

Procedures for assessment of eutrophication status including evaluation of
land-based sources of nutrients for the NOWPAP region
(Revision: 2013-Aug)

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1. Introduction

Nutrients such as nitrogen (N) and phosphorus (P) are essential for biological productivity in the marine environment. However, excessive nutrient loadings by over population and run-off from industries or agricultural activities can lead to occurrence of eutrophication. Eutrophication affects the marine environment in various ways. Phytoplankton grow by absorbing nutrients, but, harmful algal blooms (HABs) can occur when primary production and an increase in algal biomass are abnormally accelerated. HABs include red tides and an abundance of harmful toxic plankton species that affect marine life and fisheries and aquaculture by killing fish. As algal blooms and algal biomass decompose, oxygen in the water is consumed by microbial processes, and hypoxia or anoxia can occur at the bottom of the sea. Hypoxic or anoxic water masses have negative effects on benthic organisms, which often lead to the degradation of biodiversity in the sea.

In the Northwest Pacific region, especially coastal areas of China, Japan and Korea, are densely populated and eutrophication is often perceived as a potential threat for coastal environment, although eutrophication is rare in Russian waters. Ability to monitor their coastal systems is necessary to manage and sustain healthy coastal environments. However, continuous and synoptic water quality data, particularly in estuaries and bays is lacking, and it is difficult to characterize the response of water quality to human and natural impacts. Furthermore due to increases in agricultural and industrial activities as well as the possible changes of coastal run-off in this region, there has been an increase in the need for effective monitoring methods on the change of water quality.

Thus, Northwest Pacific Action Plan (NOWPAP) Working Group 3 (WG3) and Working Group 4 (WG4) have decided to use experience of the European countries and develop the "Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region (the NOWPAP Common Procedures)". It is hoped that the obtained assessments will provide arguments to limit or, if possible, to reduce anthropogenic changes of the coastal ecosystem.

1-1. Background

- 1.1. Development of the NOWPAP Common Procedure was proposed and approved at the 5th NOWPAP CEARAC (Special Monitoring and Coastal Environmental Assessment Regional Activity Centre) Focal Points Meeting (FPM) held in Toyama on September 18-19, 2007. The 12th NOWPAP Intergovernmental Meeting (Xiamen, China, 22-15 October, 2007) adopted CEARAC workplan including development of the NOWPAP Common Procedure.
- 1.2. As part of the development processes of the draft Procedures, Northwest Pacific Region Environmental Cooperation Center (NPEC) has implemented a case study in Toyama Bay (Toyama Bay case study), by referring to the 'Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area'. An interim progress of the Toyama Bay case study was presented at the 5th CEARAC FPM and the First Coastal Environment Assessment Workshop held in Toyama on March 6-8, 2008.
- 1.3. The initial version of the NOWPAP Common Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region was

adopted in June 2009.

1.4. The NOWPAP Common Procedure was first applied in five coastal areas selected by the NOWPAP member states in 2010 and the Integrated Report on Eutrophication Assessment in Selected Sea Areas in the NOWPAP Region: Evaluation of the NOWPAP Common Procedure was published in 2011.

1.5. Realizing the technical problems of the NOWPAP Common Procedure during its application to the selected sea areas and assessment of the eutrophication status of each area in the for the 2010-2011 biennium, CEARAC proposed refinement of the NOWPAP Common Procedures as an one of CEARAC activities for the 2012-2013 biennium at the 9th CEARAC FPM (Toyama, Japan, September 6-7, 2011). CEARAC workplan including the refinement work the NOWPAP Common Procedure was then approved by the member states at at the 16th Intergovernmental Meeting of NOWPAP (Beijing, China, December 20-22, 2011).

