessons learned during their initial implementation phase.

f) **Data Standards and Data Dictionaries**: Developed and integrated into the IMAP Info System for IMAP Common Indicators 13, 14, 17, 18, 20, and 21 to support standardized and harmonized data reporting by the Contracting Parties.

g) **Advancement of Quality Assurance and Quality Control (QA/QC)** efforts through:

i. Upgrading interlaboratory QA/QC procedures for IMAP Common Indicator 17, and establishing QA/QC procedures for Common Indicators 13 and 14 (covering inorganic nutrients in high salinity seawater, estuarine and low salinity seawater, and chlorophyll a and phaeopigments in seawater), as well as contaminants in seafood for Common Indicator 20 (including heavy metals, PAHs, dioxins, and PCBs).

ii. Defining interlaboratory QA/QC procedures for IMAP Common Indicator 18.

iii. Establishing initial data quality control range categories for physico-chemical parameters (Common Indicators 13&14) and contaminants (Common Indicator 17), using appropriate statistical methods and scientific expertise to ensure the quality of data reported into the IMAP Info System. These quality control categories have been integrated into the system as of 2024.

h) **Incorporating New Scientific and Policy Developments**: Evolutions since 2019 have been leveraged to support the above achievements under IMAP Pollution monitoring and implementation.

2. Guidance Factsheet on IMAP Common Indicators 13 and 14

6. The revision of IMAP **Common Indicator 13 (EO5)**: "Concentration of key nutrients in water column" is presented in the table bellow.

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**[1]

[1] Following the decisions to be made at the present meeting regarding minor adjustments to the Targets, as outlined in working document UNEP/MED WG.626/3/Rev.1, the revised Targets will be incorporated into the revised IMAP Pollution Indicators Factsheets.

<table>
<tr><td>Indicator Title</td><td colspan="2">Common Indicator 13. Concentration of key nutrients in water column (EO5)</td></tr>
<tr><td>Concentrations of nutrients in the euphotic layer are in line with prevailing physiographic, geographic and climate conditions</td><td>Human introduction of nutrients in the marine environment is not conducive to eutrophication</td><td></td></tr>
<tr><td colspan="3">Rational</td></tr>
<tr><td colspan="3">Justification for indicator selection

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 (IMAP, 2017)[2]. The direct and indirect consequences of eutrophication are undesirable when they degrade ecosystem health and/or the sustainable provision of goods and services, such as algal blooms, dissolved oxygen deficiency, declines in sea-grasses, mortality of benthic organisms and/or fish. Although, these changes may also occur due to natural processes, the management concern begins when they are attributed to anthropogenic sources.
Seawaters depending on nutrient loading and phytoplankton growth are classified according to their level of eutrophication. Low nutrient/ phytoplankton levels characterize oligotrophic areas, water enriched in nutrients is characterized as mesotrophic, whereas water rich in nutrients and algal biomass is characterized as eutrophic.</td></tr>
<tr><td colspan="3">Scientific References
Norris, N. 1940. The Standard Errors of the Geometric and Harmonic Means and Their Application to Index Numbers. Ann. Math. Statist. 11(4): 445-448. doi:10.1214/aoms/1177731830

Kirkwood, T.B.L., 1979. Geometric means and measures of dispersion. Biometrics, 35, 908-909.

Brzezinski M.A., 1985. The Si:C:N ratio of marine diatoms: interspecific variability and the effect of some environmental variables. Journal of Phycology, Vo. 21, pp. 347–357.

Giovanardi, F., Tromellini, E., (1992). An empirical dispersion model for total phosphorus in a coastal area: the Po River-Adriatic system. Sci. Total Environ. Supplement 201–210. doi:10.1016/B978-0444-9990-3.50022-5.

Conley D.J., Schelske C.L., Stoermer E. F., 1993. Modification of the biogeochemical cycle of silica with eutrophication. Mar. Ecol. Prog. Ser. 101, 179-192.
Cushman-Roisin, B., Gačić, M., Poulain, P-M., Artegianni, A., 2001. Physical Oceanography of the Adriatic Sea, Past, Present and Future, Springer Science + Business Media, Dordrecht, 312 pp.

Devlin, M., Painting, S., Best, M., 2007. Setting nutrient thresholds to support an ecological assessment based on nutrient enrichment, potential primary production and undesirable disturbance. Mar. Poll., 55., 65-73
Carstensen J., 2007. Statistical principles for ecological status classification of Water Framework Directive monitoring data. Mar. Poll., 55, 3-15.
Carletti, A., Heiskanen, A. S. (2009). Water Framework Directive intercalibration technical report. Part 3: Coastal and Transitional waters. JRC-IES EUR 23838 EN/3, pp 244.

Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., and Feld, C. K. (2010). The European water framework directive at the age of 10: a critical review of the achievements with recommendations for the future. Sci. Total Environ. 408, 4007–4019.

Borja, A., Elliott, M., Henriksen, P., and Marb, N. (2013). Transitional and coastal waters ecological status assessment: advances and challenges resulting from implementing the European water</td></tr>
</table>

[2] IMAP (2017) Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria, UN Environment/MAP Athens, Greece, pp 52.

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

framework directive. Hydrobiologia 704, 213–229. doi: 10.1007/s10750-012-1276-9

Borja A., Elliott M., Andersen J.H., Berg T., Carstensen J., Halpern B.S., Heiskanen A.-S., Korpinen S., Lowndes J.S.S., Martin G. and Rodriguez-Ezpeleta N. (2016) Overview of Integrative Assessment of Marine Systems: The Ecosystem Approach in Practice. Front. Mar. Sci., 3: 20. doi: 10.3389/fmars.2016.00020.

Dworak, T., Berglund, M., Haider, S., Leujak, W. and Claussen, U. (2016). A comparison of European nutrient boundaries for transitional, coastal and marine waters. Working Group on ecological Status ECOSTAT

Phillips,G., Kelly M., Leujak W., Salas F., Teixeira H. 2017. Best Practice Guide on establishing nutrient concentrations to support good ecological status. Common Implementation Strategy for the Water Framework Directive and the Floods Directive. 138 pp.

Berg, T., Murray, C., Carstensen, J., and Andersen, J. H. (2017). NEAT – Nested Environmental Status Assessment Tool - Manual Version 1.3. DEVOTES project.

Nemati, H., M. R. Shokri, Z. Ramezanpour, G. H. Ebrahimi Pour, I. Muxika, Á. Borja, 2017. Using multiple indicators to assess the environmental status in impacted and non-impacted bathing waters in the Iranian Caspian Sea. Ecological Indicators, 82: 175-182.

Giovanardi, F., Francé, J., Mozetič, P., Precali, R. (2018). Development of ecological classification criteria for the Biological Quality Element phytoplankton for Adriatic and Tyrrhenian coastal waters by means of chlorophyll a (2000/60/EC WFD). Ecological Indicators. 93. 316-332. doi: 10.1016/j.ecolind.2018.05.015.

Borja, A., J. M. Garmendia, I. Menchaca, A. Uriarte, Y. Sagarmínaga, 2019. Yes, We Can! Large-Scale Integrative Assessment of European Regional Seas, Using Open Access Databases. Frontiers in Marine Science, 6: 10.3389/fmars.2019.00019.

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

Borja, A., I. Menchaca, J. M. Garmendia, J. Franco, J. Larreta, Y. Sagarminaga, Y. Schembri, R. González, R. Antón, T. Micallef, S. Camilleri, O. Solaun, A. Uriarte, M. C. Uyarra, 2021. Big Insights From a Small Country: The Added Value of Integrated Assessment in the Marine Environmental Status Evaluation of Malta. Frontiers in Marine Science, 8: 10.3389/fmars.2021.638232.

Kazanidis, G., C. Orejas, A. Borja, E. Kenchington, L.-A. Henry, O. Callery, M. Carreiro-Silva, H. Egilsdottir, E. Giacomello, A. Grehan, L. Menot, T. Morato, S. Á. Ragnarsson, J. L. Rueda, D. Stirling, T. Stratmann, D. van Oevelen, A. Palialexis, D. Johnson, J. M. Roberts, 2020. Assessing the environmental status of selected North Atlantic deep-sea ecosystems. Ecological Indicators, 119: 106624.

R Development Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org

Policy Context and targets

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

Policy context description

In the Mediterranean, the UNEP/MAP MED POL Monitoring programme included from its inception the study of eutrophication as part of its seven pilot projects approved by the Contracting Parties at the Barcelona meeting in 1975 (UNEP MAP, 1990a,b). The issue of a consistent monitoring strategy and assessment of eutrophication was first raised at the UNEP/MAP MED POL National Coordinators Meeting in 2001 (Venice, Italy) which recommended to the Secretariat to elaborate a draft programme for monitoring of eutrophication in the Mediterranean coastal waters (UNEP/MAP MED POL, 2003). In spite of a series of assessments reviewing the concept and state of eutrophication, there are important gaps in the capacity to assess the intensity of this phenomenon. Efforts have been devoted to defining the concepts to assess the intensity and to extend experience beyond the initial sites in the Adriatic Sea, admittedly, the most eutrophic area in the entire Mediterranean Sea. In the context of the Mediterranean Sea, the monitoring and assessment of eutrophication were redefined in accordance with ~~the European Marine Strategy Framework Directive (200/56/EC) and~~ the Integrated Monitoring and Assessment Programme (UNEP/MAP, 2016).~~,~~ This redefinition ensures synergy with ~~are the two main policy tools for the eutrophication phenomenon.~~ the European Marine Strategy Framework Directive (200/56/EC). The Data Dictionaries and Standards for IMAP Common Indicators 13 and 14 (2019, http://imapinfosystem.info-rac.org/app/#/standard), aligned with the IMAP Guidance Factsheets, defined the list of mandatory datasets, including physico-chemical parameters, to provide an integrated assessment of eutrophication.

Targets

~~For each considered marine spatial scale (region, sub-region, local water mass, etc.) the nutrient levels should be compared based on base reference levels and trends monitoring until commonly agreed thresholds have been scientifically assessed and agreed upon in the Mediterranean Sea.~~

As part of the preparation for the 2023 MED QSR eutrophication assessment, the NEAT (Nested Environmental Status Assessment Tool) Integrated Assessment for CIs 13 and 14, and The Scale of Simplified Assessment of Chlorophyll a (IMAP Common Indicator 14) have been established and applied in the Mediterranean sub-regions to assess the Good Environmental Status (GES), as applicable. The scales are outlined in the Guidance Factsheet for Common Indicator 14.

The reference and boundary values for Dissolved Inorganic Nitrogen (DIN) and Total Phosphorus (TP) have only been set for the Adriatic Sea Sub-region. In the absence of such values for other sub-regions, the scales of other assessment methodologies could not be set, including the Scale of Simplified Assessment, which was only applied to Chlorophyll-a based on satellite-derived data.

Policy documents

General Policy documents

Decision IG.22/7 (COP19, 2016) on~~-~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria.

Decision IG.21/3 (COP18,2013) on~~-~~ Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets.

Decision IG.25/1 (COP22, 2021) on UNEP/MAP Medium-Term Strategy 2022-2027.

Decision IG.22/7 (COP19, 2016) on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria.

Decision IG.23/6 (COP20, 2017) on 2017 Mediterranean Quality Status Report.

Decision IG.24/4 (COP21, 2019) on Assessment Studies.

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean.

UNEP(DEPI)/MED WG.363/Inf.21. (2011) Initial Integrated Assessment.
UNEP(DEC)/MED WG.372/3. (2012) Approaches for definition of GES and setting targets for the pollution related ecological objectives in the framework of the ecosystem approach. (EO5: eutrophication, EP9: contaminants, EP10: marine litter, EO11: noise).

UNEP(DEPI)/MED IG.22/Inf.7. (2016) Integrated Monitoring and Assessment Guidance
UNEP(DEPI)/MED WG.427/Inf.3. Background to the Assessment Criteria for Hazardous Substances and Biological Markers in the Mediterranean Sea Basin and its Regional Scales these revised assessment criteria.

2017 Mediterranean Quality Status Report, https://www.medqsr.org/node/10/

2023 Mediterranean Quality Status Report, medqsr2023.info-rac.org
Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

Commission Directive (EU) 2017/845 of 17 May 2017 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies.

Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardized methods for monitoring and assessment, and repealing Decision 2010/477/EU.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

~~Nutrient/~~Eutrophication related Policy documents

UNEP(DEPI)MED WG.231/14. (2003). Eutrophication Monitoring Strategy of UNEP/MAP MED POL.

UNEP/FAO/WHO (1996). 'Assessment of the state of eutrophication in the Mediterranean Sea'. MAP Technical Reports Series No 106. UNEP, Athens, 211 pp.

UNEP/MAP MED POL (1990a). Activity IV: Research on the effects of pollutants on Marine Organisms and their Populations (UNEP/MAP MED POL Phase I, 1975-1981).

UNEP/MAP MED POL (1990b). Activity V: Research on the effects of pollutants on Marine Communities and Ecosystems (UNEP/MAP MED POL Phase I, 1975-1981).

~~Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.~~
WFD CIS Guidance Document No. 5 (2003) Transitional and Coastal Waters Typology, Reference Conditions and Classification Systems.

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

UNEP(DEPI)/MED WG.417/Inf.15., (2015) Report of the online groups on eutrophication, contaminants and marine litter, pp 92

UNEP/MED WG.463/Inf.6. (2019) Updated Thematic Assessments of the Eutrophication and Contaminants Status in the Mediterranean Marine Environment, as a Contribution to the 2019 State of Environment and Development Report (SoED).

UNEP/MED WG.463/8., (2019), Approaches on Scales of Monitoring for Common Indicators related to pollution.

UNEP/MED WG.463/Inf.9 (2019). Example of overall interrelationships between the IMAP and the DPSIR framework applied to the coastal and marine ecosystem. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring.

UNEP/MED WG.509/10//Rev.2, (2021) Integration and Aggregation Rules for Monitoring and Assessment of (IMAP Pollution and Marine Litter Cluster).

UNEP/MED WG 533/ 4. (2022) Assessment Criteria Methodologies for IMAP Common Indicator 13: Reference and Boundary Values for DIN and TP in the Adriatic Sea Sub-region.

UNEP/MED.WG.550/10/Rev.1, (2023), 2023 Med QSR: The IMAP Pollution Cluster Chapters; Thematic Assessments.

UNEP/MED.WG.550/Inf.13 (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Assessment Results of IMAP Common Indicators 14 in the Central Mediterranean Sea Sub-region by Applying the Simplified G/M Assessment Methodology.

UNEP/MED WG.556/Inf.3/Rev.1. (2023), The Results of GES Assessment for IMAP Common Indicators 13 and 14 in the Adriatic Sea Sub-region by Applying the NEAT GES Assessment Methodology.

UNEP/MED WG.556/Inf.4/Rev.1. (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Assessment Results of IMAP Common Indicators 13&14 in the Aegean - Levantine Sea Sub-region by Applying the Simplified G/M Assessment Methodology.

UNEP/MED WG.556/Inf.5/Rev.1. (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Assessment Results of IMAP Common Indicators 13&14 in the Western Mediterranean Sea Sub-region by Applying the Simplified G/M and EQSR Assessment Methodologies .

UNEP/MED WG.556/Inf.16/Rev.1. (2023), The Updated GIS - based Layers for the Finest Areas of Assessment and the Areas of Assessment Nested to the Levels of Integration that are Considered Meaningful for Their Use Within Application of the NEAT GES Assessment Methodology for IMAP Common Indicators 13, 14 and 17 in the Adritic Sea Sub-region.

Indicator analysis methods

Indicator Definition

Concentration of key (inorganic) nutrients in the water column:
Nítrate (NO_3-N)
Nitrite (NO_2-N)
Ammonium (NH_4-N)
Total Nitrogen (TN)
Orthophosphate (PO_4-P)

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

Total Phosphorus (TP)
Orthosilicate (SiO_4-Si)

Sub-Indicators: Nutrient ratios (molar) of silica, nitrogen and phosphorus where appropriate: Si:N, N:P, Si:P

The list of all chemical and related parameters subject to reporting for IMAP CI 13 by the Contracting Parties is elaborated in the Data Standards for IMAP CI 13.

Methodology for indicator calculation

All: Spectrophotometry (manually or automated methods and instrumentation)

The detailed analytical procedure nutrients and other related mandatory parameters, including sampling and sample transportation, analytical determination of indicators and sub-indicators, data quality control are outlined in A-2: Guidelines/Protocols for sampling and determination of key nutrients and chlorophyll a in seawater outlines the analytical procedures for the determination of Chlorophyll a and its related sub-indicators.

Indicator units

All: micromol per liter, that is micromolar concentration (μmol/L =μM)
Ratios: adimensional (simple mathematical derivation of ratios from nutrient concentrations)

Data Standards for IMAP CI 13 elaborates units for all mandatory parameters.

List of Guidance documents and protocols available

i. ~~OSPAR, 2012. OSPAR MSFD Advice Document on Eutrophication. Approaches to determining good environmental status, setting of environmental targets and selecting indicators for Marine Strategy Framework Directive descriptor 5.~~
ii. ~~Piha, H., Zampoucas, N., 2011. Review of Methodological Standards Related to the Marine Strategy Framework Directive Criteria on Good Environmental Status. JRC Scientific and Technical Reports, EUR 24743 EN~~
iii. ~~UNEP/MAP MED POL (2005). Sampling and Analysis Techniques for the Eutrophication Monitoring Strategy of UNEP/MAP MED POL. MAP Technical Reports Series No. 163. UNEP, Athens. 61pp.~~
i. ~~Durairaj, P., Sarangi, R.K., Ramalingam, S. *et al*. Seasonal nitrate algorithms for nitrate retrieval using OCEANSAT-2 and MODIS-AQUA satellite data. Environ Monitoring Assess (2015) 187: 176.~~

IMAP Monitoring Guidelines/Protocols (https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/division-of-iaea-environment-laboratories/marine-environmental-studies-laboratory/unep-map-med-pol-integrated-monitoring-and-assessment-programme-imap-monitoring-guidelines)

- A-1. Monitoring Guidelines/Protocols for Sampling and Determination of Hydrographic Physical and Chemical Parameters;
- A-2: Guidelines/Protocols for sampling and determination of key nutrients and chlorophyll a in seawater outlines the analytical procedures for the determination of Chlorophyll a and its related sub-indicators;
- E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20;
- F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20.
  - ~~See also UNEP/MAP website (http://web.unep.org/unepmap)~~

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)
Data Confidence and uncertainties Despite the great variability born by the water layers subject to active hydrodynamic processes, monitoring the characteristics of the seawater is still the most direct way of assessing eutrophication. Inorganic nutrients may be determined either at the surface or at various depths. An external quality assurance by performing regional interlaboratory QA/QC exercises has been organized for contaminants in collaboration of the UNEP/MAP - MED POL and the IAEA/MESL since 1986. As of 2024, the IAEA/MESL, the scope of proficiency testing and training courses has been expanded to support the capacities of national laboratories in monitoring eutrophication (IMAP Common Indicators 13 & 14: inorganic nutrients in high salinity seawater, in estuarine and low salinity seawater, and chlorophyll a and Phaeopigments in Seawater) and contaminants in seafood (IMAP Common Indicator 20: heavy metals, polycyclic aromatic hydrocarbons (PAHs), dioxins, and PCBs). In addition, the data quality control range categories were initially established for physico-chemical parameters related to the monitoring of IMAP Common Indicators 13 and 14, as well as for contaminants related to the monitoring of Common Indicator 17, by applying relevant statistical methods and available scientific expertise in ensuring the quality of data reported to the IMAP Info System. These data control categories have been integrated into the IMAP Info System as of 2024.	
Methodology for monitoring, temporal and spatial scope	
Available Methodologies for Monitoring and Monitoring Protocols Traditional methods for eutrophication monitoring in coastal waters involve *in situ* sampling/measurements of commonly measured parameters such as nutrients concentration. Concerning available methods for *in situ* measurements, ships provide flexible platforms for eutrophication monitoring, while remote sensing provides opportunities for a synoptic view over regions or sub-regions. Besides traditional ship measurements, ferry-boxes and other autonomous measuring devices have been developed that allow high frequency and continuous measurements. Sampling for the determination of *in vitro* fluorescence and nutrient analysis may be carried out with relatively little effort if a properly equipped pump and hose system are mounted on the vessel. Measurements may be taken -at the surface or just below it using a water intake on the vessel`s hull, at fixed or varying depths with a towed "fish" and pumping system. Building on elements elaborated in the Integrated Monitoring and Assessment Programme (2016 IMAP), including the above-mentioned components, the Monitoring Guidelines—structured around the specific technical protocols related to IMAP Common Indicators 13 and 14—were comprehensively developed by the MED POL Programme in cooperation with IAEA/MESL. These guidelines were approved by the MED POL Focal Points Meeting (2021).They build upon the knowledge and practices obtained over 40 years of MED POL monitoring implementation and recent publications, highlighting the current practices of the Contracting Parties' marine laboratories, as well as other Regional Seas Conventions and the EU. A thorough analysis of presently available practices of UNEP/MAP, UNEP and IAEA, as well the HELCOM, OSPAR and European Commission Joint Research Centre was undertaken to assist an innovative approach for preparation of the IMAP Monitoring Guidelines/Protocols. The monitoring methodologies and practices are elaborated for sampling, sample preservation and transportation, sample preparation and analysis, along with quality assurance and reporting of monitoring data, for their use by the IMAP competent laboratories in order to ensure the representativeness and accuracy of the analytical results. These guidelines present a summary of the best available known practices employed in marine monitoring by bringing integrated comprehensive analytical practices that can be applied in order to ensure the representativeness and accuracy of the analytical results needed for generation of quality assured monitoring data.	

<table>
<tr><td>Indicator Title</td><td>Common Indicator 13. Concentration of key nutrients in water column (EO5)</td></tr>
<tr><td colspan="2">The Monitoring Guidelines for IMAP Common Indicators 13 and 14 outline the following monitoring and reporting practices:

o A-1. Monitoring Guidelines/Protocols for Sampling and Determination of Hydrographic Physical and Chemical Parameters;
o A-2: Guidelines/Protocols for sampling and determination of key nutrients and chlorophyll a in seawater outlines the analytical procedures for the determination of Chlorophyll a and its related sub-indicators;
o E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20;
o F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20.</td></tr>
<tr><td colspan="2">Available data sources

IMAP Info System (http://imapinfosystem.info-rac.org/app/#/) ~~MED POL Database.~~
~~MED POL Database.~~

EMODNET Chemistry:
http://www.emodnet-chemistry.eu/data_access.html

EEA Waterbase - Transitional, coastal and marine waters:
http://www.eea.europa.eu/data-and-maps/data/waterbase-transitional-coastal-and-marine-waters-11</td></tr>
<tr><td colspan="2">Spatial scope guidance and selection of monitoring stations

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 high nutrient loads, despite some natural symptoms of eutrophication can also be found, such as in upwelling areas. 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 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;
(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.

Therefore, the geographical scale of monitoring for the assessment of GES for eutrophication will depend on the hydrological and morphological conditions of an area, particularly the freshwater inputs from rivers, the salinity, the general circulation, upwelling and stratification. The spatial distribution of the monitoring stations should, prior to the establishment of the eutrophication status of the marine sub-region/area, be risk-based and proportionate to the anticipated extent of eutrophication in the sub-region under consideration as well as its hydrographic characteristics aiming for the determination of spatially homogeneous areas. The eutrophication monitoring programmes should pursue to assess the eutrophication phenomena, based on the differentiation of the scale and time dependant signals from human induced versus natural eutrophication.

As part of the 2023 MED QSR preparation, the assessment scales for CIs 13 and 14 are defined within the framework of the IMAP nested approach, building upon the elements outlined in the section on Assessment of Eutrophication.</td></tr>
<tr><td colspan="2">Temporal Scope guidance

Flexibility should be incorporated into the design of the monitoring programme to take account of differences in each marine sub-region/area. At the Mediterranean Sea latitudes, in general terms, the</td></tr>
</table>

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

pre-summer and winter primary production bloom intensity peaks of natural eutrophication ~~will~~ define the strategy for the sampling frequency, although year-round measurements of nutrients may be more appropriate.

The current national eutrophication monitoring programme, developed within the framework of IMAP implementation, has laid the foundation for marine environment monitoring in the Mediterranean. The optimum frequency (seasonal 2 to 4 times per year or monthly 12 times per year) for the monitoring of nutrients at the selected stations should be chosen taking into account the necessity of both to control the deviations of the known natural cycles of eutrophication in coastal areas and the control of (decreasing) trends monitoring impacted areas, therefore, from low frequency (minimum)to high frequency measurements.

Therefore, either for impacted or non-impacted coastal waters the optimal frequency per year and sampling locations needs to be selected at a local scale, whilst for open waters the sampling frequency to be determined on a sub-regional level following a risk-based approach.

Mainly, in order to build a robust sampling frequency scale in future a sounded statistical approach has to be developed that takes into account the discriminant limit between classes when the nutrient boundaries approach will be widely accepted.

Let consider the approach developed for CI14 - Chlorophyll a concentration in water column as an example to be used, as for this CI accepted boundaries exists.

Sampling frequency is determined by the variability of the measured parameters and is usually determined by how many samples are needed to reliably assess the differences between two neighbouring mean values.

Discriminant limit (ie power of applied test), depends on sample size:
Discriminant limit dM = sd * t(α/2; N1+N2-2) * √2; N1+N2-2) 0
For Chl-a log10 units for different sample size N with the significance level: $\alpha/2$ = 0,025; with an average sd = 0.30

N = 12 t = 2.074 √
N = 24 t = 2.013 √ = 24 = 0.289 dM > |0.17|
N = 52 t = 1,983 √ = 52 = 0.196 dM > |0.12|

Based on the above, it follows that a particular area can be characterized best by ~~if we~~ measuringe three relevant depths (typically 0, 5 and 10 m) at one station at least monthly or at three stations one depth (0 m). It is based on ~~at annual base~~ 36 samples annually which discriminates approximately~~around~~ 0.15 chla log10 unit for mesotrophic - eutrophic area that is slightly less than half difference between two classes (0.37 as log10 unit). Due to the smaller standard deviation in an oligotrophic area, the same results are achieved with half the frequency. The following sampling~~measurement~~ frequency is ~~proposed:~~ recommended as the guidance taking into account specific local conditions:

- Eutrophic – mesotrophic: monthly,
- Mesotrophic – oligotrophic: monthly near the coast, bimonthly in open waters, and
- Oligotrophic: bimonthly near the coast, seasonally in open waters.

Data analysis and assessment outputs

Despite the individual nutrient concentrations and nutrient ratios are ~~will be~~ evaluated based on statistical analysis against known reference levels and known marine eutrophication processes, following the evaluation of information provided by a number of countries and other available information, it has to be noted that the Mediterranean countries are using different eutrophication non-

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

mandatory assessment methods such as TRIX, UNTRIX, Eutrophication scale, EI, HEAT, OSPAR, etc. Nutrients concentrations are part of these tools and is very important to continue to be used at sub-regional or national levels because there is a long-term experience within countries which can reveal / be used for assessing eutrophication trends. As part of the preparation for the 2023 MED QSR, the most relevant and applicable methods for eutrophication assessment were explored, developed, and applied, as outlined in the following section. Further advancements in eutrophication assessment should address the gaps identified during the 2023 MED QSR process ~~However, in order to increase~~ to enhance coherency and comparability regarding of eutrophication assessment methodologies ~~is recommended that further efforts should be made to harmonize existing tools through workshops, dialogue and comparative exercises at regional/subregional/subdivision levels in Mediterranean with a view to further develop common assessment methods~~.

Assessment Criteria

As part of the preparation for the 2023 MED QSR, updated reference and boundary values were provided for Chlorophyll a. Additionally, new reference and boundary values were developed for Total Phosphorus (TP) and Dissolved Inorganic Nitrogen (DIN), as adopted by Decision 26/3 (COP23) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean (Table 1 below). However, due to insufficient data from other sub-regions, assessment criteria for DIN and TP were not established outside the Adriatic Sea Sub-region.

Table 1. Coastal water types in the Mediterranean, along with the new reference conditions and boundary values for Total Phosphorous (TP) and Dissolved Inorganic Nitrogen (DIN) for coastal and open (offshore) waters in the Adriatic Sea Sub-region.
Reference conditions and boundary (Good/Moderate status) values are based on long time series (>5 years) of monthly sampling at least.

	Coastal waters	
	Reference conditions of *c*(TP) (µmol/L)	**Boundaries of *c*(TP) (µmol/L) for G/M status**
Water Typology		
Type I		
Type I Adriatic	0,19 [a]	0,55 [a]
Type II-A-FR-SP[d]	-	-
Type II-A Adriatic	0,16 [a]	0,48 [a]
Type II-A[e] Tyrrhenian	-	-
Type III-W Adriatic[c]	-	0,26
Type III-W Tyrrhenian	-	-
Type III-W-FR-SP		
Type III-E		
Type Island-W		

	Open (offshore) waters in the Adriatic Sea Sub-region	
	Reference conditions of *c*(DIN) (µmol/L)	**Boundaries of *c*(DIN) (µmol/L) for G/M status**
Water Typology		
Type I Adriatic	0,21[g]; 0,66[h]	22.3
Type II-A Adriatic	-	-
Type III-W Adriatic [c]	-	-

[a] From Giovanardi et al, 2018
[c] The ecological classification scheme would not be suitable for proper and safe classification, and therefore the boundary values for WT III-W Adriatic waters are

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)

based on the H/G values for WT II-A Adriatic in coastal waters i.e. 0.64 µg/L for Chla and 0,26 µmol/L for TP
[d] Correction of error included to ensure consistency with the classification as provided in Commission Decision 2013/480/EU i.e. Type II -FR-SP, as included in Decision IG.22/7, replaced with Type II -A-FR-SP
[e] Correction of error included to ensure consistency with the classification as provided in Commission Decision 2013/480/EU i.e., Type II-A Tyrrhenian replaced Type II-B Tyrrhenian, as included in Decision IG.22/7, since the latter does not exist in the Tyrrhenian Sea
[g] for ME; [h] for HR, IT
[h] No pressure – effect relationship was found, and therefore RC for DIN and boundary G/M values for Chla and DIN could not be proposed.

Ongoing efforts focus on establishing the new reference and boundary values for Total Phosphorus (TP) and Dissolved Inorganic Nitrogen (DIN), and the updated reference and boundary values, where applicable, for Chlorophyll a (Chl *a*), in the selected pilot sub-region(s)/sub-division(s), depending on data availability.

Assessment of Eutrophication ~~Expected assessments outputs~~

As suggested by the on-line expert group on eutrophication established by the Contracting ~~p~~Parties it is recommended that with regard to nutrient concentrations, until commonly agreed thresholds have been determined and agreed upon, GES may be determined on a levels and trend monitoring basis.

The assessment methodologies for eutrophication, as developed and applied for the preparation of the 2023 MED QSR, are detailed in the IMAP Guidance Factsheet for IMAP CI 14. Due to the limited data available for nutrients, an integrated NEAT GES assessment was applied for CIs 13 and 14, focusing on total phosphorus and dissolved inorganic nitrogen along with Chlorophyll a in the Adriatic Sea Sub-region.

Known gaps and uncertainties in the Mediterranean

~~For a complete assessment of eutrophication and GES achievement, GES thresholds and reference conditions (natural background concentrations) are needed not only for chlorophyll *a*, but such values must be set, in the near future, through dedicated workshops and exercises also, water transparency and oxygen as minimum requirements, where appropriate. This should include quality assurance schemes, as well as data quality control protocols.~~

Nutrient, transparency and oxygen thresholds and reference values may not be identical for all areas, since it is recognized that area-specific environmental conditions must define threshold values. GES could be defined on a sub-regional level, or on a sub-division of the sub-region (such as the Northern Adriatic), due to local specificities in relation to the trophic level and the morphology of the area.

Further to the significant progress achieved over the last few biennia regarding the standardizing monitoring practices and establishing Good Environmental Status (GES) and environmental assessment tools—along with the improved availability of assessment criteria – it is essential—~~F~~, for a complete assessment of eutrophication and the ~~GES~~ achievement of GES, to define GES thresholds and reference conditions (natural background concentrations) ~~are needed~~ not only for chlorophyll *a*, but also ~~such values must be set~~for total phosphorus (TP) and dissolved inorganic nitrogen (DIN) across all sub-regions. This should build on the relevant experience gained in setting ~~, in the near future, through dedicated workshops and exercises also,~~reference and boundary values for these nutrients in the Adriatic Sea Sub-region,~~ water transparency and oxygen~~ as minimum requirements.~~,~~ ~~where appropriate.~~ This process should include quality assurance schemes, as well as data quality control

Indicator Title	Common Indicator 13. Concentration of key nutrients in water column (EO5)	
protocols. The progress in establishing reference and boundary values for total phosphorus (TP) and dissolved inorganic nitrogen (DIN) is outlined in the section above. By building on the achievements up to 2023, during the preparation of the 2023 MED QSR, several knowledge gaps were identified in the monitoring and assessment of Common Indicators 13 and 14, which need to be addressed following the recommendations of the 2023 MED POL Focal Points Meeting, as outlined in the Guidance Factsheet for IMAP CI 14.		
Contacts and V~~v~~ersion Date		
http://www.unepmap.org		
Version No	**Date**	**Author**
V.1	31.5.17	MEDPOL
V.2	10.1.19	MEDPOL
Final version	31/05/2019	Approved by the Meeting of MED POL FPs
Final version	09/09/2019	Approved by the 7th Meeting of EcAp Coordination Group
V4	28/05/2025	Joint CorMon Pollution and ML Meeting
V5		Approved by the Meeting of MED POL FPs
Final version		Approved by the 12th Meeting of EcAp Coordination Group

7. The revision of IMAP **Common Indicator 14 (EO5)**: "Chlorophyll a concentration in water column" is presented in the table bellow.

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**[3]
Natural levels of algal biomass, water transparency and oxygen concentrations in line with prevailing physiographic, geographic and weather conditions	Direct and indirect effects of nutrient over-enrichment are prevented	
Rational		
Justification for indicator selection 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 (IMAP, 2017)[4]. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services, such as excessive algal blooms, dissolved oxygen deficiency, declines in sea-grasses, mortality of benthic organisms		

[3] Following the decisions to be made at the present meeting regarding minor adjustments to the Targets, as outlined in working document UNEP/MED WG.626/3/Rev.1, the revised Targets will be incorporated into the revised
IMAP Pollution Indicators Factsheets.

[4] IMAP (2017) Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria, UN Environment/MAP Athens, Greece, pp 52.

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

and/or fish. Although, these changes may also occur due to natural processes, the management concern begins when they are attributed to anthropogenic sources.

Seawaters depending on nutrient loading and phytoplankton growth are classified according to their level of eutrophication. Low nutrient/ phytoplankton levels characterize oligotrophic areas, water enriched in nutrients is characterized as mesotrophic, whereas water rich in nutrients and algal biomass is characterized as eutrophic.

Scientific References

Norris, N. 1940. The Standard Errors of the Geometric and Harmonic Means and Their Application to Index Numbers. Ann. Math. Statist. 11(4): 445-448. doi:10.1214/aoms/1177731830

Kirkwood, T.B.L., 1979. Geometric means and measures of dispersion. Biometrics, 35, 908-909.

Giovanardi, F., Tromellini, E., (1992). An empirical dispersion model for total phosphorus in a coastal area: the Po River-Adriatic system. Sci. Total Environ. Supplement 201–210. doi:10.1016/B978-0444-9990-3.50022-5.

Vollenweider, R.A., Giovanardi F., Montanari, G., Rinaldi A., 1998. Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. Environmetrics, 9, 329-357.

Cushman-Roisin, B., Gačić, M., Poulain, P-M., Artegianni, A., 2001. Physical Oceanography of the Adriatic Sea, Past, Present and Future, Springer Science + Business Media, Dordrecht, 312 pp.

Boyer J.N. Kelble C.R., Ortner P.B., Rudnick D.T., 2009. Phytoplankton bloom status: Chlorophyll a biomass as an indicator of water quality condition in the southern estuaries of Florida, USA. Ecological Indicators 9s:s56- s67.

Carletti, A., Heiskanen, A. S. (2009). Water Framework Directive intercalibration technical report. Part 3: Coastal and Transitional waters. JRC-IES EUR 23838 EN/3, pp 244.

Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., and Feld, C. K. (2010). The European water framework directive at the age of 10: a critical review of the achievements with recommendations for the future. Sci. Total Environ. 408, 4007–4019.

Primpas I., Karydis M., 2011. Scaling the trophic index (TRIX) in oligotrophic marine environments. Environmental Monitoring and Assessment July 2011, Volume 178, Issue 1-4, pp 257-269.

Borja, A., Elliott, M., Henriksen, P., and Marb, N. (2013). Transitional and coastal waters ecological status assessment: advances and challenges resulting from implementing the European water framework directive. Hydrobiologia 704, 213–229. doi: 10.1007/s10750-012-1276-9

Borja A., Elliott M., Andersen J.H., Berg T., Carstensen J., Halpern B.S., Heiskanen A.-S., Korpinen S., Lowndes J.S.S., Martin G. and Rodriguez-Ezpeleta N. (2016) Overview of Integrative Assessment of Marine Systems: The Ecosystem Approach in Practice. Front. Mar. Sci., 3: 20. doi: 10.3389/fmars.2016.00020.

Dworak, T., Berglund, M., Haider, S., Leujak, W. and Claussen, U. (2016). A comparison of European nutrient boundaries for transitional, coastal and marine waters. Working Group on ecological Status ECOSTAT

Berg, T., Murray, C., Carstensen, J., and Andersen, J. H. (2017). NEAT – Nested Environmental Status Assessment Tool - Manual Version 1.3. DEVOTES project.

Nemati, H., M. R. Shokri, Z. Ramezanpour, G. H. Ebrahimi Pour, I. Muxika, Á. Borja, 2017. Using multiple indicators to assess the environmental status in impacted and non-impacted bathing waters in the Iranian Caspian Sea. Ecological Indicators, 82: 175-182.

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

Giovanardi, F., Francé, J., Mozetič, P., Precali, R. (2018). Development of ecological classification criteria for the Biological Quality Element phytoplankton for Adriatic and Tyrrhenian coastal waters by means of chlorophyll a (2000/60/EC WFD). Ecological Indicators. 93. 316-332. doi: 10.1016/j.ecolind.2018.05.015.

Borja, A., J. M. Garmendia, I. Menchaca, A. Uriarte, Y. Sagarmínaga, 2019. Yes, We Can! Large-Scale Integrative Assessment of European Regional Seas, Using Open Access Databases. Frontiers in Marine Science, 6: 10.3389/fmars.2019.00019.

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

Borja, A., I. Menchaca, J. M. Garmendia, J. Franco, J. Larreta, Y. Sagarminaga, Y. Schembri, R. González, R. Antón, T. Micallef, S. Camilleri, O. Solaun, A. Uriarte, M. C. Uyarra, 2021. Big Insights From a Small Country: The Added Value of Integrated Assessment in the Marine Environmental Status Evaluation of Malta. Frontiers in Marine Science, 8: 10.3389/fmars.2021.638232.

Kazanidis, G., C. Orejas, A. Borja, E. Kenchington, L.-A. Henry, O. Callery, M. Carreiro-Silva, H. Egilsdottir, E. Giacomello, A. Grehan, L. Menot, T. Morato, S. Á. Ragnarsson, J. L. Rueda, D. Stirling, T. Stratmann, D. van Oevelen, A. Palialexis, D. Johnson, J. M. Roberts, 2020. Assessing the environmental status of selected North Atlantic deep-sea ecosystems. Ecological Indicators, 119: 106624.

R Development Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org

Policy Context and Targets

Policy context description

In the Mediterranean, the UNEP/MAP MED POL Monitoring programme included from its inception the study of eutrophication as part of its seven pilot projects approved by the Contracting Parties at the Barcelona meeting in 1975 (UNEP MAP, 1990a,b). The issue of a consistent monitoring strategy and assessment of eutrophication was first raised at the UNEP/MAP MED POL National Coordinators Meeting in 2001 (Venice, Italy) which recommended to the Secretariat to elaborate a draft programme for monitoring of eutrophication in the Mediterranean coastal waters (UNEP/MAP MED POL, 2003). In spite of a series of assessments reviewing the concept and state of eutrophication, there are important gaps in the capacity to assess the intensity of this phenomenon. Efforts have been devoted to defining the concepts to assess the intensity and to extend experience beyond the initial sites in the Adriatic Sea, admittedly, the most eutrophic area in the entire Mediterranean Sea. In the context of the Mediterranean Sea, the monitoring and assessment of eutrophication were redefined in accordance with ~~the European Marine Strategy Framework Directive (200/56/EC) and~~ the Integrated Monitoring and Assessment Programme (UNEP/MAP, 2016).~~,~~ This redefinition ensures synergy with ~~are the two main policy tools for the eutrophication phenomenon.~~ the European Marine Strategy Framework Directive (200/56/EC). The Data Dictionaries and Standards for IMAP Common Indicators 13 and 14 (2019, http://imapinfosystem.info-rac.org/app/#/standard), aligned with the IMAP Guidance Factsheets, defined the list of mandatory datasets, including physico-chemical parameters, to provide an integrated assessment of eutrophication.

Targets

~~For each defined marine spatial scale (region, sub-region, etc.) the levels should be compared against agreed threshold levels defining High/Good and Good/Medium environmental status based on the indicative thresholds and reference values of Chlorophyll *a*- in Mediterranean coastal water types, according to the Commission Decision of 20 September 2013 (2013/480/EU) establishing, pursuant to Directive 2000/60/EC (WFD), the values of the Member States` monitoring system classifications as a result of the intercalibration exercise and repealing Decision 2008/915/EC, recalling on reference conditions (High/Good) and boundaries of good/moderate status (G/M).~~
As part of the preparation for the 2023 MED QSR eutrophication assessment, the following two assessment scales have been established and applied in the Mediterranean sub-regions to assess the Good Environmental Status (GES), as applicable:

a) The Scale of NEAT (Nested Environmental Status Assessment Tool) Integrated Assessment of CIs 13&14

- The five-class assessment scale was applied to the data reported by countries for dissolved inorganic nitrogen (DIN), total phosphorus (TP), and chlorophyll-a (Chl-a), enabling their use in calculating assessment criteria for the sub-divisions of the Adriatic Sea sub-regions.
- The five-classes of assessment —High, Good, Moderate, Poor, and Bad—were established, with two boundary limit values that define the scale: i) the Reference Conditions (RC), representing the best conditions (High), and ii) the maximum parameter concentration (i.e., DIN, TP, and Chl-a), representing the worst conditions (Bad). Additionally, a threshold value for the GES/non-GES boundary is defined.
- The decision rule for determining GES/non-GES status is based on comparing score values against the boundary limit defined by the Good/Moderate (G/M) threshold, which distinguishes between the Good and Moderate classes.
- NEAT values range from 0 to 1 and represent the overall status assessment for each parameter, or the integrated assessment of multiple parameters based on the five-class scale. Average concentrations are calculated using geometric means, along with their respective geometric standard deviations and standard errors of the geometric mean. Threshold concentrations are normalized to a scale from 0 to 1 as follows:

$$0 \leq \text{bad} < 0.2 \leq \text{poor} < 0.4 \leq \text{moderate} < 0.6 \leq \text{good} < 0.8 \leq \text{high} \leq 1$$

- The status of class is determined by the linear distance of score values from the two boundary limits: the Reference Conditions and the maximum parameter concentrations, as well as the GES/non-GES threshold. GES status is assigned for values below 0.6, while non-GES status applies to values above 0.6.

NEAT Integrated Assessment of CIs 13&14	**GES**			**non-GES**		
	RC	**High**	**Good**	**Moderate**	**Poor**	**Bad**
Boundary Limits and Normalized NEAT Values	<RC/H limit, not in score scale	1<Score≤0.8	0.8<Score≤0.6	0.6<Score≤0.4	0.4<Score≤0.2	Score≤0.2
Good/non-Good			**G/**	**M**		

b) The Scale of Simplified Assessment of Chlorophyll a (IMAP Common Indicator 14)

- This scale was applied to satellite-derived Chlorophyll-a (Chl-*a*) data points to enable their use in calculating assessment criteria for the sub-divisions of the Aegean-Levantine Sea, the Central Mediterranean Sea, and the Western Mediterranean Sea sub-regions.
- The introduction of satellite-derived Chl-a as a new assessment parameter necessitates the calculation of a new set of assessment criteria, as there is no established relationship

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

between satellite-derived Chl-a data and in situ measurements based on the effects-pressures relationship.

- The data were aggregated as a five-year geometric mean and normalized to ensure comparability across the assessed areas. For normalization, the bestNormalize package in R was used, identifying the Ordered Quantile Normalizing Transformation as the most suitable method (Bartlett, 1947; Beasley et al., 2009).
- The GES/non-GES decision rule is established by comparing the calculated value to a boundary limit defined by the Good/Moderate (G/M) threshold. This threshold is set at the 85th percentile of the normalized distribution of calculated values, which is approximately equal to the mean plus one standard deviation (~mean +1 SD). In this distribution, the 50th percentile represents the mean value, while the 25th percentile corresponds to the mean value in heavily impacted areas.
- The reference conditions (RC) values were calculated from the normalized values and were represented by the 10th percentile.
- Values above the boundary limit are classified as GES, while values below the boundary limit are considered non-GES.
- ~~1.~~ By selecting the 85th percentile of the normalized distribution of calculated values as the G/M boundary limit, the classification compatibility is ensured for the application of the Simplified Assessment Methodology and the five-class GES/non-GES scale, as established for the NEAT GES assessment.

Simplified Assessment of CI 14	**GES**		**non-GES**
Boundary Limits*	≤10th % (RC)	>10th % CHL_GM ≤85th %	CHL_GM.>85th %
Good/non-Good		**G/**	**M**
***Percentiles are calculated from the normalized annual geometric mean (using Ordered Quantile transformation) over a minimum period of five years**			

Further details can be found in thematic eutrophication assessments and the 2023 MED QSR Pollution Assessments, as presented and approved by the Integrated Meeting of the Ecosystem Approach Correspondence Groups (CORMONs), held in Athens, Greece, on 27–28 June 2023.

Policy documents

General Policy documents

Decision IG.22/7 (COP19, 2016) on- Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria.

Decision IG.21/3 (COP18,2013) on- Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets.

Decision IG.25/1 (COP22, 2021) on UNEP/MAP Medium-Term Strategy 2022-2027.

Decision IG.22/7 (COP19, 2016) on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria.

Decision IG.23/6 (COP20, 2017) on 2017 Mediterranean Quality Status Report.

Decision IG.24/4 (COP21, 2019) on Assessment Studies.

Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean.

UNEP(DEPI)/MED WG.363/Inf.21. (2011) Initial Integrated Assessment.

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)
UNEP(DEC)/MED WG.372/3. (2012) Approaches for definition of GES and setting targets for the pollution related ecological objectives in the framework of the ecosystem approach. (EO5: eutrophication, EP9: contaminants, EP10: marine litter, EO11: noise). UNEP(DEPI)/MED IG.22/Inf.7. (2016) Integrated Monitoring and Assessment Guidance UNEP(DEPI)/MED WG.427/Inf.3. Background to the Assessment Criteria for Hazardous Substances and Biological Markers in the Mediterranean Sea Basin and its Regional Scales these revised assessment criteria. 2017 Mediterranean Quality Status Report, https://www.medqsr.org/node/10/ 2023 Mediterranean Quality Status Report, medqsr2023.info-rac.org Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) Commission Directive (EU) 2017/845 of 17 May 2017 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies. Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardized methods for monitoring and assessment, and repealing Decision 2010/477/EU. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. **~~Nutrient/~~Eutrophication related Policy documents** UNEP(DEPI)MED WG.231/14. (2003). Eutrophication Monitoring Strategy of UNEP/MAP MED POL. UNEP/FAO/WHO (1996). 'Assessment of the state of eutrophication in the Mediterranean Sea'. MAP Technical Reports Series No 106. UNEP, Athens, 211 pp. UNEP/MAP MED POL (1990a). Activity IV: Research on the effects of pollutants on Marine Organisms and their Populations (UNEP/MAP MED POL Phase I, 1975-1981). UNEP/MAP MED POL (1990b). Activity V: Research on the effects of pollutants on Marine Communities and Ecosystems (UNEP/MAP MED POL Phase I, 1975-1981). ~~Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.~~ WFD CIS Guidance Document No. 5 (2003) Transitional and Coastal Waters Typology, Reference Conditions and Classification Systems. UNEP(DEPI)/MED WG.417/Inf.15., (2015) Report of the online groups on eutrophication, contaminants and marine litter, pp 92 UNEP/MED WG.463/Inf.6. (2019) Updated Thematic Assessments of the Eutrophication and Contaminants Status in the Mediterranean Marine Environment, as a Contribution to the 2019 State of Environment and Development Report (SoED). UNEP/MED WG.463/8., (2019), Approaches on Scales of Monitoring for Common Indicators related to pollution.	

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

UNEP/MED WG.463/Inf.9 (2019). Example of overall interrelationships between the IMAP and the DPSIR framework applied to the coastal and marine ecosystem. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring.

UNEP/MED WG.509/10//Rev.2, (2021) Integration and Aggregation Rules for Monitoring and Assessment of (IMAP Pollution and Marine Litter Cluster).

UNEP/MED WG 533/ 4. (2022) Assessment Criteria Methodologies for IMAP Common Indicator 13: Reference and Boundary Values for DIN and TP in the Adriatic Sea Sub-region.

UNEP/MED.WG.550/10/Rev.1, (2023), 2023 Med QSR: The IMAP Pollution Cluster Chapters; Thematic Assessments.

UNEP/MED.WG.550/Inf.13 (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Assessment Results of IMAP Common Indicators 14 in the Central Mediterranean Sea Sub-region by Applying the Simplified G/M Assessment Methodology.

UNEP/MED WG.556/Inf.3/Rev.1. (2023), The Results of GES Assessment for IMAP Common Indicators 13 and 14 in the Adriatic Sea Sub-region by Applying the NEAT GES Assessment Methodology.

UNEP/MED WG.556/Inf.4/Rev.1. (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Assessment Results of IMAP Common Indicators 13&14 in the Aegean - Levantine Sea Sub-region by Applying the Simplified G/M Assessment Methodology.

UNEP/MED WG.556/Inf.5/Rev.1. (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Assessment Results of IMAP Common Indicators 13&14 in the Western Mediterranean Sea Sub-region by Applying the Simplified G/M and EQSR Assessment Methodologies.

UNEP/MED WG.556/Inf.16/Rev.1. (2023), The Updated GIS - based Layers for the Finest Areas of Assessment and the Areas of Assessment Nested to the Levels of Integration that are Considered Meaningful for Their Use Within Application of the NEAT GES Assessment Methodology for IMAP Common Indicators 13, 14 and 17 in the Adritic Sea Sub-region.

Indicator analysis methods

Indicator Definition

Chlorophyll *a* concentration in the water column (State, Impact Indicator);
Sub-Indicators: Water Transparency (State, Impact Indicator) and Dissolved oxygen (State, Impact Indicator)
The list of all chemical and related parameters subject to reporting for IMAP CI 14 by the Contracting Parties is elaborated in the Data Standards for IMAP CI 14.

Methodology for indicator calculation

Chlorophyll *a*: Spectrophotometry.
ISO 10260 (1992) on spectrometric determination of the chlorophyll *a* concentration provides a standard method for quantification of chlorophyll *a*.
Water transparency: measured as Secchi disk depth or according to ISO 7027:1999 Water Quality-Determination of Turbidity
Dissolved Oxygen: Chemical methods, Oxygen sensors, etc. measured near the bottom (under the euphotic layer/oxycline)

The detailed analytical procedure for Chlorophyll *a* and other related mandatory parameters, including sampling and sample transportation, analytical determination of indicators and sub-indicators, data quality control are outlined in A-2: Guidelines/Protocols for sampling and

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)
determination of key nutrients and chlorophyll a in seawater outlines the analytical procedures for the determination of Chlorophyll a and its related sub-indicators.	
Indicator units microgram per liter (µg/L) - Chlorophyll *a* meters – Secchi disk depth; NTU Turbidity Scale (Nephelometric Turbidity Units) – Water transparency milligram per liter (mg/L) and % Saturation (if temperature and salinity is known) – Dissolved Oxygen Data Standards for IMAP CI 14 elaborates units for all mandatory parameters.	
List of Guidance documents and protocols available ~~i. OSPAR, 2012. OSPAR MSFD Advice Document on Eutrophication. Approaches to determining good environmental status, setting of environmental targets and selecting indicators for Marine Strategy Framework Directive descriptor 5~~ ~~ii. Piha, H., Zampoucas, N., 2011. Review of Methodological Standards Related to the Marine Strategy Framework Directive Criteria on Good Environmental Status. JRC Scientific and Technical Reports, EUR 24743 EN~~ ~~iii. UNEP/MAP MED POL, 2005. Sampling and Analysis Techniques for the Eutrophication Monitoring Strategy of UNEP/MAP MED POL. MAP Technical Reports Series No. 163. UNEP, Athens. 61pp.~~ IMAP Monitoring Guidelines/Protocols (https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/division-of-iaea-environment-laboratories/marine-environmental-studies-laboratory/unep-map-med-pol-integrated-monitoring-and-assessment-programme-imap-monitoring-guidelines): o A-1. Monitoring Guidelines/Protocols for Sampling and Determination of Hydrographic Physical and Chemical Parameters; o A-2: Guidelines/Protocols for sampling and determination of key nutrients and chlorophyll a in seawater outlines the analytical procedures for the determination of Chlorophyll a and its related sub-indicators; o E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20; o F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20.	
Data Confidence and uncertainties Despite the great variability in water layers affected by active hydrodynamic processes, monitoring seawater characteristics remains the most direct method for assessing eutrophication. Several key parameters have been identified as providing valuable information related to eutrophication e.g. chlorophyll *a*, dissolved oxygen, inorganic nutrients, organic matter, suspended solids, light penetration, aquatic macro-phytes, zoo benthos, etc. They all may be determined either at the surface or at various depths. If only limited means are available, determination of those parameters that synthesize the most information should be retained. For example, Chlorophyll *a* determination may not offer very precise representations of the system, although it provides valuable insights. ~~are data which provide a great deal of information.~~ Turbidity may also be a good measure of eutrophication, although caution is needed ~~except~~ near river mouths, where inert suspended solids may be extremely abundant. Dissolved oxygen is a ~~one~~ parameter that integrates a wide range of ~~much~~ information on the processes involved	

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

in eutrophication, especially when measured near the bottom or, at least, below the euphotic zone, where an oxycline usually appears.

An external quality assurance by performing regional interlaboratory QA/QC exercises has been organized for contaminants in collaboration of the UNEP/MAP - MED POL and the IAEA/MESL since 1986. As of 2024, the IAEA/MESL, the scope of proficiency testing and training courses has been expanded to support the capacities of national laboratories in monitoring eutrophication (IMAP Common Indicators 13 & 14: inorganic nutrients in high salinity seawater, in estuarine and low salinity seawater, and chlorophyll a and Phaeopigments in Seawater) and contaminants in seafood (IMAP Common Indicator 20: heavy metals, polycyclic aromatic hydrocarbons (PAHs), dioxins, and PCBs).

In addition, the data quality control range categories were initially established for physico-chemical parameters related to the monitoring of IMAP Common Indicators 13 and 14, as well as for contaminants related to the monitoring of Common Indicator 17, by applying relevant statistical methods and available scientific expertise in ensuring the quality of data reported to the IMAP Info System. These data control categories have been integrated into the IMAP Info System as of 2024.

Methodology for monitoring, temporal and spatial scope

Available Methodologies for Monitoring and Monitoring Protocols

Traditional methods for eutrophication monitoring in coastal waters involve *in situ* sampling/measurements of commonly measured parameters such as nutrients concentration, chlorophyll *a* concentration, phytoplankton abundance and composition, transparency and dissolved oxygen concentration. Concerning available methods for *in situ* measurements, ships provide flexible platforms for eutrophication monitoring, while remote sensing provides opportunities for a synoptic view over regions or sub-regions. Besides traditional ship measurements, ferry-boxes and other autonomous measuring devices have been developed that allow high frequency and continuous measurements.

Modelling and remote sensing should also be considered as complementary, area-integrating approaches alongside in situ measurements, depending on data requirements

Modelling and remote sensing should also be considered as complementary, area integrating in addition to *in situ* measurements, depending on data ~~the~~ requirements. ~~with respect to data.~~ In general, *in situ* measurements always remain necessary to validate and calibrate the models and data calculated from satellite measurements. However, satellite data need to be supported by ground truth data. A good strategy appears to be a combination of remote sensing with on-site ~~and~~ scanning using ~~of the area known or suspected to be affected with~~ automatic measuring instruments such as thermo-salinometer, dissolved oxygen sensors and *in vivo* fluorometer and/or nephelometer. Sampling for the determination of *in vitro* fluorescence and nutrient analysis may be carried out with relatively little effort if a properly equipped pump and hose system are mounted on the vessel. Measurements may be taken at the surface or just below it using a water intake on the vessel`s hull, at fixed or varying depths with a towed "fish" and pumping system.

Building on elements elaborated in the Integrated Monitoring and Assessment Programme (2016 IMAP), including the above-mentioned components, the Monitoring Guidelines—structured around the specific technical protocols related to IMAP Common Indicators 13 and 14—were comprehensively developed by the MED POL Programme in cooperation with IAEA/MESL. These guidelines were approved by the MED POL Focal Points Meeting (2021).They build upon the knowledge and practices obtained over 40 years of MED POL monitoring implementation and recent publications, highlighting the current practices of the Contracting Parties' marine laboratories, as well as other Regional Seas Conventions and the EU. A thorough analysis of presently available practices of UNEP/MAP, UNEP and IAEA, as well the HELCOM, OSPAR and European Commission Joint Research Centre was undertaken to assist an innovative approach for

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

preparation of the IMAP Monitoring Guidelines/Protocols. The monitoring methodologies and practices are elaborated for sampling, sample preservation and transportation, sample preparation and analysis, along with quality assurance and reporting of monitoring data, for their use by the IMAP competent laboratories in order to ensure the representativeness and accuracy of the analytical results. These guidelines present a summary of the best available known practices employed in marine monitoring by bringing integrated comprehensive analytical practices that can be applied in order to ensure the representativeness and accuracy of the analytical results needed for generation of quality assured monitoring data.

The Monitoring Guidelines for IMAP Common Indicators 13 and 14 outline the following monitoring and reporting practices:

- A-1. Monitoring Guidelines/Protocols for Sampling and Determination of Hydrographic Physical and Chemical Parameters;
- A-2: Guidelines/Protocols for sampling and determination of key nutrients and chlorophyll a in seawater outlines the analytical procedures for the determination of Chlorophyll a and its related sub-indicators;
- E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20;
- F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20.

Available data sources
IMAP Info System (http://imapinfosystem.info-rac.org/app/#/) ~~MED POL Database.~~

EMODNET Chemistry:
http://www.emodnet-chemistry.eu/data_access.html

EEA Waterbase - Transitional, coastal and marine waters:
http://www.eea.europa.eu/data-and-maps/data/waterbase-transitional-coastal-and-marine-waters-11

Satellite databases such as in EMIS (http://mcc.jrc.ec.europa.eu/emis/), COPERNICUS, ARGANS France, and the SMED algorithm

Spatial scope guidance and selection of monitoring stations

The extent of eutrophication shows spatial variation, for instance coastal areas ~~regions~~ versus the open sea. The frequency and spatial resolution of the monitoring programme should reflect this spatial variation in eutrophication status and pressures following a risk-based approach and the precautionary principle.

The geographical extent of potentially eutrophic waters 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
(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.

Therefore, the geographical scale of monitoring for the assessment of GES for eutrophication ~~will~~ depends on the hydrological and morphological conditions of an area, particularly the freshwater inputs from rivers, the salinity, the general circulation, upwelling and stratification. The spatial distribution of the monitoring stations should, prior to the establishment of the eutrophication status of the marine sub-region/area, be risk-based and proportionate to the anticipated extent of

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

eutrophication in the sub-region under consideration as well as its hydrographic characteristics aiming for the determination of spatially homogeneous areas. The eutrophication monitoring programmes should pursue to assess the eutrophication phenomena, based on the differentiation of the scale and time dependant signals from human induced versus natural eutrophication.

As part of the 2023 MED QSR preparation, the assessment scales for CIs 13 and 14 are defined within the framework of the IMAP nested approach, building upon the elements outlined in the section on Assessment of Eutrophication.

Temporal Scope guidance

The current national eutrophication monitoring programme, developed within the framework of IMAP implementation, has laid the foundation ~~implemented so far by the Contracting Parties in the framework of the UNEP/MAP MED POL programme should be used as a sound basis~~ for marine environment monitoring in the Mediterranean. ~~under the EcAp.~~

Sampling frequency has to be determined by the variability of the measured parameters and is usually determined by how many samples are needed to reliably assess the differences between two neighbouring mean values.

Discriminant limit (i.e. power of applied test), depends on sample size:

$$\text{Discriminant limit } dM = sd * t(\alpha/2; N1+N2-2) * \sqrt{(1/N1+1/N2)} \neq 0$$

For Chl-a log10 units for different sample size N with the significance level: $\alpha/2 = 0{,}025$; with an average sd = 0.30

$N = 12$ $t = 2.074$ $\sqrt{(2/12)} = 0.408$ $dM > |0.25|$
$N = 24$ $t = 2.013$ $\sqrt{(2/24)} = 0.289$ $dM > |0.17|$
$N = 52$ $t = 1{,}983$ $\sqrt{(2/52)} = 0.196$ $dM > |0.12|$

Based on the above, it follows that a particular area can be characterized best by ~~if we~~ measuringe three relevant depths (typically 0, 5 and 10 m) at one station at least monthly or at three stations one depth (0 m). It is based on ~~at annual base~~ 36 samples annually which discriminates approximately~~around~~ 0.15 chla log10 unit for mesotrophic - eutrophic area that is slightly less than half difference between two classes (0.37 as log10 unit). Due to the smaller standard deviation in an oligotrophic area, the same results are achieved with half the frequency. The following sampling~~measurement~~ frequency is ~~proposed:~~ recommended as the guidance taking into account specific local conditions:

- Eutrophic – mesotrophic: monthly,
- mesotrophic – oligotrophic: monthly near the coast, bimonthly in open waters, and
- oligotrophic: bimonthly near the coast, seasonally in open waters.

For open waters sampling frequency should be determined on a sub-regional level following a risk-based approach:

- Water transparency: *id.* Chlorophyll *a*
- Dissolved Oxygen: *id.* Chlorophyll *a*

Data analysis and assessment outputs

Statistical Analysis and Basis for Aggregation – Water Typology and Assessment Criteria

The classification scheme on chlorophyll *a* concentration developed by MEDGIG as an assessment method easily applicable by all Mediterranean countries based on the indicative thresholds and reference values adopted. The water types for applying eutrophication assessment are based on hydrological parameters characterizing a certain area dynamics and circulation.

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

The main statistical analysis is based on the typology criteria and settings derived from the analysis of influence of freshwater inputs as the main nutrient drivers. More information on is presented in document the UNEP(DEPI)/MED WG 417/Inf.15. Three main types were identified:

Type I	coastal sites highly influenced by freshwater inputs,
Type IIA	coastal sites moderately influenced not directly affected by freshwater inputs (Continent influence),
Type IIIW	continental coast, coastal sites not influenced/affected by freshwater inputs (western Basin),
Type IIIE	not influenced by freshwater input (Eastern Basin),
Type Island	coast (western Basin).

Coastal water type III was split in two different sub basins, the western and the Eastern Mediterranean s, according to the different trophic conditions and is well documented in literature. It is recommended to define the major coastal water types in the Mediterranean for eutrophication assessment (Table 1).

Table 1. Major coastal water types in the Mediterranean

	Type I	Type IIA, IIA Adriatic	Type IIIW	Type IIIE	Type Island-W
σt (density)	<25	25<d<27	>27	>27	All range
Salinity	<34.5	34.5<S<37.5	>37.5	>37.5	All range

With the view to assess eutrophication, it is recommended to rely on the classification scheme on Chlorophyll a concentration (μg L-1) in coastal waters as a parameter easily applicable by all Mediterranean countries based on the indicative thresholds and reference values presented in Table 2. The above table of major coastal water types is also indicative of the part of offshore waters next to coastal waters; however, it should be used with caution in the offshore (open) areas.

In preparation for the 2023 MED QSR, updated reference and boundary values for Chlorophyll a were provided, as adopted by Decision 26/3 (COP23) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean (Table 2 below).

~~Major coastal water types in the Mediterranean~~

~~Table 2. Coastal Water types reference conditions and boundaries in the Mediterranean~~

~~Coastal Water Typology~~	~~Reference conditions of Chla (μg L-1)~~		~~Boundaries of Chla (μg L-1) for G/M status~~	
	~~G_mean~~	~~90% percentile~~	~~G_mean~~	~~90% percentile~~
~~Type I~~	~~1,4~~	~~3,33* - 3,93**~~	~~6,3~~	~~10* - 17,7**~~
~~Type II-FR-SP~~		~~1,9~~		~~3,58~~
~~Type II-A Adriatic~~	~~0,33~~	~~0,8~~	~~1,5~~	~~4,0~~
~~Type II-B Tyrrhenian~~	~~0,32~~	~~0,77~~	~~1,2~~	~~2,9~~
~~Type III-W Adriatic~~			~~0,64~~	~~1,7~~
~~Type III-W Tyrrhenian~~			~~0,48~~	~~1,17~~
~~Type III-W FR-SP~~		~~0,9~~		~~1,80~~
~~Type III-E~~		~~0,1~~		~~0,4~~
~~Type Island-w~~		~~0,6~~		~~1,2 – 1,22~~

~~* aapplicable to Gulf of Lion~~
~~** applicable to Adriatic~~

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

Table 2. Coastal water types reference conditions and boundary values for Chlorophyll a in the Mediterranean, along with the new and updated values for coastal and open (offshore) waters in the Adriatic Sea Sub-region.

(Shaded cells indicate the criteria which remain as provided in Decision IG.22/7 (COP 20, 2019). Unshaded cells represent the new criteria adopted in Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean. Reference conditions and boundary (Good/Moderate status) values are based on long time series (>5 years) of monthly sampling at least, which differ from type to type on the sub-regional scale, and therefore, were built with different strategies). The blue-marked cells display the G_mean values of reference and boundary values, expressed as the 90th percentile, as adopted in Decision 26/3.

	Coastal waters			
	Reference conditions of *c*(Chl*a*) (μg/L)		**Boundaries of *c*(Chl*a*) (μg/L) for G/M status**	
Water Typology	*G_mean*	90% percentile	*G_mean*	90% percentile
Type I	1,19	3,33[b]	4,1	10[b]
Type I Adriatic	1,40	3,94	5,0[a]	14,1
Type II-A-FR-SP[d]	0,78	1,9	1,48	3,58
Type II-A Adriatic	0,33	0,87	1,5	4,0
Type II-A[e] Tyrrhenian	0,32	0,77	1,2	2,9
Type III-W Adriatic[c]	-	-	0,64[f]	1,7[f]
Type III-W Tyrrhenian	-	-	0,48	1,17
Type III-W-FR-SP	0,37	0,9	0,74	1,80
Type III-E		0,1		0,4
Type Island-W		0,6		1,2-1,22

	Open (offshore) waters in the Adriatic Sea Sub-region			
	Reference conditions of *c*(Chl*a*) (μg/L)		**Boundaries of *c*(Chl*a*) (μg/L) for G/M status**	
Water Typology	*G_mean*	90 % percentile	*G_mean*	90 % percentile
Type I Adriatic	0,15[g]; 0,29[h]	0,42[f]; 0,81[g]	3,1	8,7
Type II-A Adriatic	0.11	0.29	-	-
Type III-W Adriatic [c]	-	-	0.64	1.7

a From Giovanardi et al, 2018
b Applicable to Golf of Lion Type I coastal waters
c The ecological classification scheme would not be suitable for proper and safe classification, and therefore the boundary values for WT III-W Adriatic waters are based on the H/G values for WT II-A Adriatic in coastal waters i.e. 0.64 µg/L for Chla and 0,26 µmol/L for TP
d Correction of error included to ensure consistency with the classification as provided in Commission Decision 2013/480/EU i.e. Type II -FR-SP, as included in Decision IG.22/7, replaced with Type II -A-FR-SP
e Correction of error included to ensure consistency with the classification as provided in Commission Decision 2013/480/EU i.e., Type II-A Tyrrhenian replaced Type II-B Tyrrhenian, as included in Decision IG.22/7, since the latter does not exist in the Tyrrhenian Sea
f values based on the H/G values for WT II-Ac The ecological classification scheme would not be suitable for proper and safe classification, and therefore the boundary values for WT III-W Adriatic waters are based on the H/G values for WT II-A Adriatic in coastal waters i.e. 0.64 µg/L for Chla and 0,26 µmol/L for TP
g for ME; h for HR, IT
h No pressure – effect relationship was found, and therefore RC for DIN and boundary G/M values for Chla and DIN could not be proposed.

The geometric mean (*Gmean)* calculation procedure assumes the lognormal distribution of chlorophyll a data:

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

$$\text{Chl-a 90th } percentile_{\text{ (expected)}} = 10^{(\log10(\text{Chl-a } Gmean)+1.282\ sd)}$$

where 1.282 is the value assumed by the standard normal variable zc for which P(z>zc)=10%.

In this context, the 90th percentile should not be considered a true alternative to the geometric mean, as it represents a percentile value derived from the same theoretical normal distribution of log-transformed chlorophyll a data, converted back into a number scale.

Regarding the standard deviation (SD) value, an analysis by Giovanardi et al. (2018) of long-term chlorophyll a data series—conducted in accordance with OECD recommendations (Vollenweider and Kerekes, 1982)—found that standard deviations of the $\log_{10}$-transformed chlorophyll a sample distributions ranged from 0.30 to 0.35 across all water types. Specifically:

- For Type I, SD is approximately 0.35.
- For Type II Adriatic and Type III W Adriatic, SD is around 0.33.
- For Type II Tyrrhenian and Type III W Tyrrhenian, SD is about 0.30.

Developments within the European MSFD with regard to eutrophication should also be taken into account.
It has to be noted that the Mediterranean countries are using different eutrophication non-mandatory assessment methods such as TRIX, UNTRIX, Eutrophication scale, EI, HEAT, OSPAR, etc. These tools are very important to continue to be used at sub-regional or national levels because there is a long-term experience within countries which can reveal / be used for assessing eutrophication trends. As part of the preparation for the 2023 MED QSR, the most relevant and applicable methods for eutrophication assessment were explored, developed, and applied, as outlined in the following section, Further advancements in eutrophication assessment should address the gaps identified during the 2023 MED QSR process. Ongoing efforts focus on establishing the new reference and boundary values for Total Phosphorus (TP) and Dissolved Inorganic Nitrogen (DIN), and the updated reference and boundary values, where applicable, for Chlorophyll a (Chl a), in the selected pilot sub-region(s)/sub-division(s), depending on data availability.

~~However, in order~~ to enhance ~~increase~~ coherency and comparability of ~~regarding~~ eutrophication assessment methodologies.~~, it is recommended that further efforts should be made to harmonize existing tools through workshops, dialogue and comparative exercises at regional/sub-regional/subdivision levels in Mediterranean with a view to further implement the IMAP assessment methods, in a.~~

~~Expected assessments outputs~~ Assessment of Eutrophication

GES thresholds and trends are recommended to be used in a combination, depending on data availability and agreement on GES threshold levels. Within the framework of UNEP/MAP MED POL there is existing experience in applying the quantitative thresholds. As outlined in Targets section above, ~~I~~it is proposed that for the Mediterranean region~~,~~ quantitative thresholds between “good” (GES) and “moderate” (non-GES) conditions for coastal waters be established and applied for assessment of eutrophication in the 2023 MED QSR. ~~could be based as appropriate on the work carried out in the framework of the MEDGIG intercalibration process of the EU Water Framework Directive (WFD)~~. According to the conclusions of the 2022 Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, ~~The Contracting Parties are recommended to rely on~~ the classification scheme rely on boundary and reference values of chlorophyll *a*, Dissolved Inorganic Nitrogen (DIN) and Total Phosphorous (TP) concentrations in coastal waters as these ~~as a~~ parameters are easily applicable by all Mediterranean countries. ~~based on the indicative thresholds and reference values of chlorophyll a in Mediterranean coastal water types (according to~~

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

~~2013/480/EU, see reference below), recalling on reference conditions and boundaries of good/moderate status (G/M).~~
~~In this context regarding the definition of sub-regional thresholds for chlorophyll a water typology is very important for further development of classification schemes of a certain area. Within the MEDGIG exercise the recommended water types for applying eutrophication assessment is based on hydrological parameters characterizing a certain area dynamics and circulation.~~
~~COMMISSION DECISION (EU) 2018/229 of 12 February 2018 establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Commission Decision 2013/480/EU.~~

For the eutrophication assessment conducted as part of the preparation of the 2023 MED QSR, different assessment methodologies were employed for the evaluation of CIs 13 and 14, based on the data availability provided by the Contracting Parties (CPs) across the four Mediterranean Sub-regions. The Mediterranean Sea is divided into four main sub-regions based on available database sources to facilitate the development of pollution assessment criteria. This process began with the preparation of the UNEP/MAP 2011 Initial Integrated Assessment, followed by the Med QSR 2017, and most recently, the 2023 MED QSR assessments. These sub-regions are: the Western Mediterranean, the Adriatic Sea, the Central Mediterranean, and the Aegean and Levantine Seas.

An integrated NEAT GES assessment for CIs 13 and 14 across all sub-regions was not feasible due to the high heterogeneity of data types, spatial coverage, and the lack of quality-assured, homogeneous data. As a result, the NEAT methodology was applied to the Adriatic Sea Sub-region, based on the monitoring areas defined by the concerned CPs and the harmonization of scale approaches among the Contracting Parties. In the absence of reported *in situ* data for the Western, Central Mediterranean, and Aegean and Levantine Seas Sub-regions, satellite-derived data on Chlorophyll-a concentrations from COPERNICUS, ARGANS France, and the SMED algorithm were used as substitutes.

The NEAT assessment methodology strikes a balance between overly broad scales, which may obscure significant areas of impact in specific regions or sub-regions, and excessively fine scales, which could complicate the assessment process. This methodology was applied at the IMAP CIs 13 and 14 level for TP, DIN, and Chlorophyll-a as mandatory parameters. Other parameters were excluded due to the lack of data reported by the Contracting Parties. The 4-level nesting approaches were implemented in the Adriatic Sea Sub-region. This resulted in the aggregation and integration of assessment results within the IMAP nested scheme at the following levels:

1. IMAP national Spatial Assessment Units (SAUs) and sub-SAUs (the finest level)
2. IMAP coastal and offshore assessment zones of sub-divisions
3. Sub-division and sub-regional levels (e.g., Adriatic Sea).

For setting the IMAP assessment areas for CIs 13 and 14, the finest areas defined for CI 17 were adjusted to serve the purpose of eutrophication assessment. Additionally, a GIS layer was created to show the distribution of water classes within the coastal and offshore zones.

The scope of all SAUs and sub-SAUs was defined and introduced into the NEAT tool, along with their respective codes and surface areas (in km²). Within each SAU, under 'habitats,' the water types are introduced, and under 'ecosystem component,' the three measured parameters (DIN, TP, and Chlorophyll-a) are assigned.

Data elaboration was carried out for the surface layer, as it represents the primary layer of eutrophication impact. Freshwater inputs are the main pressure drivers and largely contribute to the stratification of the water column, confining newly introduced nutrients to the surface layer. For the application of the NEAT software, data were grouped by parameter, ecosystem, and SAU. Average concentrations (geometric means), along with the geometric standard deviation and standard error

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

of the geometric means, were calculated for the respective groups. While arithmetic means and standard errors were used for CI 17, geometric means and standard errors were applied for CIs 13 and 14.

Boundary limits and class threshold values per SAU, parameter, and matrix are applied according to the assessment scale presented in the section on targets. The aggregation of TP, DIN, and Chlorophyll-a was carried out to derive a single status value (NEAT value) for all levels of the nesting scheme. The aggregation of the assessment results for these three parameters resulted in a NEAT value per specific SAU, which was then spatially integrated into the sub-divisions and regional levels. The assessment results were presented and visualized using a tabular format and graphical representations generated with a GIS tool.

For sub-regions and sub-divisions where, insufficient data was reported for applying the NEAT GES assessment methodology across nested assessment areas, three alternative methodologies were developed for eutrophication assessment:

1. **Ecological Quality Ratio (EQR) methodology**
2. **Simplified EQR methodology**
3. **Simplified Good/Moderate (G/M) comparison methodology.**

The EQR methodology was found relevant for assessing IMAP Common Indicators 13 & 14, where a full set of assessment criteria for Chlorophyll-a (Chla), Dissolved Inorganic Nitrogen (DIN), and Total Phosphorus (TP) exists. EQR is a dimensionless measure that compares the observed value of a measured parameter against reference conditions. The ratio ranges from 0 (large deviation) to 1 (equal to or better than reference conditions). EQR must be calculated for each boundary value, and a typology-based assessment must be conducted. However, due to the lack of data reported by Contracting Parties, this methodology could not be applied in the preparation of the 2023 Mediterranean Quality Status Report (MED QSR).

The Simplified EQR methodology was deemed relevant when complementary data (in situ and remote sensing) was available for Chla only, but typology-based assessment could not be applied. However, due to the lack of homogeneous, quality-assured data reported by CPs—even for Chla alone—this methodology could not be applied to any sub-region or sub-division in the 2023 MED QSR, except for the Tyrrhenian Sea. Thresholds must be defined to determine the boundary between Good Environmental Status (GES) and non-GES. Simplified Good/Moderate (G/M) Comparison Methodology

The Simplified G/M comparison methodology was used as an alternative to the NEAT GES Assessment, EQR, and Simplified EQR methodologies, relying solely on Chl-a data from remote sensing sources in cases where a typology-based assessment was not feasible. Data were aggregated as a 5-year geometric mean and normalized to ensure comparability across assessment areas. Normalization was conducted using the bestNormalize package in R. Each observation point or area was classified as GES or non-GES based on the assessment scale outlined in the Targets section.

Further details are provided in the thematic eutrophication assessments and the 2023 MED QSR Pollution Assessment.

Known gaps and uncertainties in the Mediterranean

Further to the significant progress achieved over the last few biennia regarding the standardizing monitoring practices and establishing Good Environmental Status (GES) and environmental assessment tools—along with the improved availability of assessment criteria – it is essential—~~F~~, for

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)

a complete assessment of eutrophication and the ~~GES~~ achievement of GES, to define GES thresholds and reference conditions (natural background concentrations) ~~are needed~~ not only for chlorophyll *a*, but also ~~such values must be set~~for total phosphorus (TP) and dissolved inorganic nitrogen (DIN) across all sub-regions. This should build on the relevant experience gained in setting ~~, in the near future, through dedicated workshops and exercises also,~~reference and boundary values for these nutrients in the Adriatic Sea Sub-region,~~ water transparency and oxygen~~ as minimum requirements.~~, where appropriate.~~ This process should include quality assurance schemes, as well as data quality control protocols.

~~Further, in order to increase coherency and comparability regarding eutrophication assessment methodologies is recommended that further efforts should be made to harmonize existing tools through workshops, dialogue and comparative exercises at regional/subregional/subdivision levels in Mediterranean with a view to further improve and develop common assessment methods~~.

By building on the achievements up to 2023, during the preparation of the 2023 MED QSR, several knowledge gaps were identified in the monitoring and assessment of Common Indicators 13 and 14, which need to be addressed following the recommendations of the 2023 MED POL Focal Points Meeting.

Improve the availability of the assessment criteria for CIs 13 and 14:

Upon setting the reference conditions and boundary values for DIN and TP in the Adriatic Sea Sub-region, actions need to be undertaken to improve the availability of the assessment criteria for nutrients in the AEL, the CEN and the WMS Sub-regions. To that purpose the three continuous years of monitoring need to be provided with a minimum monthly frequency for Water types I and II and bimonthly to seasonal for Type III. It should also be noted that other supporting parameters (i.e., temperature, salinity and dissolved oxygen) need to be available for defining the water typology. Further update of the assessment criteria for CI 14 should be undertaken as appropriate. The specific knowledge needs to be also built regarding the use of statistical tools for data validation and calculation of the assessment criteria.

Improve the GES assessment:

Further to the above elaborated common measures, the GES assessment for CIs 13 & 14 needs to be also improved, including the use of the remote sensing and modelling tools to complement *in situ* monitoring and adding additional sub-indicator i.e., the satellite-derived Chl*a* data for GES assessment.

Upgrade present policy measures:

For the development of the adaptive eutrophication management strategies, the following specific actions should also be undertaken:

- Extend the scope of research and monitoring programs to characterize the effects of eutrophication;
- Implement regulations to mitigate inputs of nutrient to the marine environment, such as standards, technology requirements, or pollution caps for various sectors.
- Preserve and restore natural ecosystems that capture and cycle nutrients.

Contacts and V~~v~~ersion Date

http://www.unepmap.org

Version No	Date	Author
V.1	31.5.17	MEDPOL
V.2	10.1.19	MEDPOL

Indicator Title	Common Indicator 14. Chlorophyll *a* concentration in water column (EO5)	
V.3	31/05/2019	Approved by the Meeting of MED POL FPs
Final version	09/09/2019	Approved by the 7th Meeting of EcAp Coordination Group
V4	28/05/2025	Joint CorMon Pollution and ML Meeting
V5		Approved by the Meeting of MED POL FPs
Final version		Approved by the 12th Meeting of EcAp Coordination Group

3. Guidance Factsheet on IMAP Common Indicators 17, 18, 20 and 21

8. The revision of IMAP **Common Indicator 17 (EO9)**: "Concentration of key harmful contaminants measured in the relevant matrix" is presented in the table bellow.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**[5]
Level of pollution isbelow a determined threshold defined for the area and species	Concentration of priority contaminants is kept within acceptable limits and does not increase	
Rational		
Justification for indicator selection Chemicals are everywhere in our daily life and play a fundamental role in most of our activities, as they form part of virtually every device, we use to ensure our well-being, protect our health and security, and meet new challenges through innovation. Chemicals are also the building blocks of low-carbon, zero pollution and energy- and resource-efficient technologies, materials and products. The increased investment and innovative capacity of the chemicals industry to provide safe and sustainable chemicals will be vital to offer new solutions and support both the green and the digital transitions of our economy and society. [6] Environmental chemical pollution is directly linked with humankind activities in all the earth's ecosystems. Marine environmental investigations have detected thousands of man-made chemicals (both inorganic and organic compounds) all over the world oceans, which have been shown to impair the health of the marine ecosystems and their ecosystem services. The study of the occurrence, transport, transformation and fate, through the different ecosystem compartments (seawater column, marine biota, sediment, etc.), as well as the study of their sources and entry routes (land-based, sea-based (marine) and atmospheric wet and dry deposition) are the first steps to assess the pressures, state and impact to the environment understand and to decide further management actions fora growing environmental problem. Currently, new man-made chemicals and emerging pollutants continue to enter the marine environment and interact with the different marine		

[5] Following the decisions to be made at the present meeting regarding minor adjustments to the Targets, as outlined in working document UNEP/MED WG.626/3/Rev.1, the revised Targets will be incorporated into the revised IMAP Pollution Indicators Factsheets.

[6] Chemicals Strategy for Sustainability Towards a Toxic-Free Environment, European Commission, COM(2020) 667 final

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

species, habitats and ecosystems (coastal, open ocean, deep-sea areas), increasing the complexity of the chemical pollution threats for the marine environment and their future sustainability to deliver its benefits. The monitoring and assessment of the harmful and noxious substances occurrence, at selected spatial and temporal scales, will determine either a chronic or acute contamination/pollution scenarios.

Hazardous chemicals and their complex interaction with other environmental stressors can have long-term and large-scale environmental impacts on the terrestrial and marine environment. They can contribute to the reduction of ecosystem resilience, leading to rapid declines in animal populations and, ultimately, to extinctions, as well as impacting human health and wellbeing, not least through the possible presence of contaminants in the food chain. It is estimated that 2.8 million potentially contaminated sites exist in the EU, mainly from waste disposal and treatment, posing a significant environmental hazard for terrestrial and aquatic ecosystems and affecting the productivity of soils. The current regulatory and policy framework struggles to take this into account and needs to be strengthened.[7]

Scientific References

Ahmed I., Mostefa, B., Bernard, A. and Olivier, R. (2018) Levels and ecological risk assessment of heavy metals in surface sediments of fishing grounds along Algerian coast. Marine Pollution Bulletin 136, 322-333.

Anon (2019) Contaminants in Europe's Seas. Moving towards a clean, non-toxic marine environment. EEA Report No 25/2018.

Al-Kazaghly, R., M. Hamid and K. A. Ighwela (2021). "Bioaccumulation of some Heavy Metals in Red mullet (Mullus barbatus) and Common pandora (Pagellus erythrinus) in Zliten Coast, Libya." Jurnal Ilmiah Perikanan dan Kelautan 13: 91\

Andersen, J. H., C. Murray, M. M. Larsen, N. Green, T. Høgåsen, E. Dahlgren, G. Garnaga-Budrė, K. Gustavson, M. Haarich, E. M. F. Kallenbach, J. Mannio, J. Strand, and S. Korpinen. 2016. Development and testing of a prototype tool for integrated assessment of chemical status in marine environments. Environmental Monitoring and Assessment 188:115.

Astrahan, P., J. Silverman, Y. Gertner and B. Herut (2017). "Spatial distribution and sources of organic matter and pollutants in the SE Mediterranean (Levantine basin) deep water sediments." Marine Pollution Bulletin 116(1): 521-527.

Azizi, G., M. Layachi, M. Akodad, D. R. Yáñez-Ruiz, A. I. Martín-García, M. Baghour, A. Mesfioui, A. Skalli, and A. Moumen. (2018). Seasonal variations of heavy metals content in mussels (Mytilus galloprovincialis) from Cala Iris offshore (Northern Morocco). Marine Pollution Bulletin 137, 688-694.

Azizi, G., M. Layachi, M. Akodad, A. I. Martin-Garcia, D. R. Yanez-Ruiz, M. Baghour, H. A. Hmeid, H. Gueddari and A. Moumen (2021). "Bioaccumulation and health risk assessment of trace elements in Mytilus galloprovincialis as sea food in the Al Hoceima coasts (Morocco)." E3S Web of Conferences 240, 01002 (2021).Azoury S., Tronczyński J., Chiffoleau JF., Cossa D., Nakhlé K., Schmidt S., Khalaf G. (2013). Historical records of Hg, Pb and PAH depositions in a dated sediment core from the Eastern Mediterranean. *Environ. Sci. Technol.* 47, 7101-7109.

Benali, I., Boutiba, Z., Grandjean, D., de Alencastro, L.F., Rouane-Hacene, O. and Chèvre, N. (2017) Spatial distribution and biological effects of trace metals (Cu, Zn, Pb, Cd) and organic micropollutants (PCBs, PAHs) in mussels Mytilus galloprovincialis along the Algerian west coast. Marine Pollution Bulletin 115(1), 539-550.

[7] Chemicals Strategy for Sustainability Towards a Toxic-Free Environment, European Commission, COM(2020) 667 final

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Bonsignore, M., Tamburrino, S., Oliveri, E., Marchetti, A., Durante, C., Berni, A., Quinci, E. and Sprovieri, M. (2015) Tracing mercury pathways in Augusta Bay (southern Italy) by total concentration and isotope determination. Environmental Pollution 205, 178-185.

Borja, A., M. Elliott, J. H. Andersen, T. Berg, J. Carstensen, B. S. Halpern, A.-S. Heiskanen, S. Korpinen, J. S. S. Lowndes, and G. Martin. 2016. Overview of Integrative Assessment of Marine Systems: The Ecosystem Approach in Practice. Frontiers in Marine Science 3:20

Briant, N., Chouvelon, T., Martinez, L., Brach-Papa, C., Chiffoleau, J.F., Savoye, N., Sonke, J. and Knoery, J. (2017) Spatial and temporal distribution of mercury and methylmercury in bivalves from the French coastline. Marine Pollution Bulletin 114(2), 1096-1102.

Bricker, S., Lauenstein, G., Maruya, K., 2014. NOAA’s Mussel Watch Program: Incorporating contaminants of emerging concern (CECs) into a long-term monitoring program. *Mar.Poll.Bull.*, 81, 289–290.

Cammilleri, G., P. Galluzzo, A. Pulvirenti, I. E. Giangrosso, G. M. Lo Dico, G. Montana, N. Lampiasi, M. A. Mobilia, A. Lastra, M. Vazzana, A. Vella, P. La Placa, A. Macaluso and V. Ferrantelli (2020). "Toxic mineral elements in Mytilus galloprovincialis from Sicilian coasts (Southern Italy)." Natural Product Research 34(1): 177-182.Campillo, J. A., B. Fernández, V. García, J. Benedicto, and V. M. León. 2017. Levels and temporal trends of organochlorine contaminants in mussels from Spanish Mediterranean waters. Chemosphere 182:584-594.

Cathalot C., Rabouille C., Tisnerat-Laborde N., Toussaint F., Kerherve P., Buscail R., Loftis K., Sun M.Y., Tronczynski J., Azoury S., Lansard B., Treignier C., Pastor L., Tesi T. (2013). The fate of river organic carbon in coastal areas: A study in the Rhone River delta using multiple isotopic (Δ13C, Δ14C) and organic tracers. *Geochimica et Cosmochimica Acta* 118, 33-55

Chouvelon, T., E. Strady, M. Harmelin-Vivien, O. Radakovitch, C. Brach-Papa, S. Crochet, J. Knoery, E. Rozuel, B. Thomas, J. Tronczynski and J.-F. Chiffoleau (2019). "Patterns of trace metal bioaccumulation and trophic transfer in a phytoplankton-zooplankton-small pelagic fish marine food web." Marine Pollution Bulletin 146: 1013-1030

Clark, R.B., 1986. Marine Pollution, Oxford University Press.

Elbaz-Poulichet, F.; Dezileau, L.; Freydier, R.; Cossa, D.; Sabatier, P. (2011). A 3500-year record of Hg and Pb contamination in a Mediterranean sedimentary archive (The Pierre Blanche Lagoon, France). Environ. Sci. Technol. 2011, 45 (20), 8642−8647.El Baz, S.M. and Khalil, M.M. (2018) Assessment of trace metals contamination in the coastal sediments of the Egyptian Mediterranean coast. Journal of African Earth Sciences 143, 195-200.

Esposito, M., S. Canzanella, S. Lambiase, A. Scaramuzzo, R. La Nucara, T. Bruno, G. Picazio, G. Colarusso, R. Brunetti and P. Gallo (2020). "Organic pollutants (PCBs, PCDD/Fs, PAHs) and toxic metals in farmed mussels from the Gulf of Naples (Italy): Monitoring and human exposure." Regional Studies in Marine Science 40: 101497

Esposito, G., A. G. Mudadu, M. C. Abete, S. Pederiva, A. Griglione, C. Stella, S. Ortu, A. M. Bazzoni, D. Meloni, and S. Squadrone. 2021. Seasonal accumulation of trace elements in native Mediterranean mussels (Mytilus galloprovincialis Lamarck, 1819) collected in the Calich Lagoon (Sardinia, Italy). Environmental Science and Pollution Research.European Commision, E. (2018) Guidance Document No: 27. Technical Guidance For Deriving Environmental Quality Standards.

Frapiccini, E., M. Panfili, S. Guicciardi, A. Santojanni, M. Marini, C. Truzzi and A. Annibaldi (2020). "Effects of biological factors and seasonality on the level of polycyclic aromatic hydrocarbons in red mullet (Mullus barbatus)." Environmental Pollution 258: 113742.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Furdek, M., Vahcic, M., Šcancar, J., Milacic, R., Kniewald, G., Mikac, N., 2012. Organotin compounds in seawater and Mytilusgalloprovincialis mussels along the Croatian Adriatic Coast. *Mar.Poll.Bull.*, 64, 189–199

Goldberg, E. D., 1975. The Musssel Watch - a first step in global marine monitoring. *Mar.Poll.Bull.*, 6, 111.

Guerranti, C., E. Grazioli, S. Focardi, M. Renzi and G. Perra (2016). "Levels of chemicals in two fish species from four Italian fishing areas." Marine Pollution Bulletin 111(1): 449-452.

Ghosn, M., Mahfouz, C., Chekri, R., Khalaf, G., Guérin, T., Jitaru, P. and Amara, R. (2020a) Seasonal and Spatial Variability of Trace Elements in Livers and Muscles of Three Fish Species from the Eastern Mediterranean. Environmental Science and Pollution Research 27(11), 12428-12438.

Ghosn, M., Mahfouz, C., Chekri, R., Ouddane, B., Khalaf, G., Guérin, T., Amara, R. and Jitaru, P. (2020b) Assessment of trace element contamination and bioaccumulation in algae (Ulva lactuca), bivalves (Spondylus spinosus) and shrimps (Marsupenaeus japonicus) from the Lebanese coast. Regional Studies in Marine Science 39, 101478.

Jebara, A., Lo Turco, V., Potortì, A.G., Bartolomeo, G., Ben Mansour, H. and Di Bella, G. (2021) Organic pollutants in marine samples from Tunisian coast: Occurrence and associated human health risks. Environmental Pollution 271, 116266.

Joksimović Danijela and Slavka Stanković 2012: Accumulation of trace metals in marine organisms of the southeastern Adriatic coast, J. Serb. Chem. Soc. 77 (1) 105–117 (2012).

Jović Mihajlo, Slavka Stanković 2014. Human exposure to trace metals and possible public health risks via consumption of mussels Mytilus galloprovincialis from the Adriatic coastal area Food Chem Toxicol. 2014 Aug;70:241-51

Karageorgis, A.P., Botsou, F., Kaberi, H. and Iliakis, S. (2020) Geochemistry of major and trace elements in surface sediments of the Saronikos Gulf (Greece): Assessment of contamination between 1999 and 2018. Science of the Total Environment 717, 137046.

Kucuksezgin, F., L. T. Gonul, I. Pazi, B. Ubay and H. Guclusoy (2020). "Monitoring of polycyclic aromatic hydrocarbons in transplanted mussels (Mytilus galloprovincialis) and sediments in the coastal region of Nemrut Bay (Eastern Aegean Sea)." Marine Pollution Bulletin 157: 111358.

León, V. M., L. Viñas, E. Concha-Graña, V. Fernández-González, N. Salgueiro-González, C. Moscoso-Pérez, S. Muniategui-Lorenzo, and J. A. Campillo (2020), Identification of contaminants of emerging concern with potential environmental risk in Spanish continental shelf sediments, Science of the Total Environment, 742, 140505

Lomartire, S., J. C. Marques, and A. M. M. Gonçalves. 2021. Biomarkers based tools to assess environmental and chemical stressors in aquatic systems. Ecological Indicators 122:107207.

Long, E., Macdonald, D., Smith, S. and Calder, F. (1995) Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1), 81-97.

Mandic Jelena, Tronczynski Jacek, Kuspilic Grozdan (2018). Polycyclic aromatic hydrocarbons in surface sediments of the mid-Adriatic and along the Croatian coast: Levels, distributions and sources . *Environmental Pollution* , 242(Part A), 519-527

Martínez-Guijarro, R., Paches, M., Romero, I. and Aguado, D. (2019) Enrichment and contamination level of trace metals in the Mediterranean marine sediments of Spain. Science of the Total Environment 693, 133566.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Naifar, I., Pereira, F., Zmemla, R., Bouaziz, M., Elleuch, B. and Garcia, D. (2018) Spatial distribution and contamination assessment of heavy metals in marine sediments of the southern coast of Sfax, Gabes Gulf, Tunisia. Marine Pollution Bulletin 131, 53-62.

Nakata, H., Shinohara, R.I., Nakazawa, Y., Isobe, T., Sudaryanto, A., Subramanian, A., Tanabe, S., Zakaria, M.P., Zheng, G.J., Lam, P.K.S., Young Kim, E., Yoon Min, B., Wef, S.U., Hung Viet, P., Tana, T.S., Prudente, M., Donnell, F., Lauenstein, G., Kannan, K., 2012. Asia–Pacific mussel watch for emerging pollutants: Distribution of synthetic musks and benzotriazole UV stabilizers in Asian and US coastal waters. Mar. Pollut. Bull., 64, 2211–2218

Neff, J.M., 1979. Polycyclic aromatic hydrocarbons in the aquatic environment. Sources, fates and biological effects. Applied Science Publishers, Ltd., London.

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

Pérez-Fernández, B., L. Viñas, and J. Bargiela (2019), New values to assess polycyclic aromatic hydrocarbons pollution: Proposed background concentrations in marine sediment cores from the Atlantic Spanish Coast, Ecological Indicators, 101, 702-709.

Perić, L., V. Nerlović, P. Žurga, L. Žilić, and A. Ramšak. 2017. Variations of biomarkers response in mussels Mytilus galloprovincialis to low, moderate and high concentrations of organic chemicals and metals. Chemosphere 174:554-562.

Rabaoui, L., Balti, R., Zrelli, R. and Tlig-Zouari, S. (2014) Assessment of heavy metals pollution in the gulf of Gabes (Tunisia) using four mollusk species. Mediterranean Marine Science, 15(1), pp.. 15(1), 45-58.

Richardson, S., 2004. Environmental Mass Espectrometry: Emerging contaminants and current issues. Anal. Chem., 76, 3337-3364.

Rizzi, C., S. Villa, C. Chimera, A. Finizio and G. S. Monti (2021). "Spatial and temporal trends in the ecological risk posed by polycyclic aromatic hydrocarbons in Mediterranean Sea sediments using large-scale monitoring data." Ecological Indicators **129**: 107923.

Santos-Echeandía, J., J. A. Campillo, J. A. Egea, C. Guitart, C. J. González, C. Martínez-Gómez, V. M. León, C. Rodríguez-Puente and J. Benedicto (2021). "The influence of natural vs anthropogenic factors on trace metal(loid) levels in the Mussel Watch programme: Two decades of monitoring in the Spanish Mediterranean sea." Marine Environmental Research 169: 105382.

Schulz-Bull, D.E., Petrick, G., Bruhn, R., Duinker, J.C., 1998. Chlorobiphenyls (PCB) and PAHs in water masses of the northern North Atlantic. Mar. Chem., 61, 101-114.

Spagnoli, F., R. De Marco, E. Dinelli, E. Frapiccini, F. Frontalini and P. Giordano (2021). "Sources and Metal Pollution of Sediments from a Coastal Area of the Central Western Adriatic Sea (Southern Marche Region, Italy)." Applied Sciences 11(3).

Sulimanec Grgec, A., Z. Kljaković-Gašpić, T. Orct, V. Tičina, A. Sekovanić, J. Jurasović and M. Piasek (2020). "Mercury and selenium in fish from the eastern part of the Adriatic Sea: A risk-benefit assessment in vulnerable population groups." Chemosphere 261: 127742.

Tavoloni, T., R. Miniero, S. Bacchiocchi, G. Brambilla, M. Ciriaci, F. Griffoni, P. Palombo, T. Stecconi, A. Stramenga and A. Piersanti (2021). "Heavy metal spatial and temporal trends (2008–2018) in clams and mussel from Adriatic Sea (Italy): Possible definition of forecasting models." Marine Pollution Bulletin 163: 111865.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Tornero, V., Hanke, G. and Contaminants, M.E.N.o. (2019) Marine chemical contaminants – support to the harmonization of MSFD D8 methodological standards: Matrices and threshold values/reference levels for relevant substances. EUR 29570 EN, Publications Office of the European Union.

Traina, A., G. Bono, M. Bonsignore, F. Falco, M. Giuga, E. M. Quinci, S. Vitale and M. Sprovieri (2019). "Heavy metals concentrations in some commercially key species from Sicilian coasts (Mediterranean Sea): Potential human health risk estimation." Ecotoxicology and Environmental Safety 168: 466-478.

Traina, A., A. Ausili, M. Bonsignore, D. Fattorini, S. Gherardi, S. Gorbi, E. Quinci, E. Romano, D. Salvagio Manta, G. Tranchida, F. Regoli and M. Sprovieri (2021). "Organochlorines and Polycyclic Aromatic Hydrocarbons as fingerprint of exposure pathways from marine sediments to biota." Marine Pollution Bulletin 170: 112676

Tronczyński, J., Tixier, C. and Laute, F. (2008). R.INT.DOPL/BE_LBCO/Nantes/08 – 04. Contaminants organiques persistants dans les sédiments de l'étang de Thau : bilan, historique et comportement.

Vethaak, A. D., I. M. Davies, J. E. Thain, M. J. Gubbins, C. Martínez-Gómez, C. D. Robinson, C. F. Moffat, T. Burgeot, T. Maes, W. Wosniok, M. Giltrap, T. Lang, and K. Hylland. 2017. Integrated indicator framework and methodology for monitoring and assessment of hazardous substances and their effects in the marine environment. Marine Environmental Research 124:11-20.

WHO (1993). World Health Organization & International Programme on Chemical Safety. Biomarkers and risk assessment : concepts and principles / published under the joint sponsorship of the United Nations environment Programme, the International Labour Organisation, and the World Health Organization. World Health Organization.

Zaghden, H., M. Tedetti, S. Sayadi, M. M. Serbaji, B. Elleuch, and A. Saliot. 2017. Origin and distribution of hydrocarbons and organic matter in the surficial sediments of the Sfax-Kerkennah channel (Tunisia, Southern Mediterranean Sea). Marine Pollution Bulletin 117:414-428.

Policy Context and Targets

Policy context description

In most Mediterranean countries, the monitoring of a range of hazardous chemical substances in different marine compartments are undertaken in response to the UNEP/MAP Barcelona Convention (1976) and its Land-Based Protocol, through the coordination of the UNEP/MAP MED POL Monitoring Program. For Mediterranean EU Countries, the European legislation on the Marine Environment also applies (e.g. EU WFD and EU MSFD), as well as other international and national policy drivers. A considerable amount of founding knowledge and actions are available through the pollution monitoring and assessment component of the UNEP/MAP MED POL Programme during the past decades until today. The environmental assessments have been used for the identification and confirmation of significant marine contaminants occurrence, distributions, levels and trends; as well as, for the continuous development of monitoring strategies and guidance. With respect to the Ecosystem Approach and IMAP, their implementation ~~will~~ continue under the benefits gained from this past knowledge and the policy and practical framework built in the Mediterranean Sea.

In the context of the Mediterranean Sea, the monitoring and assessment of contaminants were redefined in accordance with the Integrated Monitoring and Assessment Programme (UNEP/MAP, 2016)~~,~~. This redefinition also ensures synergy with the European Marine Strategy Framework Directive (200/56/EC). The Data Dictionaries and Standards for IMAP Common Indicator 17 (2019, http://imapinfosystem.info-rac.org/app/#/standard), aligned with the IMAP Guidance Factsheets, defined the list of mandatory datasets, including physico-chemical parameters, to provide an integrated assessment of contaminants in the Mediterranean.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Targets

~~Initial GES targets under Common Indicator 17 will be focused on the control of environmental levels, temporal trend improvements and the reduction of emissions at sources. The monitoring of these targets will be based upon data of a relatively small number of primarily legacy pollutants, reflecting the scope of current programmes and the availability of suitable agreed assessment criteria for them, despite the measurement of other chemicals remains open and is necessary. The inclusion of contemporary and emerging chemicals of new environmental concern and their targets for GES, within IMAP Common Indicator 17, will be implemented as the scientific knowledge advances.~~

As part of the preparation for the 2023 MED QSR eutrophication assessment, the following two assessment scales have been established and applied in the Mediterranean sub-regions to assess the Good Environmental Status, as applicable:

a) *The Scale of NEAT (Nested Environmental Status Assessment Tool) Integrated Assessment of Contaminants in Sediments and Biota Matrices (IMAP Common Indicator 17)*

- The five-class assessment scale was applied to the data reported by countries for mandatory heavy metals and organic contaminants, enabling their use in calculating assessment criteria for the sub-divisions of the Adriatic Sea and Western Mediterranean sub-regions.
- The five-classes of assessment —High, Good, Moderate, Poor, and Bad—is established, with two boundary limit values that define the assessment scale: i) zero contaminant concentration representing the best conditions (High), and ii) the maximum contaminant concentration representing the worst conditions (Bad). Additionally, one threshold value for the GES / non-GES boundary is defined.
- The decision rule for GES/non-GES status is based on comparing score values against the boundary limit defined by the (xBAC) threshold, which distinguishes between the Good and Moderate classes. For trace elements, the threshold is set at 1.5 BACs, while for organic contaminants, the threshold is set at 2 BACs.
- NEAT values range from 0 to 1 and represent the overall status assessment for each contaminant, or the integrated assessment of multiple contaminants, based on the five-class scale. Average concentrations are calculated using arithmetic means, along with their respective standard errors. Threshold concentrations are normalized to a scale from 0 to 1 as follows:

$$0 \leq \text{bad} < 0.2 \leq \text{poor} < 0.4 \leq \text{moderate} < 0.6 \leq \text{good} < 0.8 \leq \text{high} \leq 1$$

- The status of class is determined by the linear distance of score values from the two boundary limits i.e. the zero-contaminant concentration and the maximum contaminant concentration, and the GES/non-GES threshold. GES status is assigned for values below 0.6, while non-GES status applies to values above 0.6.

NEAT Integrated Assessment of CI 17	**GES**		**non-GEs**			
	High	Good	Moderate	Poor	Bad	
Boundary limits	0< meas. conc. ≤ BAC	BAC<meas. conc. ≤GES/nGES threshold	GES/nGES<meas. conc. ≤ moderate/poor threshold	moderate/poor threshold <mean. conc. ≤ max. conc.		
NEAT scores **0**	1 < score ≤0.8	0.8<score≤ 0.6	0.6<score ≤ 0.4	0.4< score ≤0.2	Score<0.2	**Max.**
Thresholds	**BAC**	**(xBAC)**	**2 (xBAC) ∞**	**5 (xBAC) ∞**		

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

b) The Scale of CHASE+ (Chemical Status Assessment Tool) for Contaminants in Sediments and Biota Matrices (IMAP Common Indicator 17)

- The five-class assessment scale was used to evaluate contamination levels scale. It was applied to the data reported by countries for mandatory heavy metals and organic contaminants, enabling their use in calculating assessment criteria for the sub-divisions of the Aegean – Ionian and the Central Mediterranean sub-regions
- The five-class assessment: Non-Problem Area - High, Non-Problem Area - Good, Problem Area - Moderate, Problem Area - Poor, and Problem Area (PA) – Bad, is established with the two boundary limit values: i) zero contaminant concentration, representing the best conditions (High), and ii) maximum contaminant concentration, representing the worst conditions (Bad). Additionally, a threshold value is set to distinguish between Good Environmental Status (GES) and non-GES conditions.
- The decision rule for determining GES/non-GES status is based on comparing CHASE+ score values against the threshold (xBAC), which distinguishes the Good and Moderate classes. For trace elements, the GES/non-GES threshold is 1.5 BACs. For organic contaminants, the GES/non-GES threshold is 2 BACs.
- The Moderate/Poor boundary is set at 2 × BAC, and the Poor/Bad boundary is set at 5 × BAC.
- CHASE+ values range from 0 to 5 and above, representing the overall contamination status of a station or area based on the Contamination Ratio (CR) or Contamination Score (CS).
- The GES/non-GES boundary is set at a CHASE+ score of 1, meaning only values equal to or below (x BAC) set as the GES/non GES threshold are considered GES. This classification aligns CHASE+ with the NEAT assessment methodology.
- Contamination Ratio (CR) is calculated as the ratio C_measured / C_threshold for each contaminant measured in a specific matrix (biota or sediment).
- Contamination Score (CS) is the simple average of CR values, providing an aggregated assessment of contaminants per matrix and station.
- The decision rule states that a station is considered GES if at least 75% of the elements assessed are within GES limits. The same rule applies when assessing area.

CHASE+ Assessment of CI 17	GES		non-GEs		
	High	Good	Moderate	Poor	Bad
Boundary Limits	0< meas. conc. ≤ BAC	BAC<meas. conc. ≤GES/nGES threshold	GES/nGES<meas. conc. ≤ moderate/poor threshold	moderate/poor threshold <mean. conc. ≤ max. conc.	
CHASE+ scores	0 <CR,CS ≤0.5	0.5<CR,CS≤ 1	1<CR,CS ≤ 2	2< CR,CS ≤5	CR,CS> 5
Thresholds	**½ (xBAC)**	**(xBAC)**	**2 (xBAC) ∞**	**5 (xBAC) ∞**	

Policy documents

General Policy documents

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Decision IG.21/3 (COP18,2013) ~~18th COP to the Barcelona Convention, Istanbul, Turkey,~~ on Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets (UNEP(DEPI)/MED IG.21/9).

~~19th COP to the Barcelona Convention, Athens, Greece, 2016~~ Decision IG.22/7 (COP19, 2016) on ~~Decision IG.22/7 -~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria (UNEP(DEPI)/MED IG.22/28).

Decision IG.25/1 (COP22, 2021) on UNEP/MAP Medium-Term Strategy 2022-2027.

Decision IG.22/7 (COP19, 2016) on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria.

Decision IG.23/6 (COP20, 2017) on 2017 Mediterranean Quality Status Report.

Decision IG.24/4 (COP21, 2019) on Assessment Studies.

Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean.

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (EU Marine Strategy Framework Directive and updates in 2010).

Commission Directive (EU) 2017/845 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies

Commission Decision (EU) 2017/848 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (and updated revisions).

Commission Decision (EC) No 2013/480/EU establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Decision 2008/915/EC.

2017 Mediterranean Quality Status Report, https://www.medqsr.org/node/10/

2023 Mediterranean Quality Status Report, medqsr2023.info-rac.org

UNEP(DEPI)/MED IG.22/Inf.7. (2016) Integrated Monitoring and Assessment Guidance

Contaminants related Policy documents

EEA, 1999 State and pressures of the marine and coastal Mediterranean environment. Environmental issues series nº5. European Environmental Agency, Copenhagen, 1999. http://www.eea.eu.intEEA, 2003. Hazardous substances in the European marine environment: Trends in metals and persistent organic pollutants. Topic Report 2/2003. EEA, European Environmental Agency, Copenhagen, 2003. http://www.eea.eu.int

EEA, 2018. European Waters – Assessment of status and pressures 2018. EEA Report /No 7, 2018.

European Commission, E. (2018) Guidance Document No: 27. Technical Guidance For Deriving Environmental Quality Standards.EU Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

EU Regulation on the Classification, Labelling and Packaging of hazardous substances (CLP).

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

OSPAR (2008) Co-ordinated Environmental Monitoring Programme (CEMP) Assessment Manual for contaminants in sediment and biota. OSPAR Commission No. 379/2008.

OSPAR Commission, 2013. Levels and trends in marine contaminants and their biological effects - CEMP Assessment Report 2012. Monitoring and Assessment Series, 2013

OSPAR 2017. https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/

UNEP(DEPI)/MED WG.365/Inf.5. Analysis of the trend monitoring activities and data for the MED POL Phase III and IV (1999-2010). Consultation Meeting to Review MED POL Monitoring Activities. Athens, 22-23 November 2011.

UNEP/MAP MED POL – Phase III, Programme for the Assessment and Control of Pollution in the Mediterranean Region. MAP Technical Report Series No. 120, UNEP, Athens, 1999.

UNEP/MAP, 2005. Fact sheets on Marine Pollution Indicators. Meeting of the UNEP/MAP MED POL National Coordinators. Barcelona, Spain, 24-27 May 2005. UNEP (DEC)/MED/ WG.264/ Inf.14. UNEP, Athens.

UNEP(DEPI)/MED WG. 365/Inf.8. Development of assessment criteria for hazardous substances in the Mediterranean. Consultation Meeting to Review MED POL Monitoring Activities. Athens, 22-23 November 2011.

Report from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions Findings of the Fitness Check of the most relevant chemicals legislation (excluding REACH) and identified challenges, gaps and weaknesses, COM/2019/264 final.

UNEP/MAP, 1987. Report of the Fifth Meeting of the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against pollution and its Related Protocols. UNEP/IG. 74/5. UNEP/MAP, Athens.

UNEP/MAP MED POL – Phase III, Programme for the Assessment and Control of Pollution in the Mediterranean Region. MAP Technical Report Series No. 120, UNEP, Athens, 1999.

UNEP(DEPI)/MED WG. 427/Inf.3. Background to the Assessment Criteria for Hazardous Substances and Biological Markers in the Mediterranean Sea Basin and its Regional Scales.

UNEP/MAP Report of the Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring Marseille, France, 19-21 October 2016.

UNEP(DEC)/MED WG.372/3. (2012) Approaches for definition of GES and setting targets for the pollution related ecological objectives in the framework of the ecosystem approach. (EO5: eutrophication, EP9: contaminants, EP10: marine litter, EO11: noise).

UNEP/MAP WG.462/Inf.4 (2019). Updated List of Priority Contaminants under MAP/Barcelona Convention (Draft). Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Podgorica, Montenegro, 2-3 April 2019.

UNEP /MAP (2019). (UNEP/MED WG.463/Inf.6.). Updated Thematic Assessments of the Eutrophication and Contaminants Status in the Mediterranean Marine Environment, as a Contribution to the 2019 State of Environment and Development Report (SoED).

UNEP/MAP WG.509/21 (2021). Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Sediments for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/22 (2021). Monitoring Guidelines/Protocols for Sample Preparation and

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Analysis of Sediments for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/23 (2021). Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Marine Biota for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/24 (2021). Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Marine Biota for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/25 (2021). Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Seawater for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/26 (2021). Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Seawater for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.492/10/ Rev.2 (2021). Integration and Aggregation Rules for Monitoring and Assessment of (IMAP Pollution and Marine Litter Cluster). Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 26-28 April 2021.

UNEP/MAP WG. 533/Inf.3 (2022). Adjusted Background (Assessment) Concentrations (BC/BAC) for Common Indicator 17 and Upgraded Approach for Environmental Assessment Criteria (EAC) for IMAP Common Indicators 17, 18 and 20

Indicator analysis methods

Indicator Definition

Concentrations of key contaminants in the following matrices (note this is a multiparameter pressure indicator):

MARINE BIOTA: In collected marine organisms, where whole soft tissues or dissected parts, following the analytical procedure detailed in the Monitoring Guidelines for CI 17, are processed according sampling and sample preparation protocols, and primarily, in bivalve species and/or fish the following hazardous substances should be measured ~~:~~as mandatory, as agreed upon at the 2017 Meeting of MED POL Focal Points and further elaborated during the preparation of Data Standards for CI 17

- ~~o~~ Trace/Heavy Metals (TM): ~~Total m~~Mercury and its compounds (Hg~~T~~), Cadmium and its compounds(Cd) and Lead and its compounds (Pb), Copper and its compounds;
- Organochlorinated compounds (PCB congeners 28, 52, 101, 118, 138, 153, 180, 105 and 156); Total PCBs, Hexachlorobenzene, Gamma-HCH Lindane and ΣDDTs~~)~~ (DDT, p,p' + DDT, o,p' + DDE, p,p' + DDD, p,p');
- 16 Polycyclic Aromatic Hydrocarbons (PAHs): Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene, along with total Total 16 PAHs;

The lipid content and flesh fresh/dry weight ratio should be measured in biota for normalisation and reporting purposes.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

MARINE SEDIMENTS: In coastal and marine areas, continental platform and offshore, sediments should be collected by mechanical means and processed at the laboratory (< 2 mm particle size fraction), following the analytical procedure detailed in the Monitoring Guidelines for CI 17~~.~~ Further the following hazardous substances should be measured as mandatory, as agreed upon at the 2017 Meeting of MED POL Focal Points and further elaborated during the preparation of Data Standards for CI 17~~:~~

- Trace/Heavy Metals: ~~Total m~~Mercury and its compounds (Hg~~T~~), Cadmium and its compounds(Cd) and Lead and its compounds (Pb), Copper and its
- ~~Organochlorinated~~compounds; Organochlorinated compounds (PCB congeners 28, 52, 101, 118, 138, 153, 180, 105 and 156); Total PCBs, aldrin, dieldrin, Hexachlorobenzene, Gamma-HCH Lindane and ΣDDTs~~)~~ (DDT, p,p' + DDT, o,p' + DDE, p,p' + DDD, p,p');
- 16 Polycyclic Aromatic Hydrocarbons (PAHs): Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene, along with total Total 16 PAHs;

Following the analytical procedure detailed in the Monitoring Guidelines for CI 17, the aluminium (Al), Total Organic Carbon (TOC) in the < 2mm particle size fraction should be performed for normalization and reporting purposes for TM and OCs, respectively. The < 63µm sediment fraction is also recommended to be complementary for metals.

The liophilization ratio (dry/wet sediment ratio) should be considered for datasets reporting.

SEAWATER: the monitoring and assessment of contaminants in seawater samples collected in coastal, marine and open-sea areas presents specific challenges and higher costs. For the mid/long-term monitoring programmes, such as IMAP, these are recommended to be carried out on a country decision basis. The analytical procedure is detailed in the Monitoring Guidelines for CI 17,

Sub-indicators: other relevant mandatory chemicals are elaborated in Data Standards for IMAP CI 17, whereby ~~(such as tributyltin, TBT; low molecular weight PAHs; etc.) and~~ emerging pollutants are recommended to be monitored based on the availability of relevant scientific knowledge and research, and accordingly proposed for decision making by the Contracting Parties. ~~carried out on a country decision basis until a firm COP Meeting Decision will be taken.~~ Data Standards for CI 17 include the reporting of a long list of non-mandatory parameters concerning the decision of the national IMAP competent authorities.

~~The chemical compounds above are being used to develop the IMAP Info System and those are included in the list of contaminants of concern which accompanies the Data Dictionaries (DDs) and Data Standards (DSs) for CI17.~~

Methodology for indicator calculation

Trace/Heavy Metals (TM) and Aluminium: Spectrometry, Mass Spectrometry

Organic compounds: Gas or Liquid Chromatography (GC/LC) coupled to a variety of detectors, such as Electron Capture Detectors or Mass Spectrometry, atomic adsorption.

The list of all chemical and related parameters subject to reporting for IMAP CI 17 by the Contracting Parties is elaborated in the Data Standards for IMAP CI 17.

~~TOC: Elemental Analyser~~

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)
~~Particle fractions: in-house mesh validated methods (for < 2 mm) and/or geological sieving methods.~~ ~~Additional parameters to be recorded: biometrics (size/length, age), biological parameters such as condition index (mussels), condition factor according established protocols and scientific knowledge.~~ The detailed analytical procedure for the above chemicals and other related mandatory parameters, including sampling and sample transportation, analytical determination of indicators and sub-indicators, data quality control are outlined in: o B-1. Monitoring Guidelines/Protocols for sampling and analysis of contaminants in sediment. o B-2. Monitoring Guidelines/Protocols for sampling and determination of contaminants in marine biota. o B-3. Monitoring Guidelines/Protocols for sampling and analysis of contaminants in seawater.	
Indicator units Trace/Heavy Metals (TM) and Aluminium: mass/dry or wet weight mass of sample according to Data Standards for CI 17. ~~MEDPOL Database Format Protocols.~~ The dry/wet mass ratios should be calculated and reported. Organic compounds (OCs): mass/dry or wet weight mass of sample according according to Data Standards for CI 17.~~MEDPOL Database Format Protocols~~. The dry/wet mass ratios should be calculated and reported. Data Standards for IMAP CI 17 elaborates units for other relevant mandatory chemicals and parameters. ~~TOC: Elemental Analyser (as %)~~ ~~Particle fractions (as %)~~	
List of Guidance documents and protocols available IMAP Monitoring Guidelines/Protocols (https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/division-of-iaea-environment-laboratories/marine-environmental-studies-laboratory/unep-map-med-pol-integrated-monitoring-and-assessment-programme-imap-monitoring-guidelines) o B-1. Monitoring Guidelines/Protocols for sampling and analysis of contaminants in sediment. o B-2. Monitoring Guidelines/Protocols for sampling and determination of contaminants in marine biota. o B-3. Monitoring Guidelines/Protocols for sampling and analysis of contaminants in seawater. o E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20; o F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20	

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)
~~Refer to UNEP Methods and Protocols for Marine Pollution, as well as from other recent documents from regional conventions (e.g. OSPAR) and European Guidelines, such as the Guidance Document No. 33 ON ANALYTICAL METHODS FOR BIOTA MONITORING UNDER THE WATER FRAMEWORK DIRECTIVE, Technical Report - 2014 – 084, ISBN 978-92-79-44679-5.~~	

Data Confidence and uncertainties

The implementation of IMAP provided scientific evidence of significant variations between the four Mediterranean sub-regions, therefore values of BCs/BACs at the sub-regional level were initially introduced in 2019 and furthermore elaborated in the period in the period 2020-2022. The frequency of analyzing one sample of either biota or sediment within proficiency testing organized in collaboration of UNEP/MAP-MEDPOL and IAEA-MESL is insufficient for calculation of the precision of monitoring data. Therefore, the further update of the regional and sub-regional BCs/BACs values for the Mediterranean was completed in 2022 using new data sets reported by the countries, and by applying certain adjustments to the methodology already used in 2016 and 2019 (UNEP/MED WG365/Inf.8 (2011); UNEP/MED WG.533/Inf.3; UNEP/MED WG.533/3).

Selected analytical methods and measurements are subject to internal Quality Assurance through National Laboratories QA/QC Protocols and Laboratory accreditations, as well as external Quality Assurance by performing regional interlaboratory QA/QC exercises organized in collaboration of the UNEP/MAP - MED POL and the IAEA/MESL since 1986. ~~by the UNEP/MAP MED POL/IAEA MESL~~.

Uncertainties in marine data measurements are identified at different levels (cumulative): analytical level (by use of Certified Reference Materials), reporting level (by providing averaged values and the associated uncertainties), database flagging level (primarily according the analytical and reporting compliance, number of non-detected values and levels, fulfilment of the QA/QC Protocols and Interlaboratory Exercises).

Up to 2023, the IAEA/MESL, in collaboration with the UNEP/MAP - MED POL, implemented 56 interlaboratory comparisons/proficiency tests for the analysis of trace elements and organic contaminants, as well as 64 training courses on the analysis of trace elements and organic contaminants in marine samples. Over 370 analytical laboratory practitioners have been trained at MESL. As of 2018, the scope of proficiency testing and training courses has been adjusted to meet the needs of Mediterranean laboratories in implementing monitoring programmes for trace elements (covering mandatory heavy metals – Cd, Hg, Pb, Cu in line with IMAP requirements, as well as additional elements such as Al, As, Co, Cr, Fe, Li, Mn, Ni, and Zn) and organic contaminants for IMAP Common Indicator 17 (covering mandatory organic contaminants including organochlorine (OC) pesticides, polychlorinated biphenyl congeners (PCBs), and polycyclic aromatic hydrocarbons (PAHs), also in accordance with IMAP requirements). Designated national laboratories participating in the proficiency tests receive, along with the sample, clear instructions on how to proceed with the PT sample and how to report the results. They are requested to use established analytical methods and are recommended to apply quality control and laboratory quality assurance procedures. The results of analyses of a matrix-matching quality control (QC) sample must be reported along with the results from the PT sample.

As of 2024, the scope of proficiency testing and training courses has been expanded to support the capacities of national laboratories in monitoring eutrophication (IMAP Common Indicators 13 & 14: inorganic nutrients in high salinity seawater, in estuarine and low salinity seawater, and chlorophyll a and Phaeopigments in Seawater) and contaminants in seafood (IMAP Common Indicator 20: heavy metals including the mandatory heavy metals – Cd, Hg, Pb, Cu, as well as additional elements such as Al, As, Co, Cr, Fe, Li, Mn, Ni, and Zn as specified for CI 17, polycyclic aromatic hydrocarbons (PAHs), dioxins, and PCBs).

In addition, the data quality control range categories were initially established for physico-chemical parameters related to the monitoring of IMAP Common Indicators 13 and 14, as well as for

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)
contaminants related to the monitoring of Common Indicator 17, by applying relevant statistical methods and available scientific expertise in ensuring the quality of data reported to the IMAP Info System. These data control categories have been integrated into the IMAP Info System as of 2024.	
Methodology for monitoring, temporal and spatial scope	

Available Methodologies for Monitoring and Monitoring Protocols

In line with the Ecosystem Approach and the IMAP implementation, there are considerable benefits to be gained from taking advantage of previous knowledge and information developed through the UNEP/MAP--MED POL. These actions include (1) the use of existing experience in the design of monitoring programmes, (2) the use of existing guidance on sampling and analytical methods to inform technical aspects of ecosystem approach monitoring, (3) the use of existing sampling station networks as a framework for the ecosystem approach monitoring networks, (4) the use of existing statistical assessment tools and work on assessment criteria as the basis for the assessments of ecosystem approach data, (5) the use of existing data to describe the distributions and levels of contaminants against EACs and reference concentrations, and (6) the use of existing time series as the basis of monitoring against a "no deterioration" target. The availability of quality assured data is of importance for the assessment of trends and levels and their comparability overtime and across spatial scales.

Building on elements elaborated in the Integrated Monitoring and Assessment Programme (2016 IMAP), including the above-mentioned components, the Monitoring Guidelines—structured around the specific technical protocols related to IMAP Common Indicator 17 —were comprehensively developed by the MED POL Programme in cooperation with IAEA/MESL. These guidelines were approved by the MED POL Focal Points Meeting (2021).They build upon the knowledge and practices obtained over 40 years of MED POL monitoring implementation and recent publications, highlighting the current practices of the Contracting Parties' marine laboratories, as well as other Regional Seas Conventions and the EU. A thorough analysis of presently available practices of UNEP/MAP, UNEP and IAEA, as well the HELCOM, OSPAR and European Commission Joint Research Centre was undertaken to assist an innovative approach for preparation of the IMAP Monitoring Guidelines/Protocols. The monitoring methodologies and practices are elaborated for sampling, sample preservation and transportation, sample preparation and analysis, along with quality assurance and reporting of monitoring data, for their use by the IMAP competent laboratories in order to ensure the representativeness and accuracy of the analytical results. These guidelines present a summary of the best available known practices employed in marine monitoring by bringing integrated comprehensive analytical practices that can be applied in order to ensure the representativeness and accuracy of the analytical results needed for generation of quality assured monitoring data.

The Monitoring Guidelines for IMAP Common Indicator 17 outline the following monitoring and reporting practices:

- B-1. Monitoring Guidelines/Protocols for sampling and analysis of contaminants in sediment.
- B-2. Monitoring Guidelines/Protocols for sampling and determination of contaminants in marine biota.
- B-3. Monitoring Guidelines/Protocols for sampling and analysis of contaminants in seawater.
- E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20;
- F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20

Available data sources

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

i. ~~UNEP(DEPI)/MED WG.365/Inf.5. Analysis of the trend monitoring activities and data for the MED POL Phase III and IV (1999-2010). Consultation Meeting to Review MED POL Monitoring Activities. Athens, 22-23 November 2011.~~

ii. ~~UNEP(DEPI)/MED WG. 365/Inf.8. Development of assessment criteria for hazardous substances in the Mediterranean. Consultation Meeting to Review MED POL Monitoring Activities. Athens, 22-23 November 2011.~~

iii. ~~UNEP(DEPI)/MED WG. 427/Inf.3. Background to the Assessment Criteria for Hazardous Substances and Biological Markers in the Mediterranean Sea Basin and its Regional Scales.~~

i. ~~Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring Marseille, France, 19-21 October 2016.~~IMAP Info System (http://imapinfosystem.info-rac.org/app/#/)

~~iv.~~ii. EMODNET Chemistry: http://www.emodnet-chemistry.eu/data_access.html

Additional potential data sources:

- The scientific literature providing data on no effect or adverse biological effects alongside chemical data from the environment and biota at the same site and time.
- The studies providing sediment toxicity tests, aquatic toxicity tests in conjunction with equilibrium partitioning (EqP), and field and mesocosm studies from relevant scientific sources in consultation with the national counterparts. The selected studies should include all relevant auxiliary information: citation, type of test, type of biological effect, analytical approach used, study area, test duration, species tested or the benthic community considered, TOC, Acid volatile sulphide (AVS), chemical concentrations, among others.

Spatial scope guidance and selection of monitoring stations

The spatial scope for monitoring should include reference and coastal long-term master stations, including offshore, distributed spatially as relevant and include local spatial refinements, such as transect sampling (for sediment and/or active biomonitoring); and therefore, is a direct function of the risk-based assessments and the long-term monitoring purposes. The selection of the sampling sites for the monitoring of contaminants in the marine environment should consider:

- Risk areas of concern identified on the basis of the review of the existing information.
- Vulnerable areas of known past and/or present release of chemical contaminants.
- Offshore areas where risk warrants coverage (aquaculture, offshore oil and gas activity, dredging, mining, dumping at sea and others).
- Monitoring sites representative of other sources, such as shipping and atmospheric inputs.
- Reference monitoring sites: to establish scale-based reference values and background concentrations.
- Monitoring sites representing sensitive pollution sites/areas at national and sub regional scale.
- Monitoring sites in deep-sea sites, offshore stations (sediments) and areas of potential particular concern.

The selected sites should allow the collection of a realistic number of samples over the years (e.g. to be suitable for sediment sampling, to allow sampling a sufficient number of biota for the selected species during the duration of the programme). It is essential that the monitoring strategies are being coordinated at regional and/or sub regional level. The coordination with the monitoring networks for other Ecological Objectives is crucial for cost-effective and future IMAP integrated assessment.

As part of the 2023 MED QSR preparation, the assessment scales for CI 17 are defined within the framework of the IMAP nested approach, applying, among others, the above-listed criteria for the

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

selection of the sampling sites, and building upon the elements outlined in the section on Assessment of Eutrophication.

Temporal Scope guidance

Sampling frequencies will be determined according the current status of the national marine monitoring.

INITIAL PHASE OF IMAP MONITORING: to identify key sampling sites/stations within a coastal network which should include: BIOTA samples (bivalves, e.g. *Mytilus galloprovincialis*, as commonly agreed, mandatory IMAP species where present in local ecosystems, *Donax trunculus*, etc.), ~~(~~yearly collection, ~~)~~ and fish (i.e. *Mullus barbatus*, as commonly agreed, mandatory IMAP species where present in local ecosystems) every 4 years. In this phase monitoring SEDIMENTS (coastal, offshore areas) ~~platform~~ should be collected every two years.

ADVANCED PHASE OF IMAP MONITORING (when there is a fully completed IMAP Initial ~~MED POL~~ Phase of ~~IV~~ implementation with the ongoing data reporting ~~of datasets~~) should include: BIOTA ~~(~~from 1 to 3 years according the trends and levels of chemicals assessed at the different stations/sites, ~~)~~ and SEDIMENTS ~~(~~from 3 to 6 years depending on the characteristics of sedimentation areas and the chemical concerned known through previous ~~MED POL~~ assessments~~)~~.

The temporal scope may range from seasonally variable parameters up to large time scales, e.g. sediment core monitoring (years to decades). For temporal trend determinations the sampling frequencies will depend on the ability to detect trends considering the environmental and the analytical variability (ca. total uncertainty). It can be possible to decrease the sampling frequencies and target chemicals in cases where established time trends and levels show concentrations well below levels of concern, and without any upward trend over a number of years (including the stations/sites where recurrently exhibit non-detected contaminants value; that is below detection and quantification limits).

Data analysis and assessment outputs

Statistical analysis and basis for aggregation – Assessment Criteria

Monitoring should allow the necessary statistical data treatments and long-term time-trend data analysis.

Deriving and setting up the assessment criteria to determine environmental status is not an easy task. It gets more complicated going from the local to sub-regional and regional assessments. While there are many methodologies to derive criteria, the first step is aimed at defining the background or reference conditions from which to measure/determine the status and trends. In the framework of UNEP/MAP (UNEP/MAP 2016, 2019), the background concentration (BC) is defined as "The concentration of a contaminant at a "pristine" or "remote" site based on contemporary or historical data." The BC of anthropogenic (man-made) substances was defined as zero. The same definitions are used by OSPAR and the Marine Strategy Framework Directive (MSFD) based on the Water Framework Directive (WFD) (Tornero et al. 2019).4F[8]

The calculation of BC values is the first step for the derivation of indicators that are defined as the measure, index, or model used to estimate the current state and future trends, along with thresholds for possible management action. The BCs for CI 17 were derived using the following two methodologies: i) data from sediment cores compiled from the scientific literature (UNEP/MAP

[8] Additional definitions for BC can be found in the literature and are explained in UNEP/MED WG.533/Inf.3

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)
2011),5F[9] and ii) data from the MED POL database (UNEP/MAP 2011, 2016, 2019). A complete explanation of the used methodologies, including the specific methodologies used by UNEP/MAP for the different parameters, is given in previous UNEP/MAP documents (UNEP/MAP 2011, 2016, 2019), as well as in UNEP/MED WG.533/10, Annex III, Appendix 1 and UNEP/MED WG.533/Inf.3. BAC values are the concentrations below which no deterioration of the environment can be expected. Observed concentrations are said to be near BC if the mean concentration is statistically significantly below BAC. For the calculation of BAC values from BC concentrations, UNEP/MAP adopted the methodology that corresponds to the OSPAR methodology.6F[10] The BAC values were computed as the BC concentration multiplied by a factor that was determined based on the uncertainty (precision and accuracy) of the determinations. Detailed elaboration is provided in UNEP/MED WG.533/10, Annex III, Appendix 1 and UNEP/MED WG.533/Inf.3. The MedBAC values endorsed in Decisions IG.22/7 and IG.23/6 were as follows: MedBAC for TM in sediments, mussel and fish (Tables 1 and 3 of UNEP/MED WG.533/10, Annex III, Appendix 1), PAHs in sediments and mussel (Tables 2 and 4 of UNEP/MED WG.533/10, Annex III, Appendix 1). In 2019, the same methodology was used to propose the derivation of specific sub-regional MedBAC values. Further to work undertaken in 2019, the regional and sub-regional BAC values were updated in 2022, using the same methodology applied for the previous update. The new data critically analyzed (UNEP/MED WG.533/10, Annex III, Appendix 1 and UNEP/MED WG.533/Inf.3) were used to update the BC and BAC values for the sub-regions of the Mediterranean and for the whole Mediterranean Sea, ~~as provided in Tables 4 to 8,~~ by using the same methodology as initially applied in 2016/2017 and replicated in 2019.[11] BAC values for trace metals were calculated by multiplying the BCs by a factor as follows: i) MedBAC=1.5 x MedBC (for mussel and sediments matrices); ii) MedBAC=2.0 x MedBC (fish). For Polycyclic Aromatic Hydrocarbons (PAHs) in sediments and mussel (*M. galloprovincialis*), BAC values were calculated as follows: MedBAC=1.5 x MedBC.[12] When most of the data originated from one sub-region, or there were significant differences among the sub-regions, the BC values were calculated for sub-regions and not for the whole Mediterranean. It was noted that in some instances there was a large variability (up to > 100%) on BACs values between the values re-calculated in 2017, 2019 and 2022. Therefore, it was recommended by the Meeting of CorMon (1-2 March 2023) that when deciding on the use of threshold for GES assessment, this variability should be taken into account for each sub-region. The reporting of new data from CPs to the IMAP-IS allowed for the calculation of the new BC and BAC values for PAHs in the mussel (*M. galloprovincialis*). As for sediments, data with BDL values	

[9] For the purpose of this document only the scientific elements have been considered from any reference included in this document. Legal considerations are out of the scope of the present document, which serves exclusively scientific purposes.
[10] At present, no statistical assessment was possible for the precision of the monitoring data reported into IMAP Info system given the quantity of data reported, as well as a frequency of analyzing one sample of either biota or sediments is insufficient for calculation of the precision of monitoring data. Therefore, the variability from OSPAR monitoring program was used, following its application for an upgrade of the assessment criteria in 2017 and 2019. A detailed explanation is given in section 2.3.1 of the information document UNEP/MAP WG.533/Inf.3.
[11] The calculation was performed using also the limit of detection (LOD) or the limit of quantitation (LOQ) values provided by the countries, addressed as below detection limit (BDL) values (see Annexes I and III in UNEP/MAP WG.533/Inf.3).
[12] The calculation of the multiplication factor to calculate BACs for PAHs in sediments was not provided in the previous UNEP/MAP documents (2011, 2016, 2019). Looking at the OSPAR values for BC and BAC for PAHs in the sediments, the multiplication factor used depended on the compound and ranged from 1.6 to 2.1.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

were used in the calculation of the new BCs. The BDL values were different, depending on the country and even different within the same country. Moreover, BDL values constituted 12% to 90% of the data points depending on the compound.[13] This could be the one reason for the differences in BACs between sub-regions.

The Meeting of CorMon Pollution (1-2 March 2023) also agreed to add the concentration of the Sum of (16) PAHs to the list of parameters in addition to reporting the concentrations of individual 16 PAHs, given it was included in Data Dictionaries as the mandatory parameter for CI 17.

The reporting of new data from CPs to the IMAP-IS allowed for the calculation of BACs for organochlorinated contaminants (IMAP addresses PCBs and pesticides within organochlorinated contaminants) in sediments and *M. galloprovincialis*. The BACs used for organochlorinated contaminants are based on the detection limits of the methods used and their uncertainty (precision and accuracy), as determined from CRMs (Certified reference materials) and proficiency testing.

These new BC and BAC values for IMAP CI 17, as revised and approved by the Meeting of CorMon Pollution (27 and 30 May 2022) (UNEP/MED WG.533/10, Annex III, Appendix 1), and approved by Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean, are presented here-below in Tables 1 to 5.

Table 1. New updated BC and BAC values for trace metals in sediments calculated from data available for upgrade of the criteria, as approved by the Meeting of CorMon Pollution (27 and 30 May 2022). The units of concentration are given in µg/kg dry wt, as requested by IMAP.

New updated BC and BAC values for trace metals in sediments					
New updated BC values (2022) in sediments, µg/kg dry wt					
TM	MED	WMS	ADR	CEN	AEL
Cd	107	140	120	#	78.9
Hg	50.0	90.0	50.0	#	31.5
Pb	15000	16000	15700	1805	15674
New updated BAC values (2022) in sediments, (µg/kg dry wt)					
	Med	WMS	ADR	CEN	AEL
Cd	161	210	180	#	118
Hg	75.0	135	75.0	#	47.3
Pb	22500	24000	23550	2708	23511
*#All data points for Cd are **BDL** as well as 72% of the Hg data points.*					

Table 2. New updated BC and BAC values for Polycyclic Aromatic Hydrocarbons **(**PAHs) in sediments calculated from data available for upgrade of the criteria, as approved by the Meeting of CorMon Pollution (27 and 30 May 2022). The units of concentration are given in µg/kg dry wt, as requested by IMAP.

New updated BC and BAC values for Polycyclic Aromatic Hydrocarbons (PAHs) in sediments					
	Updated BC values (2022) in sediments, µg/kg dry wt				
PAH compounds	MED	WMS	ADR	CEN	AEL
Naphthalene	2.00	8.0	2.0	#	2.3
Acenaphthylene	(1.0)#	#	#	0.4	#
Acenaphthene	(2.0)#	#	#	*	#
Fluorene	(2.0)#	#	#	0.4	#
Phenanthrene	3.10	14.9	3.5	0.8	3.1
Anthracene	(2.2)#	#	#	#	#
Fluoranthene	5.00	#	7.0	0.1	2.7
Pyrene	6.20	24.8	8.0	0.4	3.0

[13] See Annex III in UNEP/MAP WG.533/Inf 3.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Benzo[a]anthracene	3.38	19.7	4.1	*	1.8
Chrysene	2.70	35.9	4.6	1.6	1.6
Benzo(b)fluoranthene	5.00	8.7	15.0	*	2.6
Benzo(k)fluoranthene	4.00	#	3.0	*	#
Benzo[a]pyrene	(4.0)#	#	4.0	#	1.0
Benzo[g,h,i]perylene	(4.2)#	#	5.7	*	1.8
Dibenz[a,h]anthracene	(1.0)#	7.0	#	*	#
Indeno[1,2,3-c,d]pyrene	(4.0)#	#	4.4	*	2.1
Sum PAHs	27.4	160	41.0	6.3	21.4
	Updated BAC values (2022) in sediments, µg/kg dry wt				
PAH compounds	MED	WMS	ADR	CEN	AEL
Naphthalene	3.0	12.0	3.0	#	3.5
Acenaphthylene	(1.5)#	#	#	0.6	#
Acenaphthene	(3.0)#	#	#	*	#
Fluorene	(3.0)#	#	#	0.5	#
Phenanthrene	4.7	22.4	5.3	1.2	4.7
Anthracene	(3.3)#	#	#	#	#
Fluoranthene	7.5	#	10.5	0.2	4.1
Pyrene	9.3	37.1	12.0	0.6	4.5
Benzo[a]anthracene	5.1	29.6	6.2	*	2.7
Chrysene	4.0	53.9	6.9	2.4	2.4
Benzo(b)fluoranthene	7.5	13.0	22.5	*	3.8
Benzo(k)fluoranthene	6.0	#	4.5	*	#
Benzo[a]pyrene	(6.0)#	#	6.0	#	1.5
Benzo[g,h,i]perylene	(6.3)#	#	8.6	*	2.7
Dibenz [a,h]anthracene	(1.5)#	10.5	#	*	#
Indeno[1,2,3-c,d]pyrene	(6.0)#	15.0	6.5	*	3.2
Sum PAHs	41.0	240	61.5	9.5	32.0

*#most data (>50%) below detection limit, * no data reported*

Table 3. New updated BC and BAC values for trace metals in mussel (*M. galloprovincialis*) and fish (*M. barbatus*) calculated from data available for upgrade of the criteria, as approved by the Meeting of CorMon Pollution (27 and 30 May 2022). The units of concentration are given as requested by IMAP.

New updated BC and BAC values for trace metals in mussel soft tissue (*M. galloprovincialis*), µg /kg dry wt					
New updated BC values (2022)					
TM	**MED**	**WMS**	**ADR**	**CEN**	**AEL**
Cd	710	1030	629	*	942>
Hg	77.9	85.0	75.4	*	110>
Pb	1100	1260	1000	*	2300>
New updated BAC values (2022)					
TM	**MED**	**WMS**	**ADR**	**CEN**	**AEL**
Cd	1065	1545	944	*	1413>
Hg	117	128	113	*	165>
Pb	1650	1890	1500	*	3450>

** Only a few data points were available for the CEN. The calculated BCs were lower than in other sub-regions, however, the few data are not representative of the CEN.*
> Since new data were not available in the AEL to update BC/BAC values for M. galloprovincialis, it was approved to use the values calculated in 2019.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

New updated BC and BAC values for trace metals in fish muscle *(Mullus barbatus)*, µg/kg wet wt					
New updated BC values (2022)					
TM	**MED**	WMS	ADR	CEN	AEL
Cd	3.9	*	5.3	*	3.6
Hg	40.6	*	120	*	33.7
Pb	18.3	*	40.8	*	13.5
New updated BAC values (2022)					
	MED	WMS	ADR	CEN	AEL
Cd	7.8	*	10.6	*	7.2
Hg	81.2	*	240	*	67.4
Pb	36.6	*	81.6	*	27.0

** Given the lack of data, it was not possible to propose values for BC in these sub-regions, therefore it was approved to use the regional MED BC values for the GES assessment*

Table 4. New BC and BAC values for Polycyclic Aromatic Hydrocarbons **(**PAHs) in mussel (*M. galloprovincialis)* calculated from data available for upgrade of the criteria, as approved by the Meeting of CorMon Pollution (27 and 30 May 2022). The unit of concentration is given in µg/kg dry wt, as requested by IMAP. No data were available for the CEN and the AEL Sub-regions.

New BC and BAC values for Polycyclic Aromatic Hydrocarbons (PAHs) in mussel (*M. galloprovincialis*), µg/kg dry wt			
New BC values (2022)			
	MED	WMS	ADR
Naphthalene	0.56	0.52	#
Acenaphthylene	(0.05)#	#	#
Acenaphthene	(0.50)#	#	#
Fluorene	2.50	7.87	#
Phenanthrene	5.35	19.9	2.25
Anthracene	1.12	0.94	#
Fluoranthene	4.83	10.0	#
Pyrene	2.50	5.54	#
Benzo[a]anthracene	0.60	0.69	#
Chrysene	2.54	2.98	#
Benzo(b)fluoranthene	1.00	1.36	#
Benzo(k)fluoranthene	1.00	0.73	#
Benzo[a]pyrene	(1.00)#	0.94	#
Benzo[g,h,i]perylene	1.00	0.67	#
Dibenz[a,h]anthracene	(0.10)#	#	#
Indeno[1,2,3-c,d]pyrene	(0.63)#	0.29	#
Sum 16 PAHs [14]	5.80	5.60	6.60
New BAC values (2022)			
	MED	WMS	ADR
Naphthalene	0.84	0.79	#
Acenaphthylene	(0.08)#	#	#
Acenaphthene	(0.75)#	#	#
Fluorene	3.75	11.8	#

[14] Data dictionary gives 2 additional categories: Sum 4 PAHs Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene) and Sum 5 PAHs (Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(ghi)perylene, Indeno(1,2,3-cd)pyrene). It is suggested that they be considered for use in the future data reporting.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Phenanthrene	8.03	29.8	3.38
Anthracene	1.68	1.40	#
Fluoranthene	7.25	15.0	#
Pyrene	3.75	8.31	#
Benzo[a]anthracene	0.90	1.04	#
Chrysene	3.81	4.46	#
Benzo(b)fluoranthene	1.50	2.04	#
Benzo(k)fluoranthene	1.50	1.09	#
Benzo[a]pyrene	(1.50)#	1.42	#
Benzo[g,h,i]perylene	1.50	1.01	#
Dibenz[a,h]anthracene	(0.14)#	#	#
Indeno[1,2,3-c,d]pyrene	(0.94)#	0.43	#
Sum 16 PAHs	8.70	8.40	9.90

#most data (>50%) below detection limit;

Table 5. New BAC values for organochlorinated contaminants (PCBs and pesticides) in sediments and mussel (*M. galloprovincialis*), calculated from data available for upgrade of the criteria, as approved by the Meeting of CorMon Pollution (27 and 30 May 2022). The unit of soncentrations is given in µg/kg dry wt, as requested by IMAP. For sediments, very limited data were available for the CEN sub-region, while for biota no data were available for the CEN and AEL sub-regions. When most (>50%) of the data points were below the detection limit for the sub-regions, BACs were not calculated.

New BAC values (2022) for organochlorinated contaminants (PCBs and pesticides) in sediments and mussel (*M. galloprovincialis*)					
SEDIMENTS, µg/kg dry wt	MED	WMS	ADR	CEN	AEL
PCBs					
PCB28	0.10	#	#	#	0.09
PCB52	0.07	0.10	0.09	#	0.04
PCB101	0.10	0.16	0.16	*	#
PCB118	0.10	0.46	0.18	#	0.01
PCB138	0.11	0.26	0.24	#	#
PCB153	0.14	0.40	0.28	#	0.02
PCB180	0.09	0.13	0.13	#	#
Sum 7 PCBs	0.40	1.60	0.21	#	0.19
Pesticides					
γ-HCH (Lindane)	(0.1)#	#	#	*	0.02
DDE(p,p')	(0.1)#	0.23	#	#	*
Hexachlorobenzene	(0.1)#	#	#	#	*
Dieldrin	(0)#		#	#	#
BIOTA – MG, µg/kg dry wt	MED	WMS	ADR	CEN	AEL
PCBs					
PCB28	0.20	0.07	1.38	*	*
PCB52	0.38	0.3	0.5	*	*
PCB101	1.20	1.1	1.4	*	*
PCB118	1.23	1.5	1.4	*	*
PCB138	2.31	2.4	3.3	*	*
PCB153	3.45	4.6	4.6	*	*
PCB180	0.50	0.3	0.5	*	*
Sum 7 PCBs	18.4	28.6	17.3	*	*
Pesticides					
γ-HCH (Lindane)	(1.0)#	#	#	*	*
DDE(p,p')	3.05	3.05	*	*	*
Hexachlorobenzene	(0.5)#	#	#	*	*
Dieldrin	(1.0)#	#	*	*	*

*# most data (>50%) below detection limit. * no data reported*

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

EAC values are the concentrations above which significant adverse effects on the environment or human health are most likely to occur. Conversely, EAC values are defined as the concentrations below which it is unlikely that unexpected or unacceptable biological effects will occur in exposed marine species. Given it was impossible to develop EACs specific for the Mediterranean, it was agreed to use the criteria developed by OSPAR and NOAA/USEPA (ERL values) (Long et al. 1995), as the EAC values for the Mediterranean. The EAC values agreed in Decisions IG.22/7 and IG.23/6 are as follows: EAC values for TM, PAHs and organochlorinated contaminants (PCBs and pesticides) i.e., NOAAs ERLs (for TM, PAH and pesticides in sediments) and the ECs from EU Directives to protect human health (for TM and organic contaminants in biota).

The EAC values for TM in biota as endorsed by Decisions IG.22/7 and IG.23/6 are the concentrations in fish and seafood recommended as dietary limits for human consumption concerning human health (EC), derived from the following EU Directives regulating maximum levels for certain contaminants in foodstuffs: EC/EU 1881/2006 and amendment 629/2008. EAC values for organic contaminants (PAHs and organochlorinated contaminants) in mussels were taken from OSPAR.[15]

It must be noted that the EAC values set up to protect human health may be too lenient to protect the Mediterranean Sea if the goal is to achieve and maintain GES where the contaminants cause no significant impact on coastal and marine ecosystems. However, EAC values for CI 17 cannot be updated based on existing monitoring data. It needs very specific in-depth research of the ecotoxicological and environmental scientific literature.

Therefore, the methodology detailed in the European Commission Guidance Document (2018) and in Long et al. (1995) was recommended by the Meeting of CorMon Pollution (27 and 30 May 2022) for an update of Mediterranean EAC values. It includes a thorough examination of the scientific literature conducted to study where data on no effect or adverse biological effects are given in conjunction with chemical data in the environment and in the biota at the same site and time. Those include but are not limited to sediment toxicity tests, aquatic toxicity tests in conjunction with equilibrium partitioning (EqP) and field and mesocosm studies. The data should be assembled into a detailed database and analyzed, as well as the extent of the effect determined. The emphasis should be given to Mediterranean biota species.

Upgrade of the EAC values for the Mediterranean Sea is a long-term task that needs dedicated, very specific, scientific research (more detailed elaboration is provided in UNEP/MED WG.533/Inf 3). Meanwhile, the EAC values as endorsed for TM (Cd, Hg and Pb) and organic contaminants (PAHs, PCBs and pesticides) in Decisions IG.22/7 and IG.23/6 will continue to be applied in the Mediterranean. They are shown here-below in Tables 6 to 8.

Further to the gaps identified within the preparation of the IMAP Pollution Assessments of the 2023 MED QSR, it is necessary to further align the list of EAC values included in Decisions IG.23/6 and IG.22/7 with the sources originally used (i.e., Long et al., 1995, OSPAR, 2009. 16) The following slight updates are included in Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean:

a) Table 6: The new EAC values were added for the following PAHs: i) Naphthalene; Acenaphthylene; Acenaphthene Fluorene; Dibenz [a,h]anthracene and Sum16 PAHs in sediments and ii) Naphthalene in biota.

[15] OSPAR Commission, Agreement number 2009-2. Agreement on CEMP Assessment Criteria for the QSR 2010. Publication number 2009/461. CEMP: 2008/2009 Assessment of trends and concentrations of selected hazardous substances in sediments and biota. Publication number 2009/390. OSPAR QSR 2000-Chapter 4.

[16] Long, E., D. Macdonald, S. Smith and F. Calder (1995). "Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments." Environmental Management **19**(1): 81-97, OSPAR Commission, Agreement number 2009-2. Agreement on CEMP Assessment Criteria for the QSR 2010. Publication number 2009/461.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

b) Table 7: The new EAC value is added for Sum 7 PCBs in sediments. The EAC value of 11.5 µg/kg dry wt in Decision IG 22/7 originated probably from Long et al. (1995) as explained in document UNEP/MED 427/Inf.3.[17] However, Long et al. (1995) presents the ERL value of 22.7 µg/kg dry wt for Total PCBs in sediments but do not specify which congeners were considered. Moreover, OSPAR has not adopted an EAC value for the sum of 7 PCBs in sediments. Therefore, further to experience related to the preparation of the assessments within the 2023 MED QSR, the EAC value of 67,9 is included to present the sum of 7 individual IMAP PCB congeners.

Table 6. Mediterranean EAC values for trace metals in sediments and biota, as endorsed by Decision IG.23/6

Mediterranean EAC values for trace metals in sediments and biota			
	MedEAC*	**#MedEAC**	**#MedEAC**
TM	**Sediments, µg/kg dry wt**	***M. galloprovincialis,* µg/kg dry wt**	***Mullus barbatus,* µg/kg wet wt**
	IG.23/6	IG.23/6	IG.23/6
Cd	1200	5000	50
Hg	150	2500&	1000
Pb	46700	7500	300

** Med EAC values equal to ERL (Effects Range Low, Long et al. 1995, idem OSPAR values). # Med EAC values equal to the maximum regulatory levels for contaminants in foodstuffs as provided in EC/EU 1881/2006 and 629/2008 Directives*
& Not included in EU directives, but adopted by OSPAR

Table 7. Mediterranean EAC values for Polycyclic Aromatic Hydrocarbons (PAHs) in sediments and biota, as endorsed by Decisions IG.23/6 and IG.22/7, along with a few updated values to ensure consistency with ERL Long et al., and OSPAR EAC values

Mediterranean EAC values for Polycyclic Aromatic Hydrocarbons (PAHs) in sediments and biota				
	Sediments, µg/kg dw		**Biota Mussels, µg/kg dw**	
PAH compounds	**EAC* IG.22/7 and IG.23/6 - OSPAR and ERLs**	**ERL Long et al, 1995#**	**EAC** IG.22/7 and IG.23/6 - OSPAR**	**OSPAR#**
Naphthalene		160		340
Acenaphthylene		44		
Acenaphthene		16		
Fluorene		19		
Phenanthrene	240		1700	
Anthracene	85		290	
Fluoranthene	600		110	
Pyrene	660		100	
Benzo[a]anthracene	261		80	
Chrysene	384			

[17] Table A.3.1:" ERL for ICES sum of 7CB is total CB concentration/2"

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Benzo(b)fluoranthene				
Benzo(k)fluoranthene			260	
Benzo[a]pyrene	430		600	
Benzo[g,h,i]perylene	85		110	
Dibenz [a,h]anthracene		63.4		
Indeno[1,2,3-c,d]pyrene	240			
Sum 16 PAHs		4022		

** Med EAC values equal to ERL (Effects Range Low, Long et al. 1995, idem OSPAR values)*
*** Med EAC values equal to OSPAR values*
 # Med EAC values equal to ERL (Effects Range Low, Long et al., 1995) which were not included in Decisions IG.22/7 and IG.23/6.

Table 8. Mediterranean EAC values for for organochlorinated contaminants (PCBs and pesticides) in sediments and biota, as endorsed by Decisions IG.23/6 and IG.22/7 along with the one updated value

Mediterranean EAC values for for organochlorinated contaminants (PCBs and pesticides) in sediments and biota

	Sediments			**Mussel**	**Fish**
PCBs	**EAC# IG.22/7 (µg/kg dry wt) – updated**	**EAC* IG.22/7 (µg/kg dry wt)**	**EAC** IG.23/6 (µg/kg dry wt)**	**EAC** IG.22/7 and IG.23/6 (µg/kg dry wt)**	**EAC** IG.22/7 and IG.23/6 (µg/kg lipid)**
CB28			1.7	3.2	64
CB52			2.7	5.4	108
CB101			3	6	120
CB118			0.6	1.2	24
CB138			7.9	15.8	316
CB153			40	80	1600
CB180			12	24	480
Sum 7 PCBs	67,9				
Pesticides					
γ-HCH (Lindane)		3		1.45	11 µg/kg ww
DDE(p,p')		2.2		5-50	
Hexachlorobenzene		20			
Dieldrin		2		5-50	

** ERL (Effects Range Low, (Long et al., 1995) or used by OSPAR (2009)*
*** From OSPAR (2009)*
#The EAC value of 11.5 µg/kg dry wt in Decision IG 22/7 originated probably from Long et al, 1995 as explained in document UNEP/MED 427/Inf.3. However, Long et al.,1995 present the ERL value of 22.7 µg/kg dry wt for Total PCBs in sediments but do not specify which congeners were considered. Moreover, OSPAR has not adopted an EAC value for the sum of 7 PCBs in sediments. Therefore, further to experience related to the preparation of the assessments within the 2023 MED QSR, the EAC value of 67,9 is included to present the sum of 7 individual IMAP PCB congeners.

Ongoing efforts focus on establishing an improved methodology for setting the Environmental Assessment Concentration (EAC) for IMAP Common Indicator 17 at the regional and the sub-regional level subject to data availability. These efforts also include proposing the new area-specific species, contaminants, and emerging contaminants of concern recommended to strengthen pollution monitoring in the Mediterranean.

~~Expected a~~Assessment of Contaminants in sediments and biota ~~s outputs~~

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

For chemical contaminants, trends analysis and distribution levels for the assessment could be carried out on sub-regional and/or regional level, provided appropriate quality control assured datasets are available. ~~For the assessment of GES, it would be carried out using Mediterranean data from the MEDPOL database and applying a two-level threshold classification (Background Assessment Criteria-BACs and Environmental Assessment Criteria-EACs), such as the OSPAR methodology. However, the revised Mediterranean BACs and EACs for chemical contaminants, such as trace metals (mercury, cadmium and lead) and organic contaminants (chlorinated compounds and PAHs) in sediments and biota in the Mediterranean Sea should be applied.~~

For the assessment of contaminants in sediments and biota conducted as part of the preparation of the 2023 MED QSR, different assessment methodologies were employed for the evaluation of CI 17, based on the data availability provided by the Contracting Parties (CPs) across the four Mediterranean Sub-regions. The Mediterranean Sea is divided into four main sub-regions based on available database sources to facilitate the development of pollution assessment criteria. This process began with the preparation of the UNEP/MAP 2011 Initial Integrated Assessment, followed by the Med QSR 2017, and most recently, the 2023 MED QSR assessments. These sub-regions are: the Western Mediterranean, the Adriatic Sea, the Central Mediterranean, and the Aegean and Levantine Seas.

An integrated NEAT GES assessment methodology was tested, and thereafter applied, first to the assessment of contaminants (CI 17), and then to chl*a* (CI 13) and nutrients (CI 14) in the Adriatic Sea Sub-region.

The integrated NEAT GES assessment for CI 17 across all sub-regions was not feasible due to the high heterogeneity of data types, spatial coverage, and the lack of quality-assured, homogeneous data. As a result, the NEAT methodology was applied to the Adriatic Sea Sub-region and later to the Western Mediterranean Sub-region, based on the monitoring areas defined by the concerned CPs and the harmonization of scale approaches among the Contracting Parties.

For some subregions of the Mediterranean Sea, it was possible to define IMAP spatial assessment units (IMAP SAUs) based on the distribution of monitoring stations (e.g. Adriatic Sea, Western Mediterranean Sea), while for others with insufficient data reported for GES assessment this was impossible. A quality status assessment for all areas is needed either on a SAU level or alternatively on individual monitoring stations level. The NEAT methodology supports assessments in areas where SAUs are defined (e.g. Adriatic Sea; Western Mediterranean Sea). For areas where this is impossible, the CHASE+ (Chemical Status Assessment Tool) methodology was applied for assessment at the monitoring stations level.

The NEAT assessment methodology strikes a balance between overly broad scales, which may obscure significant areas of impact in specific regions or sub-regions, and excessively fine scales, which could complicate the assessment process. This methodology was applied at the IMAP CIs 17 for monitoring data collected per each Spatial Assessment Unit (SAU) and per environmental matrix (sediments, biota) and per contaminant group (trace metals (TM), PAHs, PCBs) separately, considering the temporal coverage of monitoring data used again per each SAU and per environmental matrix (sediments, biota) and per contaminant group (trace metals (TM), PAHs, PCBs) separately.

The 4-level and 3-level nesting approaches were implemented in the Adriatic Sea Sub-region and Western Mediterranean Sub-region, respectively. This resulted in the aggregation and integration of assessment results within the IMAP nested scheme at the following levels:

4. IMAP national Spatial Assessment Units (SAUs) and sub-SAUs (the finest level)
5. IMAP coastal and offshore assessment zones of sub-divisions

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

6. Sub-division and sub-regional levels (e.g., Adriatic Sea).

For setting the IMAP assessment areas for CIs 13 and 14, the finest areas defined for CI 17 were adjusted to serve the purpose of eutrophication assessment.

The scope of all SAUs and sub-SAUs was defined and introduced into the NEAT tool, along with their respective codes and surface areas (in km²). Within each SAU under 'habitats' the sediments and biota are introduced. Under 'ecosystem component' the 5 chemical compounds of CI 17 are assigned. For each SAU and 'Ecological Component' (EO9 contaminants in our case) and 'Habitat' (sediments, biota), average value and standard deviation per chemical compound is inserted. While arithmetic means and standard errors were used for CI 17, geometric means and standard errors were applied for CIs 13 and 14.

Boundary limits and class threshold values per SAU, parameter, and matrix are applied according to the assessment scale presented in the section on targets. The aggregation of the 5 chemical compounds of CI17 was carried out to derive a single status value (NEAT value) for all levels of the nesting scheme. The aggregation of the assessment results for these compounds resulted in a NEAT value per specific SAU, which was then spatially integrated into the sub-divisions and regional levels. The assessment results were presented and visualized using a tabular format and graphical representations generated with a GIS tool.

In the absence of sufficient *in situ* data reported for the Central Mediterranean, and Aegean and Levantine Seas Sub-regions, **the CHASE+ (Chemical Status Assessment Tool) methodology** was tested and then applied in these sub-regions. Its application was based on the experince of the European Environmental Agency (EEA) to assess environmental status categories for the European Seas (Andersen et al. 2016, EEA 2019)[18].

The first step in this tool is to calculate the ratio $C_{measured}/C_{threshold}$ (C is the concentration) called the contamination ratio (CR) for each assessment element in a matrix. Then a contamination score (CS) is calculated as follows[19]:

$$CS = \frac{1}{\sqrt{n}} \sum_{i=1}^{n} CR_i$$

where n is the number of elements assessed for each matrix.

Based on the contamination ratio (CR) or on contamination score (CS), the elements are assessed. In line with the results of assessments, the stations/areas are classified according to the assessment scale presented above in the section on targets.

In order to avoid possible bias in the Mediterranean regional assessment that may occur as a result of the use of different assessment methodologies in different areas, comparisons and harmonization of the NEAT and the CHASE+ assesmnet methodologies were perfomed. It ensured reducing uncertainty and achieving harmonization across assessments conducted in different sub-regions and sub-divisions, despite variations in the number of sampling locations and measurements.

Further details are provided in the thematic assessments **of contaminants** in sediments and biota and the 2023 MED QSR Pollution Assessment.

[18] Andersen, J.H., Murray, C., Larsen, M.M., Green, N., Høgåsen, T., Dahlgren, E., Garnaga-Budrė, G., Gustavson, K., Haarich, M., Kallenbach, E.M.F., Mannio, J., Strand, J. and Korpinen, S. (2016) Development and testing of a prototype tool for integrated assessment of chemical status in marine environments. Environmental Monitoring and Assessment 188(2), 115.
EEA (2019) Contaminants in Europe's Seas. Moving towards a clean, non-toxic marine environment. EEA Report No 25/2018.
[19] The contamination sum minimizes the problem of 'dilution' of high values when several substances from an area are analyzed, and takes to some extent possible synergistic effects of contaminants into account by using square root of 'n' instead of 'n'.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

Known gaps and uncertainties in the Mediterranean

Important development areas in the Mediterranean Sea over the next a few biennia ~~years will~~ included harmonization of monitoring targets (determinants and matrices) within assessment at sub-regions scales, development of suites of assessment criteria, ~~integrated chemical and biological assessment method developments,~~ and review of the scope of the national monitoring programmes to ensure that those contaminants which are considered to be important within each assessment area are included. Through these and other actions, it was ~~ill be~~ possible to develop targeted ~~and effective~~ monitoring programmes tailored to meet the needs and conditions within each GES assessment sub-region. It was ~~has been~~ recognized that the open and deep sea is much less covered by monitoring efforts than coastal areas. Therefore, ~~is a need to include~~ within monitoring programmes also areas beyond the coastal areas were included in a representative and efficient way (where risks warrant coverage).

By building on the achievements up to 2023, during the preparation of the 2023 MED QSR, several knowledge gaps were identified in the monitoring and assessment of Common Indicator 17, which need to be addressed following the recommendations of the 2023 MED POL Focal Points Meeting.

Update of Environmental Assessment Criteria (EACs):

In order to update EACs, the methodology, as detailed in the European Commission Guidance Document (2018) and in Long et al. (1995), should be considered. This entails the creation of a database of scientific literature which elaborates where adverse biological effects, or no effect, are presented in conjunction with chemical data, in the environment and biota, at the same site and time. Briefly, those include but are not limited to sediment toxicity tests, aquatic toxicity tests in conjunction with equilibrium partitioning (EqP) and field, and mesocosm studies. The literature would then be analysed by experts and conclusions drawn. Laboratory results on biomarkers (CI18) are also important for the derivation of the EAC values. The emphasis should be given to the Mediterranean Sea biota species.

Undertake regular updates of Sub-regional and regional Background Concentrations (BCs) and Background Assessment Criteria (BACs):

As more data will be submitted to IMAP IS, the Sub-regional and regional BCs should be updated. It is proposed to undertake their regular updates at least 2 years prior to the QSRs preparation. This will allow for sufficient time to analyse the data, detect data gaps and ensure the submission of missing data, to perform a more robust update of the criteria for reliable assessments.
The methodology for BACs calculation should be revised and updated. BACs are calculated from BCs by applying the multiplication factors. Due to the lack of Mediterranean data, UNEP/MAP adopted the pragmatic methodology used by OSPAR.[20] Therefore, the precision of monitoring per CP should be calculated and used to set the multiplication factors specific for the Mediterranean.

Improve the GES assessment:

Revision of IMAP needs to support the improvement of the good environmental status assessment and contribute to a more robust analysis, and facilitate integration and aggregation of CI 17 with other CIs and EOs, by undertaking the following priority actions:

- Update list of priority pollutants. Measurements of known contaminants of concern, such as As and Cu, and emerging contaminants of concern, such as pharmaceuticals and flame retardants should be considered for inclusion in the IMAP Pollution monitoring. This

[20] OSPAR calculated the ratio between BAC and BC (the multiplication factor) from known parameters. The pragmatic approach used in order to have 90% probability of concluding that concentration is below provided for BAC, BAC = BC exp (3.18 CV), where CV is the precision of the monitoring program (per determinant and matrix). In the case of OSPAR, temporal monitoring data from the UK National Marine Monitoring Programme was considered.

Indicator Title	Common Indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9)

process should follow the initial steps undertaken in 2019.[21] The updated List of Priority Contaminants could provide the basis for a prioritization of substances to be further included in the IMAP Guidance Factsheets related to Ecological Objective 9, and complement presently agreed mandatory or recommended substances for CIs 17 and 20. The decision on which contaminant to add should be based on pilot studies checking the probability of their presence in the Mediterranean Sea sub-regions.

- Extend the list of commonly agreed IMAP Pollution mandatory species. Species, other than species (*M. galloprovincialis* and *M. barbatus*) presently mandatory, should be added to the IMAP list. The species should be chosen based on their presence in the Sub-regions and their relevance as pollution indicators, which in turn will allow for an improved environmental assessment. Harmonization of the use of different species in different Sub-regions needs to be followed by setting the criteria (BCs and BACs) specific to each species.
- Utilize tools to perform Environmental Risk Analysis, to integrate chemical and biological data, as elaborated here-below for CI 18.
- Revise sediments` temporal monitoring requirements. For hot spot stations, the monitoring should remain every year or 2 years, while for other stations, the monitoring once or twice during the 6-year cycle should be considered.
- Harmonize national efforts regarding contaminants monitoring. As a minimum, it is necessary to ensure that every CP reports all mandatory parameters in mandatory matrixes, including the wet weight for mussels, LOD or LOQ values, the grain size of samples for sediments, and spatial and temporal monitoring requirements. The significant differences among the countries in terms of LOD and LOQ values, as well as differences among the areas of monitoring in the same CP, need to be analyzed and drivers of the unsatisfactory analytical performance identified.

Contacts and V~~v~~ersion Date		
http://www.unepmap.org		
Version No	**Date**	**Author**
V.1	31.05.17	MEDPOL
V.2	11.09.17	MEDPOL
V.2	12.12.18	MEDPOL
V.4	31/05/2019	Approved by the Meeting of MED POL FPs
Final version	09/09/2019	Approved by the 7th Meeting of EcAp Coordination Group
V4	28/05/2025	Joint CorMon Pollution and ML Meeting
V5		Approved by the Meeting of MED POL FPs
Final version		Approved by the 12th Meeting of EcAp Coordination Group

9. The revision of IMAP **Common Indicator 18 (EO9)**: "Level of pollution effects of key contaminants where a cause and effect relationship has been established" is presented in the table bellow.

[21] UNEP/MED WG.463/Inf.4. The List of Priority Contaminants under MAP/Barcelona Convention within the MED POL Monitoring Programme and IMAP have been revised according the latest lists of priority contaminants development in the EU region and internationally and shows no major changes compared to other RSCs.

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**[22]
Concentrations of contaminants are not giving rise to acute pollution events	Effects of released contaminants are minimized	

Rational

Justification for indicator selection

Biomarkers are used to infer on a cause-effect relationship between a stressor and a biotic effect. The biotic effects can be biochemical, physiological, toxicological and/or be detected at the ecological/community level. The World Health Organization (WHO, 1993) further defined biomarkers as: (1) a biomarker of exposure (effect measured within an organism) and (2) a biomarker of effect (effect measured as a health impairment or disease) (Lomartire et al. 2021).

Upon exposure to certain dose of harmful contaminants, marine organisms start manifesting a number of symptoms that are indicative of biological damage, the first ones appearing after a short while at the sub-cellular level. These 'sub lethal' effects, when integrated, often converge to visible harm for the organisms and possibly to the whole population at a later stage, when it will be too late to limit the extent of biological damage resulting from environmental chemical exposure and ecosystems deterioration. Most of these symptoms have been reproducibly obtained in the laboratory (at high dose) and the various biological mechanisms of response to major xenobiotics are now sufficiently well documented. In the latest decades, scientific research has been intensified towards these alternative cellular and sub-cellular methods for integrated pollution monitoring, despite it revealed a more complex panorama with samples exposed to environmental concentrations, which includes a number of confounding factors hindering the cost-effective and reliable determination of biological effects at cellular and sub-cellular levels.

As a consequence, most of these methods (biomarkers), based on the chemical exposure to biological effects cause relationships, are envisaged to monitor hotpots stations, dredging materials assessments and local damage evaluations rather than for continuous long-term environmental monitoring (surveillance).

Ongoing research (biomarkers, bioassays) and future research trends, such as 'omics' developments, will further define the indicators and the methodologies for these common indicators for toxicological effects.

Biomarkers are classified as per the expected protection/defense response, including the most used as collected from the recent literature for the Mediterranean Sea, as presented below in the Section on Indicator Definition.

Scientific References

Amamra, F., Sifi, K., Kaouachi, N. and Soltani, N. (2019) Evaluation of the impact of pollution in the gulf of Annaba (Algeria) by measurement of environmental stress biomarkers in an edible mollusk bivalve Donax trunculus. Fresenius Environmental Bulletin 28(2), 908-915.

[22] Following the decisions to be made at the present meeting regarding minor adjustments to the Targets, as outlined in working document UNEP/MED WG.626/3/Rev.1, the revised Targets will be incorporated into the revised IMAP Pollution Indicators Factsheets.

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Barranger, A., Langan, L.M., Sharma, V., Rance, G.A., Aminot, Y., Weston, N.J., Akcha, F., Moore, M.N., Arlt, V.M., Khlobystov, A.N., Readman, J.W., Jha, A.N., 2019a. Antagonistic interactions between benzo[a]pyrene and fullerene (C60) in toxicological response of marine mussels. Nanomaterials (Basel) 8;9(7). pii: E987. doi: 10.3390/nano9070987.

Barranger, A., Rance, G.A., Aminot, Y., Dallas, L.J., Sforzini, S, Weston, N.J., Lodge, R.W., Banni, M., Arlt, V.M., Moore, M.N., Readman, J.W., Viarengo, A., Khlobystov, A.N., Jha, A.N., 2019b. An integrated approach to determine interactive genotoxic and global gene expression effects of multiwalled carbon nanotubes (MWCNTs) and benzo[a]pyrene (BaP) on marine mussels: evidence of reverse 'Trojan Horse' effects. Nanotoxicology 13, 1324-1343.

Benaissa, M., Rouane-Hacene, O., Boutiba, Z., Habib, D., Guibbolini-Sabatier, M.E. and Risso-De Faverney, C. (2020) Ecotoxicological effects assessment of brine discharge from desalination reverse osmosis plant in Algeria (South Western Mediterranean). Regional Studies in Marine Science 39, 101407.

Bouhedi, M., Antit, M., Chaibi, M., Perrein-Ettajani, H., Gillet, P. and Azzouna, A. (2021) Assessment of trace element accumulation on the Tunisian coasts using biochemical biomarkers in Perinereis cultrifera. Scientia Marina 85(2), 91-102.

Capó, X., Alomar, C., Compa, M., Sole, M., Sanahuja, I., Soliz Rojas, D.L., González, G.P., Garcinuño Martínez, R.M. and Deudero, S. (2022) Quantification of differential tissue biomarker responses to microplastic ingestion and plasticizer bioaccumulation in aquaculture reared sea bream Sparus aurata. Environmental Research 211, 113063.

Capo, X., Rubio, M., Solomando, A., Alomar, C., Compa, M., Sureda, A. and Deudero, S. (2021) Microplastic intake and enzymatic responses in Mytilus galloprovincialis reared at the vicinities of an aquaculture station. Chemosphere 280, 130575.

Chenet, T., Mancia, A., Bono, G., Falsone, F., Scannella, D., Vaccaro, C., Baldi, A., Catani, M., Cavazzini, A. and Pasti, L. (2021) Plastic ingestion by Atlantic horse mackerel (Trachurus trachurus) from central Mediterranean Sea: A potential cause for endocrine disruption. Environmental Pollution 284, 117449.

Davies, I. M. And Vethaak, A.D., 2012. Integrated marine environmental monitoring of chemicals and their effects. ICES Cooperative Research Report N)

Dagnino A, Allen JI, Moore MN, Broeg K, Canesi L, Viarengo A. 2007. Development of an expert system for the integration of biomarker responses in mussels into an animal health index. Biomarkers 12, 155–172.

Dagnino A, Sforzini S, Dondero F, Fenoglio S, Bona E, Jensen J, Viarengo A, 2008. A “weight-of-evidence” approach for the integration of environmental “Triad” data to assess ecological risk and biological vulnerability. Integr. Environ. Assess. Manag. 4, 314–326.

Dagnino A; Bo T; Copetta A; Fenoglio S; Oliveri C; Bencivenga M; Felli A; Viarengo A, 2013. Development and application of an innovative expert decision support system to manage sediments and to assess environmental risk in freshwater ecosystems. Environ. Int. 60, 171-182.

Dagnino A, Viarengo A, 2014. Development of a decision support system to manage contamination in marine ecosystems. Sci. Total Environ. 466-467, 119-126.

Doğan, S., E. Kiliç, E. Uğurlu and Ö. Duysak (2022). "Investigation of Metal Toxicity Response and Health Risk Assessment of Commonly Consumed Marine Fish Species along the Turkish coast. Submitted to Research Square, not peer reviewed by a scientific journal.

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Frapiccini, E., Panfili, M., Guicciardi, S., Santojanni, A., Marini, M., Truzzi, C. and Annibaldi, A. (2020) Effects of biological factors and seasonality on the level of polycyclic aromatic hydrocarbons in red mullet (Mullus barbatus). Environmental Pollution 258, 113742.

Gabr, G.A.E.-F., Masood, M.F., Radwan, E.H., Radwan, K.H. and Ghoenim, A.Z. (2020) Potential Effects of Heavy Metals Bioaccumulation on Oxidative stress Enzymes of Mediterranean clam Ruditapes decussatus. Catrina: The International Journal of Environmental Sciences 21(1), 75-82.

George, S.G. and Per-Erik Olsson (1994), Metallothioneins as indicators of trace metal pollution in Biomonitoring of Coastal Waters and Estuaries, edited by J.M. Kees. Boca Raton, FL 33431, Kramer CRC Press Inc., pp.151-171

Ghribi, R., Correia, A.T., Elleuch, B. and Nunes, B. (2020) Effects of chronic exposure to sediments from the Zarzis area, Gulf of Gabes, measured in the mussel (Mytilus spp.): a multi-biomarker approach involving oxidative stress and neurotoxicity. Soil and Sediment Contamination: An International Journal 29(7), 744-769.

ICES Cooperative Research Report, No 315, November 2012. Integrated marine environmental monitoring of chemicals and their effects. Ed. Ian M. Davis and Dick Vethaack.

Kaddour, A., Belhoucine, F. and Alioua, A. (2021) Integrated use of condition indexes, genotoxic and cytotoxic biomarkers for assessing pollution effects in fish (Mullus barbatus L., 1758) on the West coast of Algeria. South Asian Journal of Experimental Biology 11(3), 287-299.

Laouati, I., Rouane-Hacene, O., Derbal, F. and Ouali, K. (2021) The mussel caging approach in the assessment of trace metal contamination in southern Mediterranean coastal waters: a multi-biomarker study. Environmental Science and Pollution Research 28(44), 63032-63044.

Lomartire, S., J. C. Marques and A. M. M. Gonçalves (2021). Biomarkers based tools to assess environmental and chemical stressors in aquatic systems. Ecological Indicators 122: 107207.

Lowe, D., M.N. Moore and B.M. Evans (1992), Contaminant impact on interactions of molecular probes with lysosomes in living hepatocytes from dab Limandalimanda. Mar.Ecol.Progr.Ser., 91:135-140

Lowe, D.M., C. Soverchia and M.M. Moore (1995), Lysosomal membrane responses in the blood and digestive cells of mussels experimentally exposed to fluoranthene. Aquatic Toxicol., 33:105-112

Mansour, C., Ben Taheur, F., Mzoughi, R. and Mosbahi, D.S. (2021) Hydrocarbon levels and biochemical biomarkers in the clam Ruditapes decussatus collected from Tunis lagoon (Tunisia), Basel, Switzerland.

Missawi, O., Bousserrhine, N., Belbekhouche, S., Zitouni, N., Alphonse, V., Boughattas, I. and Banni, M. (2020) Abundance and distribution of small microplastics (≤ 3 μm) in sediments and seaworms from the Southern Mediterranean coasts and characterisation of their potential harmful effects. Environmental Pollution 263, 114634.

Morroni, L., d'Errico, G., Sacchi, M., Molisso, F., Armiento, G., Chiavarini, S., Rimauro, J., Guida, M., Siciliano, A., Ceparano, M., Aliberti, F., Tosti, E., Gallo, A., Libralato, G., Patti, F.P., Gorbi, S., Fattorini, D., Nardi, A., Di Carlo, M., Mezzelani, M., Benedetti, M., Pellegrini, D., Musco, L., Danovaro, R., Dell'Anno, A. and Regoli, F. (2020) Integrated characterization and risk management of marine sediments: The case study of the industrialized Bagnoli area (Naples, Italy). Marine Environmental Research 160, 104984.

Moore, M.N. (1985), Cellular responses to pollutants. Mar.Pollut.Bull., 16:134-139

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Moore, M.N., 1988. Cytochemical responses of the lysosomal system and NADPH-ferrihemoprotein reductase in molluscan digestive cells to environmental and experimental exposure to xenobiotics. Mar. Ecol. Progr. Ser. 46, 81-89.

Moore, M.N. (1990), Lysosomal cytochemistry in marine environmental monitoring. Histochem J., 22:187-191

Moore, M.N., Allen, J.I. & McVeigh, 2006a. Environmental prognostics: an integrated model supporting lysosomal stress responses as predictive biomarkers of animal health status. Mar. Environ. Res., 61, 278–304.

Moore, M.N., Allen, J.I. & Somerfield, P.J., 2006b. Autophagy: role in surviving environmental stress. Marine Environmental Research, 62 Suppl. 1, S420-S425.

Moore, M.N., Koehler, A., Lowe, D. & Viarengo, A., 2008. Lysosomes and autophagy in aquatic animals. In: Methods in Enzymology (D.Klionsky, Ed), vol. 451, pp. 582-620. Academic Press/Elsevier, Burlington.

Moore, M.N., Sforzini, S., Viarengo, A. et al., 2021. Antagonistic cytoprotective effects of C60 fullerene nanoparticles in simultaneous exposure to benzo[a]pyrene in a molluscan animal model., Science of the Total Environment 755 (2021) 142355), https://doi.org/10.1016/j.scitotenv.

Moore, M.N., Viarengo, A.G., Somerfield, P.J., Sforzini, S., 2013. Linking lysosomal biomarkers and ecotoxicological effects at higher biological levels. In - Ecological Biomarkers: Indicators of Ecotoxicological Effects, (Eds.C. Amiard-Triquet, J.C. Amiard, P.S. Rainbow), pp. 107-130. CRC Press, Boca Raton (Florida), New York & Oxford.

Nyström, T., 2005. Role of oxidative carbonylation in protein quality control and senescence. EMBO J. 24(7), 1311-1317.

Parrino, V., Minutoli, R., Lo Paro, G., Surfaro, D. and Fazio, F. (2020) Environmental assessment of the pesticides in Parablennius sanguinolentus along the Western Calabrian coast (Italy). Regional Studies in Marine Science 36, 101297.

Rios-Fuster, B., Alomar, C., Capó, X., Paniagua González, G., Garcinuño Martínez, R.M., Soliz Rojas, D.L., Silva, M., Fernández Hernando, P., Solé, M., Freitas, R. and Deudero, S. (2022) Assessment of the impact of aquaculture facilities on transplanted mussels (Mytilus galloprovincialis): Integrating plasticizers and physiological analyses as a biomonitoring strategy. Journal of Hazardous Materials 424, 127264.

Rodríguez-Romeu, O., A. Soler-Membrives, F. Padrós, S. Dallarés, E. Carreras-Colom, M. Carrassón and M. Constenla (2022). "Assessment of the health status of the European anchovy (Engraulis encrasicolus) in the NW Mediterranean Sea from an interdisciplinary approach and implications for food safety." Science of The Total Environment 841: 156539.

Salvaggio, A., Tiralongo, F., Krasakopoulou, E., Marmara, D., Giovos, I., Crupi, R., Messina, G., Lombardo, B.M., Marzullo, A., Pecoraro, R., Scalisi, E.M., Copat, C., Zuccarello, P., Ferrante, M. and Brundo, M.V. (2019) Biomarkers of Exposure to Chemical Contamination in the Commercial Fish Species Lepidopus caudatus (Euphrasen, 1788): A Particular Focus on Plastic Additives. Frontiers in Physiology 10.

Scarpato, R., L. Migliore, G. Alfinito-Cognetti and R. Barale (1990), Induction of micronuclei in gill tissue of Mytilusgalloprovincialisexposed to polluted marine waters Mar.Pollut.Bull., 21:74-80

Shaw, J.P., Dondero, F., Moore, M.N., (...), Thain, J.E., Viarengo, A., 2011. Integration of biochemical, histochemical and toxicogenomic indices for the assessment of health status of mussels from the Tamar Estuary, U.K. Mar. Environ. Res. 72(1-2), pp. 13-24.

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Solomando, A., Cohen-Sánchez, A., Box, A., Montero, I., Pinya, S. and Sureda, A. (2022) Microplastic presence in the pelagic fish, Seriola dumerili, from Balearic Islands (Western Mediterranean), and assessment of oxidative stress and detoxification biomarkers in liver. Environmental Research, 113369.

Stern, S.T., Adiseshaiah, P.P., Crist, R.M., 2012. Autophagy and lysosomal dysfunction as emerging mechanisms of nanomaterial toxicity. Particle and Fibre Toxicology, 9:20. https://doi.org/10.1186/1743-8977-9-20.

Telahigue, K., Rabeh, I., Chouba, L., Mdaini, Z., El Cafsi, M.h., Mhadhbi, L. and Hajji, T. (2022) Assessment of the heavy metal levels and biomarker responses in the smooth scallop Flexopecten glaber from a heavily urbanized Mediterranean lagoon (Bizerte lagoon). Environmental Monitoring and Assessment 194(6), 397.

Viarengo, A., 1989. Heavy metals in marine invertebrates: mechanisms of regulation and toxicity at the cellular level. Aquat. Sci. Review 1, 295-317.

Viarengo, A., Nott, J.A., 1993. Mechanisms of heavy metal cation homeostasis in marine invertebrates. Comp. Biochem. Physiol. C, Comp. Pharmacol. Toxicol. 104, 355-372.

Viarengo, A.; Lafaurie, M.; Gabrielides, G.P.; Fabbri, R.; Marro, A., Roméo, M., 2000. Critical evaluation of an intercalibration exercise undertaken in the framework of the MED POL biomonitoring program. Mar. Environ. Res. 49, 1-18.

Viarengo, A., Lowe, D., Bolognesi, C., Fabbri, E., Koehler, A., 2007. The use of biomarkers in biomonitoring: a 2-tier approach assessing the level of pollutant-induced stress syndrome in sentinel organisms. Comp. Biochem. Physiol. C 146, 281-300.

WHO (1993). World Health Organization & International Programme on Chemical Safety. Biomarkers and risk assessment : concepts and principles / published under the joint sponsorship of the United Nations environment Programme, the International Labour Organisation, and the World Health Organization. World Health Organization.

Zaidi, M., Athmouni, K., Metais, I., Ayadi, H. and Leignel, V. (2022) The Mediterranean limpet Patella caerulea (Gastropoda, Mollusca) to assess marine ecotoxicological risk: a case study of Tunisian coasts contaminated by metals. Environmental Science and Pollution Research 29(19), 28339-28358.

Zitouni, N., Bousserrhine, N., Belbekhouche, S., Missawi, O., Alphonse, V., Boughatass, I. and Banni, M. (2020) First report on the presence of small microplastics (≤ 3 μm) in tissue of the commercial fish Serranus scriba (Linnaeus. 1758) from Tunisian coasts and associated cellular alterations. Environmental Pollution 263, 114576.

Policy Context and Targets

Policy context description

In most Mediterranean countries, the monitoring of a range of hazardous chemical substances in different marine compartments are undertaken in response to the UNEP/MAP Barcelona Convention (1976) and its Land-Based Protocol, through the coordination of the UNEP/MAP MED POL Monitoring Program. For Mediterranean EU countries, the European legislation on the Marine Environment also applies (e.g. EU WFD and EU MSFD), as well as other international and national policy drivers. A considerable amount of founding knowledge and actions are available through the pollution monitoring and assessment component of the UNEP/MAP MED POL Programme during the past decades until today, including monitoring pilot programmes (Eco-toxicological effects of contaminants). The environmental assessments have been used for the identification and confirmation of significant marine contaminants effects on biota and therefore, impacts on biodiversity; as well as, for the continuous development of monitoring strategies and guidance. With respect to the Ecosystem

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)
Approach and IMAP, their implementation will continue under the benefits gained from this past knowledge and the policy and practical framework built in the Mediterranean Sea. The 2017 MED QSR assessment identified significant knowledge gaps, emphasizing the need for future development efforts in the Mediterranean Sea to focus on several key areas. These include validating the added value of biomarkers as 'early warning' indicators in long-term marine monitoring, testing innovative research-based tools such as ‘omics’ technologies, harmonizing analytical quality standards, and developing comprehensive assessment criteria that integrate chemical and biological methods. Additionally, a review of the scope and effectiveness of current biological effects monitoring programmes is recommended. Together, these actions will support the design of targeted and effective monitoring strategies aligned with CI18 requirements under the IMAP framework and GES assessments. In light of the above, progress was made in 2021 with the proposal agreed by the Ecosystem Approach Correspondence Group on Pollution Monitoring to integrate data from CI-18 (Biomarkers) and CI-17 (Chemical Monitoring) into the assessment process. The proposed methodology combines the effects of single chemical pollutants, to take into consideration possible additive or synergistic environmental effects among them and then evaluate the risk to marine organisms exposed to the pollutants in water and sediments. The integration procedure consists of three modules: (i) a chemical module for integration of the data concerning the concentration of the pollutants; (ii) an ecotoxicological module that integrates data of the biological effects in marine organisms; and (iii) an integration module that combines the two lines of evidence in an Environmental Risk Index. Evaluation of the environmental risk is usually obtained by an “expert judgement of a panel of qualified environmental scientists. Applying the Environmental Risk Index will result in objective risk values which allow national and regional policy makers and environmental managers to decide on required actions to decrease marine contamination, or to remediate a polluted area. The effectiveness of these actions can subsequently be monitored and quantified until an acceptable Environmental Risk Index is achieved. However, this approach still cannot be applied given lack of data reporting and capacities at the national level.	
Targets The ~~Initial targets of~~ GES targets under Common Indicator 18 need to maintain the contaminants effects below threshold further to decreasing trend in the operational releases of oil and other contaminants from coastal, maritime and off-shore activities. ~~will be based upon data of a selected biological effects parameters and biomarkers (reflecting the scope of current programmes and research, see Indicator Justification above) and the availability of suitable agreed assessment criteria.~~ The present lack of data availability in the IMAP Integrated Monitoring and Assessment Programme (IMAP IS) and relevant scientific studies does not allow for the proposal of a boundary limit between Good Environmental Status (GES) and non-GES status of CI 18. This boundary limit should primarily follow on progress in determining or updating the Background Assessment Concentrations (BAC) and Environmental Assessment Criteria (EAC) for biomarkers in the selected pilot sub-region(s)/sub-division(s) based on studies and *in situ* biomarker data. All relevant national and international practices and sources need to be considered, along with gathering information on biomarkers including relevant information, such as citation, type of test, biological effect measured, analytical approach used, study area, test duration, species/tissues tested, chemical concentrations, and other pertinent details.	
Policy documents **General Policy documents**	

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Decision IG.21/3 (COP18,2013) ~~18th COP to the Barcelona Convention, Istanbul, Turkey,~~ on Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets (UNEP(DEPI)/MED IG.21/9).

~~19th COP to the Barcelona Convention, Athens, Greece, 2016~~ Decision IG.22/7 (COP19, 2016) on ~~Decision IG.22/7 -~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria (UNEP(DEPI)/MED IG.22/28).

Decision IG.25/1 (COP22, 2021) on UNEP/MAP Medium-Term Strategy 2022-2027.

Decision IG.22/7 (COP19, 2016) on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria.

Decision IG.23/6 (COP20, 2017) on 2017 Mediterranean Quality Status Report.

Decision IG.24/4 (COP21, 2019) on Assessment Studies.

Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean.

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (EU Marine Strategy Framework Directive and updates in 2010).

Commission Directive (EU) 2017/845 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies

Commission Decision (EU) 2017/848 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (and updated revisions).

Commission Decision (EC) No 2013/480/EU establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Decision 2008/915/EC.

2017 Mediterranean Quality Status Report, https://www.medqsr.org/node/10/

2023 Mediterranean Quality Status Report, medqsr2023.info-rac.org

UNEP(DEPI)/MED IG.22/Inf.7. (2016) Integrated Monitoring and Assessment Guidance

Biological Effects ~~Contaminants~~ related Policy documents

~~i.Targets: UNEP(DEPI)/MED WG.421/Inf.9. Integrated Monitoring and Assessment Guidance. Agenda item 5.7: Draft Decision on Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria. Meeting of the MAP Focal Points. Athens, Greece, 13-16 October 2015.~~

OSPAR Commission, 2013. Levels and trends in marine contaminants and their biological effects - CEMP Assessment Report 2012. Monitoring and Assessment Series, 2013

OSPAR Commission, 2013. Levels and trends in marine contaminants and their biological effects - CEMP Assessment Report 2012. Monitoring and Assessment Series, 2013

OSPAR 2017. https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

human-activities/contaminants/

OSPAR (2008) Co-ordinated Environmental Monitoring Programme (CEMP) Assessment Manual for contaminants in sediments and biota. OSPAR Commission No. 379/2008

UNEP(DEC)/MED WG.372/3. (2012) Approaches for definition of GES and setting targets for the pollution related ecological objectives in the framework of the ecosystem approach. (EO5: eutrophication, EP9: contaminants, EP10: marine litter, EO11: noise).

UNEP/RAMOGE: Manual on the Biomarkers Recommended for the UNEP/MAP MED POL Biomonitoring Programme. UNEP, Athens, 1999.

UNEP (1997), The MED POL Biomonitoring Programme Concerning the Effects of Pollutants on Marine Organisms Along the Mediterranean Coasts. UNEP(OCA)/MED WG.132/3, Athens, 15 p.

UNEP (1997), Report of the Meeting of Experts to Review the MED POL Biomonitoring Programme. UNEP(OCA)/MED WG.132/7, Athens, 19 p.

UNEP(DEPI)/MED WG. 365/Inf.8. Development of assessment criteria for hazardous substances in the Mediterranean. Consultation Meeting to Review MED POL Monitoring Activities. Athens, 22-23 November 2011.

UNEP/MAP WG.492/6 (2021). The Proposal for Strengthening Implementation of Biomonitoring related to IMAP Common Indicator 18. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 19-21 April 2021

UNEP/MAP WG.509/27 (2021). Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Marine Molluscs (such as Mytilus sp.) and Fish (such as Mullus barbatus) for IMAP Common Indicator 18. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/28 (2021). Monitoring Guidelines/Protocols for Biomarker Analysis of Marine Molluscs (such as Mytilus sp.) and Fish (such as Mullus barbatus) for IMAP Common Indicator 18 – Analysis of Lysosomal membrane stability (LMS). Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/29 (2021). Monitoring Guidelines/Protocols for Biomarker Analysis of Marine Molluscs (such as Mytilus sp.) and Fish (such as Mullus barbatus) for IMAP Common Indicator 18 – Analysis of and micronuclei (MNi) frequency, Acetylcholinesterase (AChE) activity and Stress on Stress (SoS). Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG. 533/Inf.3 (2022). Adjusted Background (Assessment) Concentrations (BC/BAC) for Common Indicator 17 and Upgraded Approach for Environmental Assessment Criteria (EAC) for IMAP Common Indicators 17, 18 and 20. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 27 and 30 May 2022.

UNEP/MAP – MED POL (2022). UNEP/MED WG 533/10, Appendix V. Data Standards and Data Dictionaries for IMAP Common Indicator 18. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 27 and 30 May 2022.

Indicator analysis methods

Indicator Definition

In marine bivalves (such as *Mytilusgalloprovincialis*) and/or fish (such as *Mullus barbatus*)

Lysosomal Membrane Stability (LMS) ~~as~~ a method for general physiological status screening.

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Acetylcholinesterase (AChE) enzymatic activity - enzyme involved in impulse transmission providing ~~**assay** as~~ a method for assessing neurotoxic effects in aquatic organisms.~~.~~

Micronucleus assay test (MN frequency) - ~~as~~ a tool for assessing cytogenetic/DNA damage in marine organisms.

Sub-indicators:

In addition to the biomarkers listed above for monitoring IMAP Common Indicator 18, the sub-indicators also include the following biomarkers, classified according to the expected protection/defense responses. Biomarkers highlighted in bold are included in the IMAP Common Indicator 18 Data Standards (DSs). Their classification (mandatory or additional/non-mandatory), along with the relevant organism and tissue for testing, is provided in the table below. All other parameters required for reporting data under IMAP Common Indicator 18 are outlined in the Common Indicator 18 Data Standards (DSs).~~-~~.

- **Lysosomal Membrane Stability (LMS)- Neutral red retention time (NRRT) assay**
- **Metallothionein (MTs).** An increase of the cellular MT-protein level is considered as a protective effect against an excess of harmful metals
- **Stress on Stress (SoS),** the survival on air is a general method to determine the physiological condition in bivalves
- Antioxidant defense enzymes: Superoxide dismutase (SOD) that eliminates superoxide anion, catalase (CAT) and glutathione peroxidase (GPx) which remove hydrogen peroxide and glutathione reductase (GRd) which regenerates glutathione (GSH), an important non-enzymatic antioxidant against ROS (reactive oxygen species)
- **Detoxification enzymes: CYP1A1 (frequently measured as ethoxyresorufin-O21 deethylase (EROD)** activity and glutathione-S-transferase (GST)
- Aldehyde, formed from oxidative damage to lipids- malondialdehyde accumulation levels (MDA)
- Butyrylcholinesterase enzymatic activity (BChE)
- Detoxifying enzyme Carboxylesterase (CE) activity - potential biomarkers of chemical exposure, as they are an important family of enzymes involved in the metabolism of xenobiotic and endogenous compounds.
- Expression of vitellogenin (VTG), a lipoprotein produced in female fish and used as a biomarker for endocrine disruption
- Metabolic biomarkers: Electron Transport System activity (ETS) and glycogen reserves (GLY)
- Lactate dehydrogenase (LDH), and citrate synthase (CS): biomarkers for anaerobic and aerobic metabolism.
- Oxidative damage markers: lipid peroxidation (LPO) and protein carbonyl derived levels (CARB)
- Phase I detoxifying enzyme - 7-benzyloxy-4-[trifluoromethyl]-coumarin-O-debenzyloxylase (BFCOD)
- Histopathological alteration
- DNA damage.

~~Sub-indicators: complementary biomarkers, bioassays and histology techniques and methods are also recommended to be carried out on a country basis (such as, hepatic pathologies assessment, reduction of survival in air by Stress on Stress (SoS), larval embryotoxicity assay, Comet assay, etc.). Metallothionnein in mussels and Ethoxyresorufin-O-deethylase (EROD) activity in fish as a biomarker of chemical exposures.~~

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

~~The biochemical parameters and toxicological measurements above will be used to develop the IMAP Info System which will include Data Dictionaries (DDs) and Data Standards (DSs) for CI18 accordingly~~

~~.~~

Biomarker	**Description (EN)**	**Organism**	**Tissue**	**Mandatory**	**Additiona (Not-mandatory**
LMS-HEXO	Lysosomal membrane stability on cryostat sections - enzymatic determination	Fish/Mussel	Liver/Digestive gland	Y	
LMS-NRRT	Lysosomal membrane stability in mussel haemocytes - in vivo determination (neutral red retention time (NRRT) assay)	Mussel	Haemocytes (in vivo)	Y	
MN_F	Micronuclei frequency in fish blood cells	Fish	Erythrocytes	Y	
MN_MH	Micronuclei (MNi) frequency in mussel gill cells and haemocytes	Mussel	Gill cells, Haemocytes	Y	
AChE	Acetylcholinesterase activity - enzymatic determination	Mussel / Fish	Gills / Muscle	Y	
% LMS	% LMS Mean percentage of Lysosomal membrane stability in mussel	Mussel	Haemocytes		Y
MT	Metallothioneins	Mussel	Digestive gland		Y
SoS	Stress on stress	Mussel	Whole organism		Y
EROD	Ethoxyresorufin-o-deethylase activity	Fish	Liver		Y
NM	Other: not mandatory biomarker	Specify	Specify		Y

Methodology for indicator calculation

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Lysosomal Membrane Stability (LMS): Biological techniques (neutral red retention), including microscopy

Acetylcholinesterase (AChE) assay: Biochemical techniques, including spectrophotometry

Micronucleus assay: Biochemical techniques, including microscopy

Additional parameters to be recorded: biometrics (size/length, age), biological parameters such as condition index (mussels), condition factor, gonadosomatic index, hepatosomatic index (fish) and data on temperature, salinity and oxygen dissolved.

The detailed analytical procedure for the contaminants regulated under CI 18 and other related mandatory parameters, including sampling and sample transportation, analytical determination of indicators and sub-indicators, and data quality control are outlined in C-1. Monitoring Guidelines/Protocols for sampling and analysis of biomarkers in marine molluscs (such as Mytilus sp.) and fish (such as Mullus barbatus).

Indicator units

(retention) minutes - Lysosomal Membrane Stability (LMS)
nmol/min mg protein in gills (bivalves) - Acetylcholinesterase (AChE) assay
n~~N~~umber of cases, ‰ in haemocytes - Micronucleus assay

Data Standards for IMAP CI 218 elaborates units for all mandatory and other chemicals and parameters

List of Guidance documents and protocols available

European Commission, 2014. Technical report on effect-based monitoring tools. Technical Report 2014 – 077. European Commission, 2014.
UNEP/RAMOGE: Manual on the Biomarkers Recommended for the UNEP/MAP MED POL Biomonitoring Programme. UNEP, Athens, 1999.
UNEP/MAP, 2005. Fact sheets on Marine Pollution Indicators. Meeting of the UNEP/MAP MED POL National Coordinators. Barcelona, Spain, 24-27 May 2005. UNEP(DEC)/MED/ WG.264/ Inf.14. UNEP, Athens.
ICES Cooperative Research Report. No.315. Integrated marine environmental monitoring of chemicals and their effects. I.M. Davies and D. Vethaak Eds., November 2012.

Data Confidence and uncertainties

Selected analytical validated methods should be subject to Quality Assurance Protocols and interlaboratory exercises: QA/QC~~ through UNEP/MAP MED POL intercalibration supported exercises in agreement with University of Piemonte Orientale (Italy)~~.

Up to 2023, the IAEA/MESL, in collaboration with the UNEP/MAP - MED POL, implemented 56 interlaboratory comparisons/proficiency tests for the analysis of trace elements and organic contaminants, as well as 64 training courses on the analysis of trace elements and organic contaminants in marine samples. At its 2021 meeting, the Ecosystem Approach Correspondence Group on Pollution Monitoring agreed on the scope of an intercalibration exercise to support quality assurance related to IMAP Common Indicator 18. This included the intercalibration of Lysosomal Membrane Stability (LMS), Micronuclei frequency (MNi), Acetylcholinesterase activity (AChE), and Stress on Stress (SoS), as well as the organization of a training course aimed at strengthening the implementation of IMAP Common Indicator 18.

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)
However, the implementation of this intercalibration component for CI 18 could not be carried out in collaboration with IAEA/MESL, due to the absence of the specific technical and scientific expertise required. The extended intercalibration exercise included enhancement of the capacities of national laboratories in monitoring eutrophication, in line with IMAP Common Indicators 13 and 14, and contaminants in seafood in line with IMAP Common Indicator 20. Further efforts are required to establish an intercalibration exercise for IMAP Common Indicator 18.	
Methodology for monitoring, temporal and spatial scope	
Available Methodologies for Monitoring and Monitoring Protocols With regard the Ecosystem Approach and IMAP implementation, there are considerable benefits to be gained from taking advantage of previous knowledge and information developed through the UNEP/MAP MED POL. These actions include (1) the use of existing experience in the design of monitoring programmes, (2) the use of existing guidance on sampling and analytical methods to inform technical aspects of ecosystem approach monitoring, (3) the use of existing sampling station networks as a framework for the ecosystem approach monitoring networks, (4) the use of existing statistical assessment tools and work on assessment criteria as the basis for the assessments of ecosystem approach data, (5) the use of existing data to describe the distributions and levels of contaminants and effects against EACs and reference concentrations , and (6) the use of existing time series as the basis of monitoring against a "no deterioration" target. The availability of quality assured data is essential ~~of importance~~ for the assessment of levels and trends, and thus, their comparability overtime and across spatial scales. ~~Therefore, based on the work already carried out, the results of the intercalibration exercises and the scientific and technical publications within the UNEP/MAP MED POL programme on biological effects monitoring, there is a network of laboratories in the Mediterranean region with the capacity to carry out biological effects monitoring activities, in line with the monitoring requirements. Available guidelines and monitoring protocols can be found in the framework of other Regional Seas Conventions (e.g. OSPAR) as well.~~ Building on elements elaborated in the Integrated Monitoring and Assessment Programme (2016 IMAP), including the above-mentioned components, the Monitoring Guidelines—structured around the specific technical protocols related to IMAP Common Indicator 18 —were comprehensively developed by the MED POL Programme in cooperation with IAEA/MESL. These guidelines were approved by the MED POL Focal Points Meeting (2021).They build upon the knowledge and practices obtained over 40 years of MED POL monitoring implementation and recent publications, highlighting the current practices of the Contracting Parties' marine laboratories, as well as other Regional Seas Conventions and the EU. A thorough analysis of presently available practices of UNEP/MAP, UNEP and IAEA, as well the HELCOM, OSPAR and European Commission Joint Research Centre was undertaken to assist an innovative approach for preparation of the IMAP Monitoring Guidelines/Protocols. The monitoring methodologies and practices are elaborated for sampling, sample preservation and transportation, sample preparation and analysis, along with quality assurance and reporting of monitoring data, for their use by the IMAP competent laboratories in order to ensure the representativeness and accuracy of the analytical results. These guidelines present a summary of the best available known practices employed in marine monitoring by bringing integrated comprehensive analytical practices that can be applied in order to ensure the representativeness and accuracy of the analytical results needed for generation of quality assured monitoring data. The Monitoring Guidelines for IMAP Common Indicator 18 outline the following monitoring and reporting practices: o C-1. Monitoring Guidelines/Protocols for sampling and analysis of biomarkers in marine molluscs (such as Mytilus sp.) and fish (such as Mullus barbatus).	

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)
o E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20; o F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20.	
Available data sources ~~i.MED POL Database.~~ ~~ii.UNEP/RAMOGE: Manual on the Biomarkers Recommended for the UNEP/MAP MED POL Biomonitoring Programme. UNEP, Athens, 1999.~~ ~~ICES Cooperative Research Report, No 315, November 2012. Integrated marine environmental monitoring of chemicals and their effects. Ed. Ian M. Davis and Dick Vethaack.~~ i. IMAP Info System (http://imapinfosystem.info-rac.org/app/#/) – once datasets will be reported for CI 18 (the MEDPOL Pilot Biomonitoring Program (presently with only a few countries reporting data by 2005) and one dataset reported by a Contracting Party in 2023). ~~2.~~ii. Recently reviewed literature, due to the absence of in situ data reported for CI 18, as elaborated in the CI 18 thematic assessment and the 2023 MED QSR Pollution Assessment ~~1.~~ Additional potential data sources: iii. The new scientific literature sources providing data on the no effect or adverse biological effects, in conjunction with chemical data from the environment and biota at the same site and time (to be made available during the revision of the EAC for IMAP Common Indicator 17). ~~i.~~iv. The data and information derived from the execution of EU-funded research programmes related to the biological effects of environmental pollution in marine and coastal ecosystems. ~~ii.~~v. Studies and results from biological effects monitoring, as available from the International Council for the Exploration of the Sea (ICES), the OSPAR Commission, and the Baltic Marine Environment Protection Commission (HELCOM).	
Spatial scope guidance and selection of monitoring stations The spatial scope for monitoring should include reference and coastal long-term master stations, including offshore, as applicable, distributed spatially as relevant and include local spatial refinements, such as transect sampling, and therefore, is a direct function of the risk-based assessments and the long-term monitoring purpose. The selection of the sampling sites for the monitoring of biological effects in the marine environment should consider: • Risk areas of concern identified on the basis of the review of the existing information. • Vulnerable areas of known past and/or present release of chemical contaminants. • Offshore areas where risk warrants coverage (aquaculture, offshore oil and gas activity, dredging, mining, dumping at sea and others). • Monitoring sites representative of other sources, such as shipping and atmospheric inputs. • Reference monitoring sites: to establish scale-based reference values and background concentrations. • Monitoring sites representing sensitive pollution sites/areas at national and sub regional scale. • Monitoring sites in deep-sea sites, offshore stations (sediments)and areas of potential particular concern. The selected sites should allow the collection of a realistic number of samples over the years (e.g. allow to sample sufficient number of biota for the selected species during the duration of the programme). It is essential that the monitoring strategies are being coordinated at regional and/or sub	

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

regional level, in particular with chemical monitoring. The coordination with monitoring for other Ecological Objectives is crucial for cost-effective and future integrated assessment.

Temporal Scope guidance

Sampling frequencies is ~~will be~~ determined according the current status of the pilots and national marine monitoring programmes:

INITIAL PHASE of IMAP MONITORING (PILOT): to identify monitoring stations to collect BIOTA (bivalves, such as *Mytilus galloprovincialis*) on a yearly basis (or higher frequencies if the environmental variability study needs to be carried out), and in the same manner as for chemical monitoring, focusing on few locations such as hotspots and reference stations.

ADVANCED PHASE of IMAP MONITORING: when fully completed ~~and reported~~ IMAP Initial ~~MED POL~~ Phase ~~IV~~ implementation with the ongoing data reporting on ~~datasets, including~~ biological effects, ~~is achieved, then, at this stage~~ the objective should be the integration of the chemical and biological monitoring on a efficient manner in line with the integration of data from CI-18 (Biomarkers) and CI-17 (Chemical Monitoring) into the assessment process as agreed by the Ecosystem Approach Correspondence Group on Pollution Monitoring. Therefore, a refinement of the successful strategies for biological effects long-term monitoring should be implemented and maintained based on the experiences from developing pilot monitoring activities (Initial Phase).

For trend determinations the sampling frequencies will depend on the ability to detect trends considering the environmental and the analytical variability (ca. total uncertainty). It can be possible to decrease the sampling frequencies in cases where established time trends and levels show concentrations well below levels of concern, and without any upward trend over a number of years.

Data analysis and assessment outputs

Statistical analysis and basis for aggregation – Assessment Criteria

Monitoring should allow the necessary statistical data treatments and long-term time-trend analysis. Deriving and setting up the assessment criteria to determine environmental status is not an easy task. It gets more complicated going from the local to sub-regional and regional assessments.

The BAC and EAC values for IMAP Common Indicator 18 were not updated by Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean given the lack of data reported for biomarkers. Therefore, these criteria remain as endorsed in Decisions IG.22/7 and IG.23/6 and are shown table here-below. The Mediterranean EACs for Biomarkers remains based on OSPAR values.

Decision IG.23/6 provided the calculation of BAC values, and an update of EAC values, for Stress on Stress (SOS) and Micronuclei Frequency (MN) by using datasets from reference stations submitted by Contracting Parties in 2015.

Laboratory results on biomarkers (CI18) are also important for the derivation of the EAC values for CI 17.

Mediterranean BACs and EACs for biomarkers in mussel (*M. galloprovincialis*) as endorsed by Decisions IG.22/7 and IG.23/6.

Biomarkers/Bioassays and units	BACs IG.23/6 in Mussels (*Mytilus galloprovincialis*)	EACs IG.23/6 in Mussels (*Mytilus galloprovincialis*)	BACs IG.22/7 in Mussels (*Mytilus galloprovincialis*)	EACs IG.22/7 in Mussels (*Mytilus galloprovincialis*)
Lysosomal membrane stability Neutral Red			120[a*]	50 [a*]

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)

Retention Assay (minutes)				
Lysosomal membrane stability Cytochemical method (minutes)			20 [a*]	10 [a*]
AChE activity (nmol min-1 mg-1 protein) in gills (French Mediterranean waters)			29	20
AChE activity (nmol min^{-1} mg^{-1} protein) in gills (Spanish Mediterranean waters)			15	10
Stress on Stress (days)	11	5		
Metallothioneins (µg/g digestive gland)	247			
Micronuclei frequency (number of cases /1000 cells) in haemocytes)	1			

[a]Technical annex: assessment criteria for biological effects measurements. Integrated monitoring of chemicals and their effects. ICES Cooperative Research Report No. 315. Davies, I.M. and Vethaak, A.D.Eds.
**Moore et al., 2006 (Standard values adopted by ICES)*

Ongoing efforts focus on establishing an improved methodology for determining Background Assessment Concentrations (BAC) and Environmental Assessment Criteria (EAC) for biomarkers at regional and sub-regional levels, depending on data availability. These efforts also include proposing new biomarkers to enhance the monitoring and assessment of CI 18.

Expected assessments outputs

For biological effects, trends analysis and distribution levels could be carried out on sub-regional level, provided appropriate quality assured datasets are available. For the integrated assessment of GES, it would be carried out using Mediterranean data from IMAP Info System and relevant scientific literatur sources ~~the MEDPOL database~~ and applying IMAP CI 18 assessment criteria~~a two-level threshold classification (such as the OSPAR methodology). Assessing biomarker responses against Background Assessment Criteria (BACs) and Environmental Assessment Criteria (EACs) allows establishing if the responses measured are at levels that are not causing deleterious biological effects, at levels where deleterious biological effects are possible or at levels where deleterious biological effects are likely in the long-term. In the case of biomarkers of exposure, only BAC can be estimated, whereas for biomarkers of effects both BAC and EAC can be established.~~

Due to the complete lack of data reporting into the IMAP Information System (IMAP IS) by the Contracting Parties (CPs), the assessment input for the 2023 MED QSR related to the status assessment of IMAP CI-18 was based on bibliographic studies. This approach mirrors the methodology used in the preparation of the 2017 MED QSR, updated with more recent scientific literature. The studies included in the review were selected according to the following criteria:

- Data derived exclusively from the Mediterranean Sea;
- Studies conducted since 2016 and published from 2018 onwards.

<table>
<tr><td>Indicator Title</td><td>Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)</td></tr>
<tr><td colspan="2">A total of 24 studies were retrieved from the scientific literature. In the Central and Western Mediterranean Sea (CEN and WMS), the biomarkers examined were either not listed under IMAP or, if listed, were not analyzed in the required organ or tissue as specified by IMAP guidelines. Most studies assessed multiple biomarkers at the same sampling stations, with inconsistent results—some showing effects and others not.

The mandatory monitoring species, Mytilus galloprovincialis and Mullus barbatus, were included in five and four studies, respectively. Additionally, ten fish species, six mollusc species, and two polychaete species were examined across the reviewed literature.

Among the mandatory biomarkers for IMAP CI-18:
• Acetylcholinesterase (AChE) was reported in 13 studies,
• Metallothionein (MT) in 5 studies (2 on molluscs, 2 on fish, and 1 on a polychaete species),
• Micronuclei (MN) in 2 studies,
• Lysosomal membrane stability via Neutral Red Retention Time (LMS-NRRT) in 1 study.

The most frequently reported additional biomarkers were:
• Catalase (CAT) in 15 studies,
• Malondialdehyde (MDA) in 12 studies,
• Glutathione S-transferase (GST) in 11 studies,
• Superoxide dismutase (SOD) in 9 studies,
• Glutathione peroxidase (GPx) in 8 studies.
Further details are provided in the thematic eutrophication assessments and the 2023 MED QSR Pollution Assessment.</td></tr>
<tr><td colspan="2">Known gaps and uncertainties in the Mediterranean

~~Important development areas in the Mediterranean Sea over the next few years will include harmonization of monitoring targets (determinants and matrices) within assessment sub-regions, development of suites of assessment criteria integrated chemical and biological assessment methods, and review of the scope of the monitoring programmes to ensure that those contaminants which are considered to be important within each assessment area are included in monitoring programmes~~.
Further to the significant progress achieved over the last few biennia regarding the standardizing monitoring practices and progressing towards the environmental assessment tools, it is essential to ensure GES assessment for CI 18 . Revision of IMAP needs to support the good environmental status assessment for CI 18 and facilitate its integration and aggregation with other CIs and EOs, by undertaking the priority actions to address key gaps:
o Review and update the list of CI 18 biomarkers, along with the monitoring species;
o Review and update, as appropriate, the assessment criteria as adopted by Decisions IG.22/7 (COP 19) and IG.23/6 (COP 20), as well as the assessment methodologies;
o Further to the initial work undertaken in 2021 towards the development of the Biomonitoring related to IMAP CI 18, the following further actions should be tested:
i) An application of new biomarkers should be explored to support the strengthening of CI 18 monitoring and assessment.
ii) Use of the Environmental Risk Analysis should be provided by combing the chemical and ecotoxicological data, to support the evaluation of the risk related to marine organisms exposed to contaminated waters and sediments. It should result in objective risk values which allow national and regional policymakers and environmental managers to decide on the actions to decrease marine contamination, or to remediate a polluted area.</td></tr>
</table>

Indicator Title	Common Indicator 18. Level of pollution effects of key contaminants where a cause and effect relationship has been established (EO9)	
Through these and other actions, it will be possible to develop targeted and effective monitoring programmes tailored to meet the needs and conditions within each GES assessment sub-region. It has been recognized that the open and deep sea is much less covered by monitoring efforts than coastal areas. There is a need to include within monitoring programmes also areas beyond the coastal areas in a representative and efficient way, where risks warrant coverage.		
Contacts and version Date		
http://www.unepmap,org		
Version No	**Date**	**Author**
V.1	31.05.17	MEDPOL
V.2	12.12.18	MEDPOL
V.3	31/05/2019	Approved by the Meeting of MED POL FPs
Final version	09/09/2019	Approved by the 7th Meeting of EcAp Coordination Group
V4	28/05/2025	Joint CorMon Pollution and ML Meeting
V5		Approved by the Meeting of MED POL FPs
Final version		Approved by the 12th Meeting of EcAp Coordination Group

10. The revision of IMAP **Common Indicator 20 (EO9)**: "Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood" is presented in the table bellow.

<table>
<tr><td>Indicator Title</td><td colspan="2">Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)</td></tr>
<tr><td>Relevant GES definition</td><td>Related Operational Objective</td><td>Proposed Target(s)[23]</td></tr>
<tr><td>Concentrations of contaminants are within the regulatory limits for consumption by humans.</td><td>Levels of known harmful contaminants in major types of seafood do not exceed established standards</td><td></td></tr>
<tr><td colspan="3">Rational</td></tr>
<tr><td colspan="3">Justification for indicator selection

One of the potential risks associated with the occurrence of harmful substances (chemicals, nanoparticles, microplastics, toxins) in the marine environment is the human exposure through commercial fish and shellfish species (primarily, from wild fisheries and aquaculture). These organisms are exposed to environmental contaminants which enter their organism through different mechanisms and pathways according their thropic level, which include from filter feeding to predatory strategies (crustaceans, bivalves, fish). Consequently, there exist both bioaccumulation and biomagnification processes of these chemicals released in the marine environment. Common examples are the well-known bioaccumulation of metals and organic compounds in commercial bivalve species (such as the Mytillus galloprovincialis in the Mediterranean Sea) or alkyl mercury compounds (methylmercury) in tuna fish, which should be increased by new and emerging contaminants in the near future.

The studies considered for the assessment of contaminants in seafood within the 2023 MED QSR reported concentrations of contaminants and compared them to EU regulations, while some also addressed national regulations as well as international regulations or advisories (De Witte et al. 2022). Most of the studies also provided risk assessments to human health from the consumption of seafood by calculating the estimated daily intake (EDI), target hazard quotient (THQ), total risk (HI), cancer risk, among others. This emphasizes that the risk to human health (and hence GES-non GES status) should not be evaluated based on the concentration of a single contaminant but should be evaluated together with other factors such as synergy with other contaminants, temporal and spatial scales.</td></tr>
<tr><td colspan="3">Scientific References

Abbassy, M.M.S. (2018) Distribution pattern of persistent organic pollutants in aquatic ecosystem at the Rosetta Nile branch estuary into the Mediterranean Sea, North of Delta, Egypt. Marine Pollution Bulletin 131, 115-121.

Aissioui, S., Poirier, L., Amara, R. and Ramdane, Z. (2021) Concentrations of lead, cadmium, and mercury in Mullus barbatus barbatus (L.) from the Algerian coast and health risks associated to its consumption. Regional Studies in Marine Science 47, 101959.</td></tr>
</table>

[23] Following the decisions to be made at the present meeting regarding minor adjustments to the Targets, as outlined in working document UNEP/MED WG.626/3/Rev.1, the revised Targets will be incorporated into the revised IMAP Pollution Indicators Factsheets.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Aissioui, S., Poirier, L., Amara, R. and Ramdane, Z. (2022) Concentrations of lead, cadmium and mercury in sardines, Sardina pilchardus (Walbaum, 1792) from the Algerian coast and health risks for consumers. Journal of Food Composition and Analysis 109, 104490.

Azizi, G., Layachi, M., Akodad, M., Martin-Garcia, A.I., Yanez-Ruiz, D.R., Baghour, M., Hmeid, H.A., Gueddari, H. and Moumen, A. (2021) Bioaccumulation and health risk assessment of trace elements in Mytilus galloprovincialis as sea food in the Al Hoceima coasts (Morocco). E3S Web of Conferences 240, 01002 (2021).

Azizi, G., Layachi, M., Akodad, M., Yáñez-Ruiz, D.R., Martín-García, A.I., Baghour, M., Mesfioui, A., Skalli, A. and Moumen, A. (2018) Seasonal variations of heavy metals content in mussels (Mytilus galloprovincialis) from Cala Iris offshore (Northern Morocco). Marine Pollution Bulletin 137, 688-694.

Barhoumi, B., Sander, S.G., Driss, M.R. and Tolosa, I. (2022) Survey of legacy and emerging per- and polyfluorinated alkyl substances in Mediterranean seafood from a North African ecosystem. Environmental Pollution 292, 118398.

Barone, G., Storelli, A., Busco, A., Mallamaci, R. and Storelli, M.M. (2021) Polychlorinated dioxins, furans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (dl-PCBs) in food from Italy: Estimates of dietaryintake and assessment. Journal of Food Science 86(10), 4741-4753.

Bartalini, A., Muñoz-Arnanz, J., Baini, M., Panti, C., Galli, M., Giani, D., Fossi, M.C. and Jiménez, B. (2020) Relevance of current PCB concentrations in edible fish species from the Mediterranean Sea. Science of the Total Environment 737, 139520.

Bilandžić, N., Sedak, M., Čalopek, B., Đokić, M., Varenina, I., Kolanović, B.S., Luburić, Đ.B., Varga, I., Benić, M. and Roncarati, A. (2018) Element contents in commercial fish species from the Croatian market. Journal of Food Composition and Analysis 71, 77-86.

Cammilleri, G., Galluzzo, P., Pulvirenti, A., Giangrosso, I.E., Lo Dico, G.M., Montana, G., Lampiasi, N., Mobilia, M.A., Lastra, A., Vazzana, M., Vella, A., La Placa, P., Macaluso, A. and Ferrantelli, V. (2020) Toxic mineral elements in Mytilus galloprovincialis from Sicilian coasts (Southern Italy). Natural Product Research 34(1), 177-182.

Castro-Jiménez, J., Bănaru, D., Chen, C.-T., Jiménez, B., Muñoz-Arnanz, J., Deviller, G. and Sempéré, R. (2021) Persistent Organic Pollutants Burden, Trophic Magnification and Risk in a Pelagic Food Web from Coastal NW Mediterranean Sea. Environmental Science & Technology 55(14), 9557-9568.

Ceci, R., Diletti, G., Bellocci, M., Chiumiento, F., D'Antonio, S., De Benedictis, A., Leva, M., Pirito, L., Scortichini, G. and Fernandes, A.R. (2022) Brominated and chlorinated contaminants in food (PCDD/Fs, PCBs, PBDD/Fs PBDEs): Simultaneous determination and occurrence in Italian produce. Chemosphere 288, 132445.

Chanto-García, D.A., Saber, S., Macías, D., Sureda, A., Hernández-Urcera, J. and Cabanellas-Reboredo, M. (2022) Species-specific heavy metal concentrations of tuna species: the case of Thunnus alalunga and Katsuwonus pelamis in the Western Mediterranean. Environmental Science and Pollution Research 29(1), 1278-1288.

Cruz, R. Brominated flame retardants and seafood safety: A review. Environment International, 77, 116-131.

Dellate, E. *et al.* 2014. Individual methylmercury intake estimates from local seafood of the Mediterranean Sea, in Italy. Regulatory Toxicology and Pharmacology, 69, 105-112.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

De Witte, B., Coleman, B., Bekaert, K., Boitsov, S., Botelho, M.J., Castro-Jiménez, J., Duffy, C., Habedank, F., McGovern, E., Parmentier, K., Tornero, V., Viñas, L. and Turner, A.D. (2022) Threshold values on environmental chemical contaminants in seafood in the European Economic Area. Food Control 138, 108978.

Di Bella, G., Bua, G.D., Fede, M.R., Mottese, A.F., Potortì, A.G., Cicero, N., Benameur, Q., Dugo, G. and Lo Turco, V. (2020) Potentially Toxic Elements in Xiphias gladius from Mediterranean Sea and risks related to human consumption. Marine Pollution Bulletin 159, 111512.

Di Lena, G., Casini, I., Caproni, R., Fusari, A. and Orban, E. (2017) Total mercury levels in commercial fish species from Italian fishery and aquaculture. Food Additives & Contaminants: Part B 10(2), 118-127.

Esposito, G., Mudadu, A.G., Abete, M.C., Pederiva, S., Griglione, A., Stella, C., Ortu, S., Bazzoni, A.M., Meloni, D. and Squadrone, S. (2021) Seasonal accumulation of trace elements in native Mediterranean mussels (Mytilus galloprovincialis Lamarck, 1819) collected in the Calich Lagoon (Sardinia, Italy). Environmental Science and Pollution Research.

Esposito, M., Canzanella, S., Lambiase, S., Scaramuzzo, A., La Nucara, R., Bruno, T., Picazio, G., Colarusso, G., Brunetti, R. and Gallo, P. (2020) Organic pollutants (PCBs, PCDD/Fs, PAHs) and toxic metals in farmed mussels from the Gulf of Naples (Italy): Monitoring and human exposure. Regional Studies in Marine Science 40, 101497.

Ferrante, M., Zanghì, G., Cristaldi, A., Copat, C., Grasso, A., Fiore, M., Signorelli, S.S., Zuccarello, P. and Oliveri Conti, G. (2018) PAHs in seafood from the Mediterranean Sea: An exposure risk assessment. Food and Chemical Toxicology 115, 385-390.

Ghosn, M., Chekri, R., Mahfouz, C., Khalaf, G., Amara, R. and Jitaru, P. (2019) Levels of Pb, Cd, Hg and As in Fishery Products from the Eastern Mediterranean and Human Health Risk Assessment due to their Consumption. International Journal of Environmental Research 13(3), 443-455.

Ghosn, M., Mahfouz, C., Chekri, R., Khalaf, G., Guérin, T., Jitaru, P. and Amara, R. (2020a) Seasonal and Spatial Variability of Trace Elements in Livers and Muscles of Three Fish Species from the Eastern Mediterranean. Environmental Science and Pollution Research 27(11), 12428-12438.

Ghosn, M., Mahfouz, C., Chekri, R., Ouddane, B., Khalaf, G., Guérin, T., Amara, R. and Jitaru, P. (2020b) Assessment of trace element contamination and bioaccumulation in algae (Ulva lactuca), bivalves (Spondylus spinosus) and shrimps (Marsupenaeus japonicus) from the Lebanese coast. Regional Studies in Marine Science 39, 101478.

Girolametti, F., Panfili, M., Colella, S., Frapiccini, E., Annibaldi, A., Illuminati, S., Marini, M. and Truzzi, C. (2022) Mercury levels in Merluccius merluccius muscle tissue in the central Mediterranean Sea: Seasonal variation and human health risk. Marine Pollution Bulletin 176, 113461.

Hamida, S., Ouabdesslam, L., Ladjel, A.F., Escudero, M. and Anzano, J. (2018) Determination of Cadmium, Copper, Lead, and Zinc in Pilchard Sardines from the Bay of Boumerdés by Atomic Absorption Spectrometry. Analytical Letters 51(16), 2501-2508.

Jebara, A., Lo Turco, V., Potortì, A.G., Bartolomeo, G., Ben Mansour, H. and Di Bella, G. (2021) Organic pollutants in marine samples from Tunisian coast: Occurrence and associated human health risks. Environmental Pollution 271, 116266.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Karayakar, F., Işık, U., Cicik, B. and Canli, M. (2022) Heavy metal levels in economically important fish species sold by fishermen in Karatas (Adana / TURKIYE (AEL)). Journal of Food Composition and Analysis 106, 104348.

Kucuksezgin, F., Gonul, L.T., Pazi, I., Ubay, B. and Guclusoy, H. (2020) Monitoring of polycyclic aromatic hydrocarbons in transplanted mussels (Mytilus galloprovincialis) and sediments in the coastal region of Nemrut Bay (Eastern Aegean Sea). Marine Pollution Bulletin 157, 111358.

Kuplulu, O., Cil, G., Korkmaz, S., Aykut, O. and Cengiz, G. (2018) Determination of Metal Contamination in Seafood from the Black, Marmara, Aegean and Mediterranean Sea Metal Contamination in Seafood. Journal of the Hellenic Veterinary Medical Society 69, 749.

Maggi, C., S. Lomiri, M. Berducci, B. Di Lorenzo, M. D'Antona and A. Ausili (2015). "MSFD Descriptor 9: Between Health and Environment." International Journal of Environmental Science and Development **6**: 958-963.

Mahjoub, M., El Maadoudi, M. and Smiri, Y. (2021) Trace metal concentrations in water and edible tissues of Liza ramada from the Northeastern Moroccan Mediterranean coast: Implications for health risk assessment. Regional Studies in Marine Science 46, 101881.

Maulvault, A.M. *et al*. 2015. Toxic elements and speciation in seafood samples from different contaminated sites in Europe. Environmental Research, 143B, 72-81.

Molin, M. *et al.*, 2015. Arsenic in the human food chain, biotransformation and toxicology – Review focusing on seafood arsenic. Journal of Trace Elements in Medicine and Biology, 31, 249-259.

Ozmen, S.F. and Yilmaz, M. (2020) Radioactivity concentrations of farmed and wild European seabass (Dicentrarchus labrax L., 1758) in the eastern Mediterranean and risk assessment of their consumption. Regional Studies in Marine Science 36, 101316.

Perello, G. *et al.*, 2015. Human exposure to PCDD/Fs and PCBs through consumption of fish and seafood in Catalonia (Spain): Temporal trend. Food and Chemical Toxicology, 81, 28-33.

Renieri, E.A., Safenkova, I.V., Alegakis, A.K., Slutskaya, E.S., Kokaraki, V., Kentouri, M., Dzantiev, B.B. and Tsatsakis, A.M. (2019) Cadmium, lead and mercury in muscle tissue of gilthead seabream and seabass: Risk evaluation for consumers. Food and Chemical Toxicology 124, 439-449.

Sofoulaki, K., Kalantzi, I., Machias, A., Pergantis, S.A. and Tsapakis, M. (2019) Metals in sardine and anchovy from Greek coastal areas: Public health risk and nutritional benefits assessment. Food and Chemical Toxicology 123, 113-124.

Spada, L. *et al.* 2014. Mercury and methylmercury concentrations in Mediterranean seafood and surface sediments, intake evaluation and risk for consumers. International Journal of Hygiene and Environmental Health, 215, 418-42.

Storelli, A., Barone, G., Dambrosio, A., Garofalo, R., Busco, A. and Storelli, M.M. (2020) Occurrence of trace metals in fish from South Italy: Assessment risk to consumer's health. Journal of Food Composition and Analysis 90, 103487.

Sulimanec Grgec, A., Kljaković-Gašpić, Z., Orct, T., Tičina, V., Sekovanić, A., Jurasović, J. and Piasek, M. (2020) Mercury and selenium in fish from the eastern part of the Adriatic Sea: A risk-benefit assessment in vulnerable population groups. Chemosphere 261, 127742.

Tavoloni, T., Miniero, R., Bacchiocchi, S., Brambilla, G., Ciriaci, M., Griffoni, F., Palombo, P., Stecconi, T., Stramenga, A. and Piersanti, A. (2021) Heavy metal spatial and temporal trends (2008–2018) in clams and mussel from Adriatic Sea (Italy): Possible definition of forecasting models. Marine Pollution Bulletin 163, 111865.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Traina, A., Ausili, A., Bonsignore, M., Fattorini, D., Gherardi, S., Gorbi, S., Quinci, E., Romano, E., Salvagio Manta, D., Tranchida, G., Regoli, F. and Sprovieri, M. (2021) Organochlorines and Polycyclic Aromatic Hydrocarbons as fingerprint of exposure pathways from marine sediments to biota. Marine Pollution Bulletin 170, 112676.

Tornero Alvarez, M.V., Boschetti, S. and Hanke, G., Marine Strategy Framework Directive - Review and analysis of EU Member States’ 2018 reports - Descriptor 8: Contaminants in the environment - Descriptor 9: Contaminants in seafood, EUR 30659 EN, Publications Office of the European Union, Luxembourg, 2021.

Vandermeersch, G. *et al.* 2015. Environmental contaminants of emerging concern in seafood – European database on contaminant levels. Environmental Research, 143B, 29-45.

Wakkaf, T., El Zrelli, R., Kedzierski, M., Balti, R., Shaiek, M., Mansour, L., Tlig-Zouari, S., Bruzaud, S. and Rabaoui, L. (2020) Microplastics in edible mussels from a southern Mediterranean lagoon: Preliminary results on seawater-mussel transfer and implications for environmental protection and seafood safety. Marine Pollution Bulletin 158, 111355.

Zaza, S. *et al.* 2015. Human exposure in Italy to lead, cadmium and mercury through fish and seafood product consumption from Eastern Central Atlantic Fishing Area. Journal of Food Composition and Analysis, 40, 148-153.

Policy Context and Targets

Policy context description

The understanding of the health risks to humans (maximum levels, intake, toxic equivalent factors, etc.) and the food safety prevention, including emerging contaminants, through the consumption of potentially poisoned seafood is a challenge and a priority policy issue for governments, as well as a major societal concern. There are different initiatives and regulations at national and international levels mainly for the fishery economic sector, which have established public health recommendations and maximum regulatory levels for different contaminants in numerous marine commercial target species. Methylmercury poisoning continues as a global priority policy issue and in 2013 the Global Legally Binding Treaty (Minamata Convention on Mercury) was launched by UNEP. Further, the US Food and Drugs Administration, the European Food Safety Authority, as well as Food and Agriculture Organization (FAO), are also national and international authorities with regard seafood safety, respectively.

Within the current efforts to establish a baseline for measuring trends in contaminant concentrations in seafood, the JRC (2010) is considered, which suggests taking into account 'the frequency with which levels exceed regulatory levels, the actual levels that have been detected, the number of contaminants for which exceeding levels have been detected, and in parallel the origin of the contamination (geological versus anthropogenic, local versus long distance).' It also stipulates that 'Further, an intake assessment considering the importance of the species showing exceeding levels in the human diet could be taken into account. If regulatory levels are exceeded in one species, it does not mean that all seafood consumption from this sub-region is dangerous.' The literature search on seafood quality in the Mediterranean Sea in preparation for the 2023 MED QSR focused on studies reporting data from 2016/2017 onward, emphasizing contaminants regulated in the EU. Another point to note is that recent literature emphasizes the connection between seafood safety and quality and the presence of microplastics in the marine environment (i.e., Wakkaf et al. 2020, among many others). The human health may be impacted either by consuming seafood with microplastic content, or seafood with contaminants that were leached from the microplastic to the organism.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Targets

The ~~Initial targets of~~ GES targets under Common Indicator 20 need to ~~will be to~~ maintain the chemical contaminants of human health concern under regulatory levels in seafood as ~~set/recommended/~~agreed by national and~~/or~~ international authorities and their trends with regard their occurrence should decrease pointing towards zero events.

The present lack of data availability in the IMAP Integrated Monitoring and Assessment Programme (IMAP IS) for and relevant scientific studies does not allow for the proposal of a boundary limit between Good Environmental Status (GES) and non-GES status of CI 20. The boundary limit should primarily be based on the frequency of contaminants' occurrence. However, more substantial considerations need to be undertaken following the expected future availability of sufficient data reported by the Contracting Parties (CPs), in order to propose a GES–non-GES boundary limit. All relevant national and international practices need to be considered, along with gathering information on the cumulative impact of the contaminants on different seafood species and conducting calculations of daily/monthly intake and related risk analysis.

Policy documents

General Policy documents

Decision IG.21/3 (COP18,2013) ~~18th COP to the Barcelona Convention, Istanbul, Turkey,~~ on~~-~~ Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets (UNEP(DEPI)/MED IG.21/9).

~~19th COP to the Barcelona Convention, Athens, Greece, 2016~~ Decision IG.22/7 (COP19, 2016) on ~~Decision IG.22/7 -~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria (UNEP(DEPI)/MED IG.22/28).

Decision IG.21/3 (COP18,2013) ~~18th COP to the Barcelona Convention, Istanbul, Turkey,~~ on~~-~~ Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets (UNEP(DEPI)/MED IG.21/9).
~~19th COP to the Barcelona Convention, Athens, Greece, 2016~~ Decision IG.22/7 (COP19, 2016) on ~~Decision IG.22/7 -~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria (UNEP(DEPI)/MED IG.22/28).
Decision IG.25/1 (COP22, 2021) on UNEP/MAP Medium-Term Strategy 2022-2027.
Decision IG.22/7 (COP19, 2016) on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria.
Decision IG.23/6 (COP20, 2017) on 2017 Mediterranean Quality Status Report.
Decision IG.24/4 (COP21, 2019) on Assessment Studies.
Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean.
Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (EU Marine Strategy Framework Directive and updates in 2010).

Commission Directive (EU) 2017/845 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies

Commission Decision (EU) 2017/848 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (and updated revisions).

Commission Decision (EC) No 2013/480/EU establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Decision 2008/915/EC.

2017 Mediterranean Quality Status Report, https://www.medqsr.org/node/10/

2023 Mediterranean Quality Status Report, medqsr2023.info-rac.org

UNEP(DEPI)/MED IG.22/Inf.7. (2016) Integrated Monitoring and Assessment Guidance

Contaminants in Seafood related Policy documents

~~EU 1881/2006.~~ Commission Regulation (EC) No 1881/2006 ~~of 19 December 2006~~ setting maximum levels for certain contaminants in foodstuffs. ~~European Commission.~~

Commission Regulation (EC) No 835/2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs.

Commission Regulation (EC) No 1259/2011, amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs.

Commission Decision (EC) No 2013/480/EU establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Decision 2008/915/EC.

European Commision, E. (2018) Guidance Document No: 27. Technical Guidance For Deriving Environmental Quality Standards.

Global Legally Binding Treaty (Minamata Convention on Mercury) http://www.mercuryconvention.org/

Joint FAO/WHO Expert consultation on the risk and benefits of fish consumption. FAO Fisheries and Aquaculture Report No. 978. ISSN 2070-6987. Rome, January, 2010.

List of maximum levels for contaminants in foods set by the FAO/WHO Codex Alimentarius Commission can be found at ftp://ftp.fao.org/codex/Meetings/cccf/cccf7/cf07_INFe.pdf

OSPAR Commission, 2013. Levels and trends in marine contaminants and their biological effects - CEMP Assessment Report 2012. Monitoring and Assessment Series, 2013

OSPAR Commission, 2013. Levels and trends in marine contaminants and their biological effects - CEMP Assessment Report 2012. Monitoring and Assessment Series, 2013

OSPAR 2017. https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/

OSPAR (2008) Co-ordinated Environmental Monitoring Programme (CEMP) Assessment Manual for contaminants in sediments and biota. OSPAR Commission No. 379/2008

UNEP(DEC)/MED WG.372/3. (2012) Approaches for definition of GES and setting targets for the pollution related ecological objectives in the framework of the ecosystem approach. (EO5: eutrophication, EP9: contaminants, EP10: marine litter, EO11: noise).

UNEP/MAP WG.509/30 (2021). Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Sea Food for IMAP Common Indicator 20: Heavy and Trace Elements and Organic

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.509/31 (2021). Monitoring Guidelines/Protocols for Sample Preparation and Analysis of Sea Food for IMAP Common Indicator 20: Heavy and Trace Elements and Organic Contaminants. Meeting of the MED POL Focal Points, Videoconference, 6-7 October 2021.

UNEP/MAP WG.492/10/ Rev.2 (2021). Integration and Aggregation Rules for Monitoring and Assessment of (IMAP Pollution and Marine Litter Cluster). Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 26-28 April 2021.

UNEP/MAP WG. 533/Inf.3 (2022). Adjusted Background (Assessment) Concentrations (BC/BAC) for Common Indicator 17 and Upgraded Approach for Environmental Assessment Criteria (EAC) for IMAP Common Indicators 17, 18 and 20. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 27 and 30 May 2022.

UNEP/MAP – MED POL (2022). UNEP/MED WG 533/10, Appendix VI. Data Standards and Data Dictionaries for IMAP Common Indicator 20. Meeting of the Ecosystem Approach Correspondence Group on Pollution Monitoring, Videoconference, 27 and 30 May 2022.

US FDA http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm115644.htm

Indicator analysis methods

Indicator Definition

Number of detected regulated contaminants* in commercial species.

Number of detected regulated contaminants* exceeding regulatory limits.

~~(*lists of regulated contaminants can be found in the links from the previous section, including the European Regulation EU 1881/2006)~~

Sub-indicators: other relevant chemicals and emerging pollutants are recommended to be carried out on a country decision basis.

*The list of all chemical and related parameters to be reported for IMAP CI 20 by the Contracting Parties is detailed in the Data Standards for IMAP CI 20. This list includes cadmium (Cd), mercury (Hg), lead (Pb), benzo(a)pyrene, and the sum of four polycyclic aromatic hydrocarbons (PAHs): benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene, and chrysene. It also includes the sum of dioxins (WHO-PCDD/F-TEQ), the combined sum of dioxins and dioxin-like PCBs (WHO-PCDD/F-PCB-TEQ), and the sum of six PCBs (ICES 6): PCB28, PCB52, PCB101, PCB138, PCB153, and PCB180. The concentration limits for regulated contaminants, as included in Data Standards and Data Dictionaries for IMAP CI 20, are provided in the section below titled *Statistical Analysis and Basis for Aggregation – Assessment Criteria*.

Non-regulated contaminants may also be included in the IMAP CI 20 monitoring programme; however, concentration limits for these substances have not yet been established under EU legislation. ~~Additional parameters required: sample identification, location, date and biometrics~~

~~The chemical compounds list, as in the case of CI17, accompanies the development of the IMAP Info System along Data Dictionaries (DDs) and Data Standards (DSs) for CI20.~~

Methodology for indicator calculation

Number of detected contaminants: monitoring by national regulatory and inspection bodies through statistics and databases.

<table>
<tr><td>Indicator Title</td><td>Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)</td></tr>
<tr><td colspan="2">Number of detected contaminants exceeding regulatory limits: monitoring by national regulatory and inspection bodies through statistics and databases.

The detailed analytical procedure for the contaminants regulated under CI 20 and other related mandatory parameters, including sampling and sample transportation, analytical determination of indicators and sub-indicators, and data quality control are outlined in D-1. Monitoring Guidelines/Protocols for Sampling and Determination of Contaminants in Seafood.</td></tr>
<tr><td colspan="2">Indicator units

~~(~~F~~f~~requencies (~~,~~ %) of the ~~–~~n~~N~~umber of detected contaminants in individual commercial species

~~(~~Frequencies~~,~~ (%) of the ~~–N~~number of detected contaminants exceeding regulatory limits in appropriate units, for example, mg/kg fresh weight (parts per million, ppm, and fresh weight) or µg/g fresh weight (part per billion, ppb, fresh weight).

Data Standards for IMAP CI 20 elaborates units for all mandatory and other chemicals and parameters.</td></tr>
<tr><td colspan="2">Data Confidence and uncertainties

Up to 2023, the IAEA/MESL, in collaboration with the UNEP/MAP - MED POL, implemented 56 interlaboratory comparisons/proficiency tests for the analysis of trace elements and organic contaminants, as well as 64 training courses on the analysis of trace elements and organic contaminants in marine samples. Over 370 analytical laboratory practitioners have been trained at MESL. As of 2018, the scope of proficiency testing and training courses has been adjusted to meet the needs of Mediterranean laboratories in implementing monitoring programmes for trace elements (covering mandatory heavy metals – Cd, Hg, Pb, Cu in line with IMAP requirements, as well as additional elements such as Al, As, Co, Cr, Fe, Li, Mn, Ni, and Zn) and organic contaminants for IMAP Common Indicator 17 (covering mandatory organic contaminants including organochlorine (OC) pesticides, polychlorinated biphenyl congeners (PCBs), and polycyclic aromatic hydrocarbons (PAHs), also in accordance with IMAP requirements). Designated national laboratories participating in the proficiency tests receive, along with the sample, clear instructions on how to proceed with the PT sample and how to report the results. They are requested to use established analytical methods and are recommended to apply quality control and laboratory quality assurance procedures. The results of analyses of a matrix-matching quality control (QC) sample must be reported along with the results from the PT sample.

As of 2024, the scope of proficiency testing and training courses has been expanded to support the capacities of national laboratories in monitoring eutrophication (IMAP Common Indicators 13 & 14: inorganic nutrients in high salinity seawater, in estuarine and low salinity seawater, and chlorophyll a and Phaeopigments in Seawater) and contaminants in seafood (IMAP Common Indicator 20: heavy metals including the mandatory heavy metals – Cd, Hg, Pb, Cu, as well as additional elements such as Al, As, Co, Cr, Fe, Li, Mn, Ni, and Zn as specified for CI 17, polycyclic aromatic hydrocarbons (PAHs), dioxins, and PCBs).</td></tr>
<tr><td colspan="2">Methodology for monitoring, temporal and spatial scope</td></tr>
<tr><td colspan="2">Available Methodologies for Monitoring and Monitoring Protocols

~~There are no directly applicable monitoring protocols in order to fulfil the requirement of this Common Indicator. Risk-based public health methodologies to define the monitoring are recommended.~~</td></tr>
</table>

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

Building on elements elaborated in the Integrated Monitoring and Assessment Programme (2016 IMAP), the Monitoring Guidelines—structured around the specific technical protocols related to IMAP Common Indicator 20 were comprehensively developed by the MED POL Programme in cooperation with IAEA/MESL. These guidelines were approved by the MED POL Focal Points Meeting (2021).They build upon the knowledge and practices obtained over 40 years of MED POL monitoring implementation and recent publications, highlighting the current practices of the Contracting Parties' marine laboratories, as well as other Regional Seas Conventions and the EU. A thorough analysis of presently available practices of UNEP/MAP, UNEP and IAEA, as well the HELCOM, OSPAR and European Commission Joint Research Centre was undertaken to assist an innovative approach for preparation of the IMAP Monitoring Guidelines/Protocols. The monitoring methodologies and practices are elaborated for sampling, sample preservation and transportation, sample preparation and analysis, along with quality assurance and reporting of monitoring data, for their use by the IMAP competent laboratories in order to ensure the representativeness and accuracy of the analytical results. These guidelines present a summary of the best available known practices employed in marine monitoring by bringing integrated comprehensive analytical practices that can be applied in order to ensure the representativeness and accuracy of the analytical results needed for generation of quality assured monitoring data.

The Monitoring Guidelines for IMAP Common Indicator 20 outline the following monitoring and reporting practices (https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/division-of-iaea-environment-laboratories/marine-environmental-studies-laboratory/unep-map-med-pol-integrated-monitoring-and-assessment-programme-imap-monitoring-guidelines):

- D-1. Monitoring Guidelines/Protocols for Sampling and determination of contaminants in seafood
- E-1. Monitoring Guidelines/Protocols for Analytical Quality Assurance for IMAP Common Indicators 13, 14, 17, 18 and 20;
- F-1. Monitoring Guidelines/Protocols for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20.

Available data sources

~~At present national databases (if available), research papers and environmental databases (the MED POL Database)~~

i. IMAP Info System (http://imapinfosystem.info-rac.org/app/#/) – one dataset reported by one Contracting Party for CI 20, and data reported for contaminants in biota (CI 17);
ii. Recently reviewed literature, due to the absence of *in situ* data reported for CI 20, as elaborated in the CI 20 thematic assessment and the 2023 MED QSR Pollution Assessment

The two additional potential data sources:

iii. Data/reports that might be available from https://cdr.eionet.europa.eu/ (MSFD) that should be further discussed with EIONET;
~~i.~~iv. Data that might be available at GFCM-FAO data base for the Mediterranean Sea.

Spatial scope guidance and selection of monitoring stations

Risk-based methodologies were used as much as possible in defining the scope of ~~to define~~ monitoring for IMAP Common Indicator 20, along with establishment of national monitoring networks. ~~are recommended.~~

~~Guidance for monitoring stations: environmental monitoring, fish markets~~

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

~~, aboard fishing fleets, sampling at regular inspections by national authorities~~

The D-1. Monitoring Guidelines/Protocols for IMAP CI 20 sets a detailed analytical procedure for sampling and determination of contaminants in seafood.

Temporal Scope guidance

Risk-based methodologies were used as much as possible in defining the scope of monitoring for IMAP Common Indicator 20, along with establishment of national monitoring networks~~to define monitoring are recommended~~. The temporal scope is highly linked to the data confidence and uncertainty of the indicator. Yearly statistics is ~~would be~~ the basic time period.

Data analysis and assessment outputs

Statistical analysis and basis for aggregation – Assessment Criteria

Monitoring should allow the necessary statistical data treatments and long-term time-trend evaluations. Deriving and setting up the assessment criteria to determine environmental status is not an easy task. It gets more complicated going from the local to sub-regional and regional assessments. ~~Geographic reporting scales (within IMAP implementation) should be also considered in terms of indictor aggregation:~~

~~(1) Whole region (i.e. Mediterranean Sea);~~
~~(2) Mediterranean sub-regions, as presented in the Initial Assessment of the Mediterranean Sea, UNEP(DEPI)/MED IG.20/Inf.8;~~
~~(3) Coastal waters and other marine waters;~~
~~(4) Subdivisions of coastal waters provided by Contracting Parties~~

The Mediterranean EAC values for Common Indicator 20, as approved by the Meeting of CorMon Pollution (27 and 30 May 2022) (UNEP/MED WG.533/10, Annex III, Appendix 1), and adopted by Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean, are presented here-below in Tables 1 to 3. They are based on the maximum regulatory levels for certain contaminants in foodstuffs as provided in EC/EU Directives 1881/2006, 1259/2011 and amendments 488/2014 and 1005/2015. The approval of the MedEAC values for CI 20 was provided further to the results of a survey undertaken by the UNEP/MAP – MED POL of the existing sources providing the actual levels of contaminants that have been detected and several contaminants that have exceeded maximum regulatory levels in commonly consumed seafood. Tables 1 to 3 show EAC CI 20 values for TM (Cd, Hg and Pb) and organic contaminants (PCBs, PAHs and dioxin).

The MedEAC values for CI 20 are in the low and mid-range of criteria used around the world and have the advantage of being consistent with the regulations of the EU. Their consistent application across the region is necessary. It should also be highlighted that these values were agreed upon at EU level also considering the ecosystem characteristics of the Mediterranean Sea. These values are taxa-specific (fish, mussel, crustacean), as well as species-specific.

Table 1. Mediterranean EACs values for CI 20 related to trace metals as approved by the Meeting of CorMon Pollution (27 and 30 May 2022) based on the maximum regulatory levels for trace metals in foodstuffs for the protection of human health, as provided in EC/EU Directives1881/2006 and its amendments 488/2014 and 1005/2015. The concentrations are presented in mg/kg wet wt.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

New EAC CI 20 for trace metals- EU 1881/2006 directive and its amendments 488/2014 and 1005/2015			
	TM, mg/kg wet wt		
matrix	**Cd**	**Hg**	**Pb**
fish muscle	0.05-0.25	0.5-1	0.3
cephalopods	1		1
crustaceans	0.5	0.5	0.5
bivalve mollusc	1		1.5

Table 2. Mediterranean EAC values for IMAP CI 20 related to Benzo(a)pyrene and sum of four PAHs as approved by the Meeting of CorMon Pollution (27 and 30 May 2022) based on the maximum regulatory levels for these contaminants in foodstuffs for the protection of human health, as provided in EC/EU EC Regulations 835/2011 and 1259/2011 amending Regulation (EC) 1881/200.6. The concentrations are presented in μg/kg wet wt.

New EACs values for CI 20 related to Benzo(a)pyrene and sum of four PAHs (benzo(a)pyrene, benz(a)anthracene, benzo(b)fluorantheneand chrysene) - EC Regulation (EC) 1881/2006 and amendments 835/2011 and 1259/2011		
Matrix	**Maximum levels (μg kg^{-1} wet wt)**	
	Benzo(a) pyrene	**Sum of Benzo(a) pyrene, Benzo(a) anthracene, Benzo(a) fluoranthene and chrysene**
Smoked fish muscle	2-5	12-30
Smoked bivalve mollusc	6	35
Bivalve mollusk (fresh, chilled or frozen)	5	30

Table 3. Mediterranean EAC values for CI 20 related to Dioxins and PCBs as approved by the Meeting of CorMon Pollution (27 and 30 May 2022) based on the maximum regulatory levels for these contaminants in foodstuffs for the protection of human health, as provided in EC/EU EC Regulation 1259/2011 amending EC Regulation 1881/2006. The concentrations are presented in wet wt.

New EACs values for CI 20 related to Dioxins and PCBs – EC Regulation 1259/2011 amending EC Regulation 1881/2006			
Foodstuffs	**Maximum levels**		
	Sum of dioxins (WHO-PCDD/F-TEQ) (1) pg g^{-1} ww	**Sum of dioxins and dioxin-like PCBS (WHO-PCDD/F-PCB-TEQ) (1) pg g^{-1} ww**	**Sum of PCB28, PCB52 PCB101, PCB138, PCB1 and PCB180 (ICES 6) ng g^{-1} ww**
Fish muscle	3.5	6.5	75
Fish liver	3.5	20	200
Eel muscle	3.5	10	300

(1) Dioxins (sum of polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), express as World Health Organisation (WHO) toxic equivalent using the WHO-toxic equivalency factors (WHO-TEFs)) and su of dioxins and dioxin-like PCBs (sum of PCDDs, PCDFs and polychlorinated biphenyls (PCBs), expressed as WHO toxic equivalent using the WHO-TEFs). WHO-TEFs for human risk assessment based on the conclusions of the World Health Organization (WHO) (For TEF values see note 31, (EC) Regulation 1259/2011 – Annex 1.1.9.). Where fish are intended to be eaten whole, the maximum level shall apply to the whole fish.

~~Expected a~~Assessment of contaminants in seafood~~s outputs~~

~~Assessment outputs would be based on trend analysis and annual statistics~~The previous assessment of IMAP Common Indicator 20, performed during the preparation of the 2017 Mediterranean Quality Status Report (2017 MED QSR), was based on bibliographic studies and scientific documents in the Mediterranean Sea. There were no data sets reported to MEDPOL for IMAP CI

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)

20. In the 2017 MED QSR it was concluded that " a few research studies and EU policy driven reports i.e., related to MSFD in some Mediterranean countries investigated the occurrence of contaminants in seafood from an environmental perspective i.e., the ecosystem approach, which are exceeding the maximum regulatory levels established within regulatory standards.

Due to the lack of data reported in IMAP IS, it was not possible to implement the recommendations of COP 19 regarding integrated assessments based on quality-assured data. As a result, the input for the 2023 Mediterranean Quality Status Report (2023 MED QSR), related to the initial environmental assessment of CI 20, was developed using the following two approaches:

i. **The Environmental initial exemplary assessment of CI 20 based on data reported in IMAP IS for CI 17 contaminants in biota**, further to the absence of *in situ* data reported for CI 20. CI 17 data for *M. galloprovinciallis* were available only for the WMS and the ADR, and CI 17 TM data for M. barbatus were available for the ADR (56 data points), CEN (15 data points) and AEL (213 data points).
ii. **The Environmental Assessment of CI 20 based on recent peer reviewed literature** in the absence of *in situ* data reported in IMAP IS for CI 20, Examination of the literature data per sub-regions was performed by counting the number of times contaminants (Cd, Hg, Pb, B(a)P) and the number of group of contaminants (Σ4 PAHs, Σ6 PCBs, PCDD/Fs and Σ (PCDD/Fs and dl PCBs)) were addressed in the literature. There were 37 entries for the WMS, 25 for the ADR, 24 for the CEN and 23 for the AEL sub-region.

Further details are provided in the thematic assessments of contaminants in seafood and the 2023 MED QSR Pollution Assessment.

Known gaps and uncertainties in the Mediterranean

As IMAP ~~this is a new~~ Common Indicator 20 is the new indicator within the ~~context of marine environmental protection policy (*ca.* Ecosystem Approach and~~ IMAP implementation,~~)~~ its applicability beyond food consumer protection and public health was necessary to ~~ould need to be~~ determin~~ed~~, although intuitively reflects the health status of the marine environment in terms of their delivery of benefits (e.g. fisheries industry). Thus, ~~-~~monitoring protocols, risk-based approaches, analytical testing and assessment methodologies would need to be further examined between Contracting Parties national food safety authorities, research organisations and/or environmental agencies.

Further to the significant progress achieved over the last few biennia regarding the standardizing monitoring practices and progressing towards the environmental assessment tools—along with the improved availability of assessment criteria – it is essential to procced by setting a multidisciplinary approach needed to ensure GES assessment for CI 20 . By building on the achievements up to 2023, during the preparation of the 2023 MED QSR, several knowledge gaps were identified in the monitoring and assessment of Common Indicator 20, which need to be addressed following the recommendations of the 2023 MED POL Focal Points Meeting.

A multidisciplinary approach will be essential to ensure the GES assessment for CI 20, by implementing priority actions aimed at addressing the existing gaps:

- Agree on the maximal percentage of detected regulated contaminants exceeding regulatory limits in seafood, above which non-GES needs to be assigned to the area assessed;
- Incorporate the risk assessments to human health from consumption of seafood by calculating the estimated daily intake (EDI), the target hazard quotient (THQ), the total health risk (HI), and the cancer risk, among others;
- Incorporate into the overall evaluation the suite of contaminants analyzed, together with other factors such as synergy among contaminants, and temporal and spatial scales.

Indicator Title	Common Indicator 20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood (EO9)	
o Harmonize the choice of species among the CPs, whereby data from national reports on seafood safety and cooperation with national health authorities should be used to complement data reporting to IMAP IS; o Examine and coordinate monitoring protocols, risk-based approaches, analytical testing, and assessment methodologies between the CPs; the national food safety authorities; research organisations and/or environmental agencies; o Determine the applicability of CI 20 beyond food consumer protection and public health, although it intuitively reflects the health status of the marine environment in terms of delivery of benefits (e.g., fisheries industry).		
Contacts and version Date		
http://www.unepmap.org		
Version No	**Date**	**Author**
V.1	31.05.17	MED POL
V.2	12.12.18	MED POL
V.3	31/05/2019	Approved by the Meeting of MED POL FPs
Final version	09/09/2019	Approved by the 7th Meeting of EcAp Coordination Group
V4	28/05/2025	Joint CorMon Pollution and ML Meeting
V5		Approved by the Meeting of MED POL FPs
Final version		Approved by the 12th Meeting of EcAp Coordination Group

11. The revision of IMAP **Common Indicator 21 (EO9)**: "Percentage of intestinal enterococci concentration measurements within established standards" is presented in the table bellow.

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**[24]
Concentrations of intestinal enterococci are within established standards	Water quality in bathing waters and other recreational areas does not undermine human health	
Rational		
Justification for indicator selection The Mediterranean Sea continues to attract every year an ever-increasing number of international and local tourists that among their activities use the sea for recreational purposes. The establishment of sewage treatment plants and the construction of submarine outfall structures have decreased the		

[24] Following the decisions to be made at the present meeting regarding minor adjustments to the Targets, as outlined in working document UNEP/MED WG.624/3, the revised Targets will be incorporated into the revised IMAP Pollution Indicators Factsheets.

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)

potential for microbiological pollution, despite major hotpots still exist. High levels of intestinal enterococci bacteria in recreational marine waters (coasts, beaches, tourism spots, etc) are known to be indicative of human pathogens, which is a serious public health concern, as well as economical. Therefore, intestinal enterococci concentrations are frequently used as a faecal indicator bacteria proxy or general indicators of faecal contamination in the marine environment. It has been suggested and later on demonstrated that *enterococci sp*. might be more appropriate than traditional *Escherichia coli* in marine waters as an index of faecal pollution. Currently, is the only faecal indicator bacteria recommended by the US Environmental Protection Agency (US EPA, 2012) for brackish and marine waters, since they correlate better than faecal coliforms or *E.coli*. The World Health Organization (WHO) is also in line with this approach (Ashbolt et al., 2001; Kay et al., 2004). Within the framework of Integrated Monitoring and Assessment Programme (UN/MAP IMAP) this indicator has been selected.

Scientific References

Ashbolt, N.J., Grabow, W.O.K, and Snozzi, M., 2001. Indicators of microbial water quality, Chapter 13. In: Water Quality: Guidelines, Standards and Health. 2001 World Health Organization (WHO). Edited by Lorna Fewtrell and Jamie Bartram. Published by IWA Publishing, London, UK.

Cabelli VJ, Dufour AP, Levin MA, McCabe LJ, Haberman PW. 1979. Relationship of microbial indicators to health effects at marine bathing beaches. Am. J. Public Health, 69, 690–696

Byappanahalli, MN. *et al.*, 2012. Enterococci in the environment. Microbiol. Mol. Biol.Rev., 76, 685-706

Kay, D. et al, 2004. Derivation of numerical values for the World Health Organization guidelines for recreational waters. Water Research 38 (2004) 1296–1304

Kay D, *et al.* 1994. Predicting likelihood of gastroenteritis from sea bathing: results from randomised exposure. Lancet, 344, 905–909

Prüss A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. Int. J. Epidemiol., 27, 1–9

US EPA RWQC 2012. Recreational Water Quality Criteria. OFFICE OF WATER 820-F-12-058. Scientific document.

Policy Context and targets

Policy context description

The World Health Organisation (WHO) has been concerned with health aspects of the management of water resources for many years and published various documents concerning the safety of the water environment, including marine waters, and its importance for health. Revised Mediterranean guidelines for bathing water quality were formulated in 2007 based on the WHO guidelines for “Safe Recreational Water Environments” and on the EC Directive for “Bathing Waters” (EU/2006/7), and through Decision IG.20/9 (Criteria and Standards for bathing waters quality in the framework of the implementation of Article 7 of the LBS Protocol. COP17, Paris, 2012). The proposal was made in an effort to provide updated criteria and standards that can be used in the Mediterranean countries and to harmonize their legislation in order to provide homogenous data. Therefore, the standards for bathing waters quality in the framework of the implementation of Article 7 of the LBS Protocol, could be further used to define GES for the indicator on pathogens in bathing waters.

Targets

The ~~I~~initial target of GES under Common Indicator 21 is ~~will be~~ an increasing trend in measurements to test that levels of intestinal enterococci comply with established national or international standards and the methodological approach itself. Particularly, under Decision IG.20/9 and the EU 2006/7

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)
Directive, excellent (95th percentile < 100 CFU/100 mL) or good (95th percentile < 200 CFU/100 mL) quality categories for the "last assessment"; which means the last four years. ~~(see documents below)~~ Decision IG.20/9 on *Criteria and Standards for Bathing Water Quality*—adopted in the context of implementing Article 7 of the LBS Protocol (COP 17, Paris, 2012; UNEP/MAP, 2012)—established threshold values for bathing water quality in the Mediterranean region, as outlined in the referenced section. These threshold values were used in the preparation of the 2023 MED QSR bathing water quality assessment to define the boundary between Good Environmental Status (GES) and non-GES status in relation to pathogens in bathing waters. The assessment scale shown below was developed and applied across Mediterranean sub-regions to evaluate GES, where applicable. • A four-class assessment scale—Category A - Excellent, Category B - Good, Category C - Sufficient, category D - Poor/Immediate Action —is established in accordance with Decision IG.20/9 and the EU 2006/7 Directive. Categories A, B and C are considered to meet GES, while Category D is classified as non-GES for intestinal enterococci (IE) in Mediterranean bathing waters. • A threshold value for the GES / non-GES boundary is defined. The decision rule for GES/non-GES status is based on comparing assessment score values against the boundary limit value defined for Category D. • Bathing water classification is based on the 90th or 95th percentile of the log10 normal probability density function of microbiological data. Each location must have at least 16 data points collected over four bathing seasons, with a minimum of four samples per season (exceptions are outlined in Directive 2006/7/EC and Decision IG.20/9).	
Policy documents **General Policy documents** Decision IG.21/3 (COP18,2013) ~~18th COP to the Barcelona Convention, Istanbul, Turkey,~~ on Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets (UNEP(DEPI)/MED IG.21/9). ~~19th COP to the Barcelona Convention, Athens, Greece, 2016~~ Decision IG.22/7 (COP19, 2016) on ~~Decision IG.22/7~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria (UNEP(DEPI)/MED IG.22/28). Decision IG.21/3 (COP18,2013) ~~18th COP to the Barcelona Convention, Istanbul, Turkey,~~ on Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and Targets (UNEP(DEPI)/MED IG.21/9). ~~19th COP to the Barcelona Convention, Athens, Greece, 2016~~ Decision IG.22/7 (COP19, 2016) on ~~Decision IG.22/7~~ Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria (UNEP(DEPI)/MED IG.22/28). Decision IG.25/1 (COP22, 2021) on UNEP/MAP Medium-Term Strategy 2022-2027. Decision IG.22/7 (COP19, 2016) on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria. Decision IG.23/6 (COP20, 2017) on 2017 Mediterranean Quality Status Report. Decision IG.24/4 (COP21, 2019) on Assessment Studies. Decision 26/3 (COP23, 2023) on the 2023 Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean.	

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (EU Marine Strategy Framework Directive and updates in 2010).

Commission Directive (EU) 2017/845 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies

Commission Decision (EU) 2017/848 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (and updated revisions).

Commission Decision (EC) No 2013/480/EU establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Decision 2008/915/EC.

2017 Mediterranean Quality Status Report, https://www.medqsr.org/node/10/

2023 Mediterranean Quality Status Report, medqsr2023.info-rac.org

UNEP(DEPI)/MED IG.22/Inf.7. (2016) Integrated Monitoring and Assessment Guidance

Bathing Waters ~~Contaminants~~ related Policy documents

~~UNEP(DEPI)/MED IG 20/8.~~ Decision IG.20/9. Criteria and Standards for B~~b~~athing W~~w~~aters Q~~q~~uality in the framework of the implementation of Article 7 of the LBS Protocol. (COP17, Paris, 2012.

Directive 2006/7/EC of the European Parliament and of the C~~c~~ouncil of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC

(http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006L0007&from=EN)

UNE/MAP MED POL, 2010. Assessment of the state of microbial pollution in the Mediterranean Sea. MAP Technical Reports Series No. 170 (Amended).

UNEP/MED WG.556/Inf.13/Rev.1. (2023), The Marine Environment Assessment in the Areas with Insufficient Data: The Results of Assessment for IMAP Common Indicator 21 in the Mediterranean.

~~WHO, 2003. Guidelines for safe recreational water environments. VOLUME 1: Coastal and fresh waters. WHO Library. ISBN 92 4 154580. World Health Organisation, 2003.~~

Indicator analysis methods

Indicator Definition

The concentration (Colony-forming unit, CFU) of intestinal enterococci in the water sample (normalised to 100 mL) collected at one beach location.

Methodology for indicator calculation

For the indicator calculation, ~~A~~the methodology was set ~~has been proposed~~ by Directive 2006/7/EC with the ~~following~~ specification outlined below:

Based upon percentile evaluation of the log10 normal probability density function of microbiological data acquired from the particular bathing water, the 90th and 95thpercentile values are derived as follows:

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)

1) Take the log10 value of all bacterial enumerations in the data sequence to be evaluated. (If a zero value is obtained, take the log10 value of the minimum detection limit of the analytical method used instead)

2) Calculate the arithmetic mean of the log10 values (μ).

3) Calculate the standard deviation of the log10 values (σ).

The upper 90-percentile point of the data probability density function is derived from the following equation: upper 90-percentile = antilog (μ + 1,282 σ). The upper 95-percentile point of the data probability density function is derived from the following equation: upper 95-percentile = antilog (μ + 1,65 σ).

Indicator units

The 90th and 95th percentiles of the log10 normal probability density function of the CFU datasets measured at one single location according established monitoring and assessment protocols and standards.

List of Guidance documents and protocols available

ISO 7899-1[Water quality – Detection and enumeration of intestinal enterococci: Part 1: Miniaturized method (Most Probable Number) for surface and wastewater]

ISO 7899-2 [Water quality – Detection and enumeration of intestinal enterococci: Part 2: Membrane filtration method].

WHO Guidelines for Safe Recreational Water Environments. Volume 1: Coastal and fresh waters, 2003.

WHO Guidelines for Safe Recreational Water Environments Recreational Water Environments. Volume 2: Swimming Pools and Similar Environments, 2006.

~~UNEP(DEPI)/MED IG 20/8. Decision IG.20/9. Criteria and Standards for bathing waters quality in the framework of the implementation of Article 7 of the LBS Protocol. COP17, Paris, 2012.~~

Revised Mediterranean guidelines for bathing waters based on the WHO guidelines for Safe Recreational Water Environments and on the EC Directive for Bathing Waters" (EU/2006/7), and Decision IG.20/9 on Criteria and Standards for Bathing Water Quality in the framework of the implementation of Article 7 of the LBS Protocol, 2007.

European Environment Agency (EEA). European Topic Centre on Inland, Coastal and Marine Waters, 2021.

Data Confidence and uncertainties

As in the case of analytical chemistry, the data confidence originates in the maintenance of internal QA/QC programmes by national laboratories, as well as regular interlaboratory or proficiency testing exercises. It should be mentioned that the level of uncertainty in measurements could be considered low, provided the above is fulfilled. On the other hand, the ISO 7899-2 methodology describes the isolation of intestinal enterococci (*Enterococcus faecalis*, *E. faecium*, *E. durans*and *E. hirae*), pointing out that, other Enterococcus species and some species of the genus Streptococcus (namely *S. bovis*and *S. equinus*) may occasionally be detected. These Streptococcus species do not survive long in water and are probably not enumerated quantitatively. Further, for purposes of water examination, *enterococci sp.* can be regarded as indicators of faecal pollution, despite it should be mentioned that some enterococci found in water can occasionally also originate from other habitats.

Methodology for monitoring, temporal and spatial scope

Available Methodologies for Monitoring and Monitoring Protocols

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)

Revised Mediterranean guidelines for bathing waters were formulated in 2007 based on the WHO guidelines for "Safe Recreational Water Environments" and on the EC Directive for "Bathing Waters" (EU/2006/7), and through Decision IG.20/9 on Criteria and Standards for Bathing Water Quality in the framework of the implementation of Article 7 of the LBS Protocol (COP17, Paris, 2012). The proposal was made in an effort to provide updated criteria and standards that can be used in the Mediterranean countries and to harmonize their legislation in order to provide homogenous data.

Available data sources

~~For some Mediterranean countries European and non-European, the European Environmental Agency (EEA) has published a number of reports and the datasets are available through their website services.~~

i. IMAP Info System (http://imapinfosystem.info-rac.org/app/#/);
ii. The European Environment Agency (EEA) (https://www.eea.europa.eu/data-and-maps/indicators/bathing-water-quality; https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/state-of-bathing-water/state-of-bathing-waters-in-2020).

Spatial scope guidance and selection of monitoring stations

Sampling should be performed in recreational waters where microbiological pollution could threat the recreational uses. The measurements are made in selected monitoring stations during the summer season focusing in the touristic beaches and other sites of concern. The full description of indications to prepare a monitoring strategy is outlined ~~can be found~~ in Directive 2006/7/~~EC of the European Parliament and of the council of 15 February 2006~~ concerning the management of bathing water quality. ~~and repealing Directive 76/160/EEC.~~

Temporal Scope guidance

According to ~~Annex IV (~~EU Directive 2006/7EC~~)~~ (Annex IV) and Decision IG.20/9, the temporal scope guidance is as follows:

1. One sample is to be taken shortly before the start of each bathing season. Taking account of this extra sample and subject to paragraph 2 (below), no fewer than four samples are to be taken and analysed per bathing season.
2. However, only three samples need be taken and analysed per bathing season, as detailed in the below section on the assessment, in the case of a bathing water that either:
(a) has a bathing season not exceeding eight weeks; or
(b) is situated in a region subject to special geographical constraints.
3. Sampling dates are to be distributed throughout the bathing season, with the interval between sampling dates never exceeding one month.
4. In the event of short-term pollution, one additional sample is to be taken to confirm that the incident has ended. This sample is not to be part of the set of bathing water quality data. If necessary to replace a disregarded sample, an additional sample is to be taken seven days after the end of the short-term pollution.

Data analysis and assessment outputs

Statistical analysis and basis for aggregation ~~–~~ – Assessment Criteria

Decision IG.20/9 on *Criteria and Standards for Bathing Water Quality*—adopted in the context of implementing Article 7 of the LBS Protocol (COP 17, Paris, 2012)— agreed on the threshold values in the Mediterranean region as presented in below table.

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)

Microbial Water Quality Assessment Category based on Intestinal enterococci (cfu/100 mL) in bathing waters in the Mediterranean (Decision IG.20/9).

Category	**A**	**B**	**C**	**D**
Limit values	<100*	101-200*	185**	>185**[(1)]
Water Quality	Excellent	Good	Sufficient	Poor/Immediate Action

*Based on the 95th percentile; ** Based on the 90th percentile;

- [(1)] For single sample appropriate action is recommended to be carried out once the
- count for IE exceeds 500 cfu/100 mL:
- For classification purposes at least 12 sample results are needed spread over 3-4 bathing seasons; Exceptions related to the assessment of monitoring data are outlined in Directive 2006/7/EC and Decision IG.20/9, as detailed in the following section on assessment outputs.~~.~~
- Reference method of analysis: ISO 7899-2 based on membrane filtration technique or any other approved technique;
- Transitional period 4 years (starting by 1st January 2012).

Monitoring should allow the necessary statistical data treatments, as well as time-trend evaluations. While considering the IMAP nested ~~In order to comply with the stated Common Indicator within IMAP, the geographic reporting scales~~for presentation of the assessment findings, ~~(nested approach) should be taken into account. However,~~ the balance between data, locations and spatial resolution should be carefully considered for coherence in areas ~~(1) and (2)~~, as CI 21 ~~this Common Indicator~~ is ~~largely (if not entirely) evaluated~~assessed in coastal waters ~~(3) and (4):~~

~~(1) Whole region (i.e. Mediterranean Sea);~~
~~(2) Mediterranean sub-regions, as presented in the Initial Assessment of the Mediterranean Sea, UNEP(DEPI)/MED IG.20/Inf.8;~~
~~(3) Coastal waters and other marine waters;~~
~~(4) Subdivisions of coastal waters provided by Contracting Parties .~~

Assessment of Bathing Water Quality ~~Expected assessments outputs~~

For pathogenic microorganisms in bathing water, monitoring for the assessment of GES could be carried out on a sub-regional and/or local level due to the nature of microbiological contamination (the impact is restricted to a relatively short distance from the pollution source due to the short survival time of microorganisms in seawater and dilution effects).Distribution maps and short-term temporal trend assessments ~~(short periods)~~ should ~~are~~ also be utilized.~~envisaged.~~

Due to insufficient data reported in the IMAP Information System (IMAP IS), the full implementation of the COP 19 recommendations on integrated assessments based on quality-assured data was not possible. Consequently, the input related to the environmental assessment of Common Indicator 21 (CI 21) for the 2023 Mediterranean Quality Status Report (2023 MED QSR) was developed upgrading the approach applied in the 2017 MED QSR. This approach combined assessment results from nine Contracting Parties, as presented in the EEA 2020 State of Bathing Water Quality report (https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/state-of-bathing-water/state-of-bathing-waters-in-2020), with the evaluation of monitoring data reported for CI 21 in IMAP Info System by five Contracting Parties.

The methodology used in the EEA's 2020 assessment of bathing water quality followed the EEA Guidelines for assessments under the Bathing Water Directive. This approach is consistent with the requirements of Directive 2006/7/EC and IMAP Decision IG.20/9. Specifically, bathing waters

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)

were classified based on the 90th or 95th percentile values derived from the log10 normal probability density function of microbiological data. Each monitoring location included a minimum of 16 samples collected over four bathing seasons, with at least four samples per season.

Exceptions to this standard are outlined in Directive 2006/7/EC and Decision IG.20/9. In brief, assessments may be conducted using data from three bathing seasons if the bathing water is newly designated or if significant changes have occurred that could affect its classification. The dataset must still include at least 16 samples in such cases. Under special circumstances—such as when the bathing season lasts no longer than eight weeks or when the site is located in a region with particular geographical constraints—only 12 samples may be used (as stipulated in Annex IV, paragraph 2 of the Directive).

The Directive defines two key microbiological indicators: *Intestinal enterococci* (IE) and *Escherichia coli* (E. coli), both measured in colony-forming units per 100 ml (cfu/100 ml). The final classification of bathing waters is determined by the lower status of the two indicators. For instance, if the water quality for IE is classified as "excellent" but the E. coli level is "poor," the overall classification for the site is "poor."

The same methodology used in the EEA 2020 assessment of bathing water quality was applied to the dataset reported in the IMAP Info System by three Contracting Parties, using intestinal enterococci as the sole indicator. However, this methodology could not be applied to data from two other Contracting Parties, as the required 16 data points over four consecutive bathing seasons were not available. For these two Contracting Parties, classification was instead based on the geometric mean calculated for each location. The geometric mean was chosen because it minimizes the impact of outliers and is less affected by skewed data distributions compared to the arithmetic mean.

The table below compares the two methodologies.

Comparison between the methodology used by the EEA and the methodology used in present document for the assessment of Bathing waters quality (CI-21)

Assessment methodology	**EEA**	**Present assessment of IMAP CI 21***
Assessment Category	Based on Intestinal enterococci and Escherichia coli (cfu/100 mL)	Based on Intestinal enterococci (cfu/100 mL)
Number of data points	At least 16	Less than 16, depending on the CP
Number of monitoring years	4	Less than 4, depending on the CP
Classification of station	Percentile evaluation of the log10 normal probability density function	Geometric mean

Further details are provided in the thematic bathing waters assessments and the 2023 MED QSR Pollution Assessment.

Known gaps and uncertainties in the Mediterranean

~~Within the context of Ecosystem Approach and IMAP implementation its applicability beyond bathing waters (recreational waters) protection and management would need to be determined, although intuitively reflects the health status of the coastal environment in terms of their delivery of benefits (e.g. tourism).~~

Building on the significant progress made over recent biennia in standardizing monitoring practices and advancing environmental assessment tools, it is essential to ensure a robust Good Environmental Status (GES) assessment for Common Indicator 21 (CI 21). This requires strengthening data reporting to enhance the reliability and confidence of the assessment. To apply

Indicator Title	Common Indicator 21. Percentage of intestinal enterococci concentration measurements within established standards (EO9)	
the uniform assessment methodology consistently across the Mediterranean, a minimum of 16 data points over four consecutive bathing seasons is required. This will significantly improve the comparability and consistency of the assessment findings.		
Contacts and version Date		
http://www.unepmap.org		
Version No	**Date**	**Author**
V.1	31.05.17	MED POL
V.2	12.12.18	MED POL
V.3	29.04.19	MED POL
Final version	31/05/2019	Approved by the Meeting of MED POL FPs
V4	28/05/2025	Joint CorMon Pollution and ML Meeting
V5		Approved by the Meeting of MED POL FPs
Final version		Approved by the 12th Meeting of EcAp Coordination Group