1-2. Objectives of the NOWPAP Common Procedures

1.6. The objectives of the NOWPAP Common Procedures are to enable each NOWPAP member state to assess the status and impacts of eutrophication in their respective sea areas, by using information obtained through existing monitoring activities. The assessment results could hopefully then be utilized by each NOWPAP member state for consideration and development of monitoring systems and countermeasures against eutrophication. The content of the NOWPAP Common Procedures will be continuously revised and improved by reflecting the feedbacks from each NOWPAP member state through the implementation of the NOWPAP Common Procedures. Figure 1 schematically shows the concept of the NOWPAP Common Procedures.

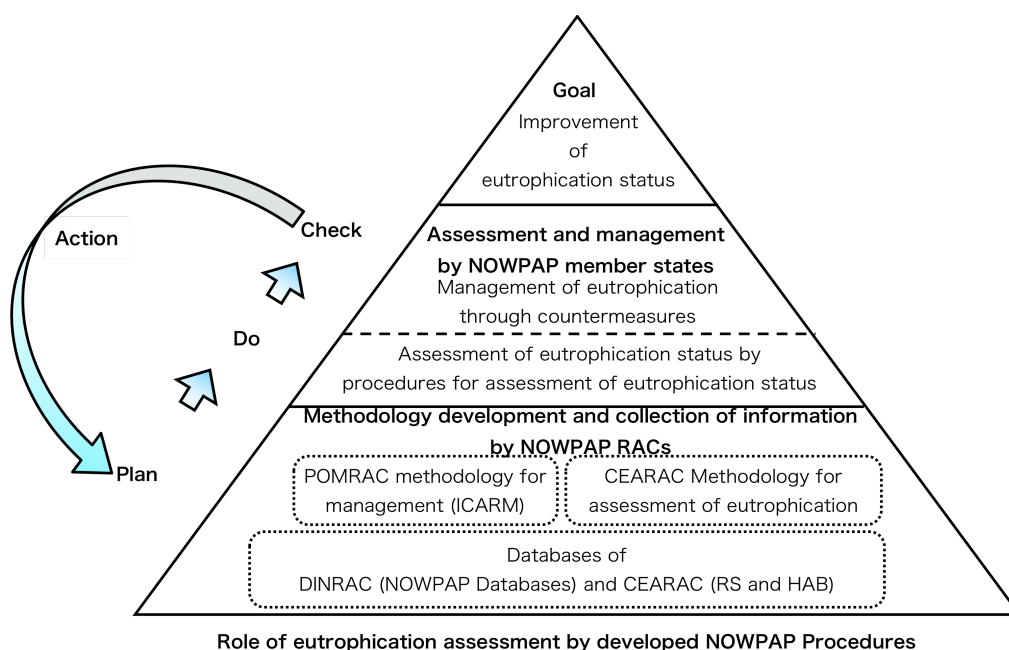


Figure 1 Concept of the NOWPAP Common Procedures.

RACs are regional activity centers of NOWPAP. CEARAC: Special Monitoring and Coastal Environment Assessment Regional Activity Centre, DINRAC: Data and Information Network Regional Activity Centre and POMRAC: Pollution Monitoring Regional Activity Centre.

1-3. Characteristics of the NOWPAP Common Procedure

1.7. The NOWPAP Common Procedure was developed based on the following principle:

- i) It should be adaptable to various environmental conditions in different types of areas in the NOWPAP region
- ii) There are two steps in assessment of the eutrophication status: screening procedure to detect symptom of eutrophication with the minimum required parameters, and comprehensive procedure to assess the eutrophication status in details.
- iii) Eutrophication status is assessed through a holistic approach by integrating the level and trend of collected parameters categorized by the degree of nutrient enrichment, direct/indirect effects of nutrient enrichment and other possible effects of nutrient enrichment.
- iv) With the use of NOWPAP Common Procedure, the eutrophication status is classified into one of six classifications: High-Increase (HI); High-No Trend (HN), High-Decrease (HD), Low-Increase (LI), Low-No trend (LN) and Low-Decrease (LD) (Fig. 2.1). If the assessment parameter is assessed only with the trend, the eutrophication status is classified as either 'decrease trend', 'no trend' or 'increase trend'.

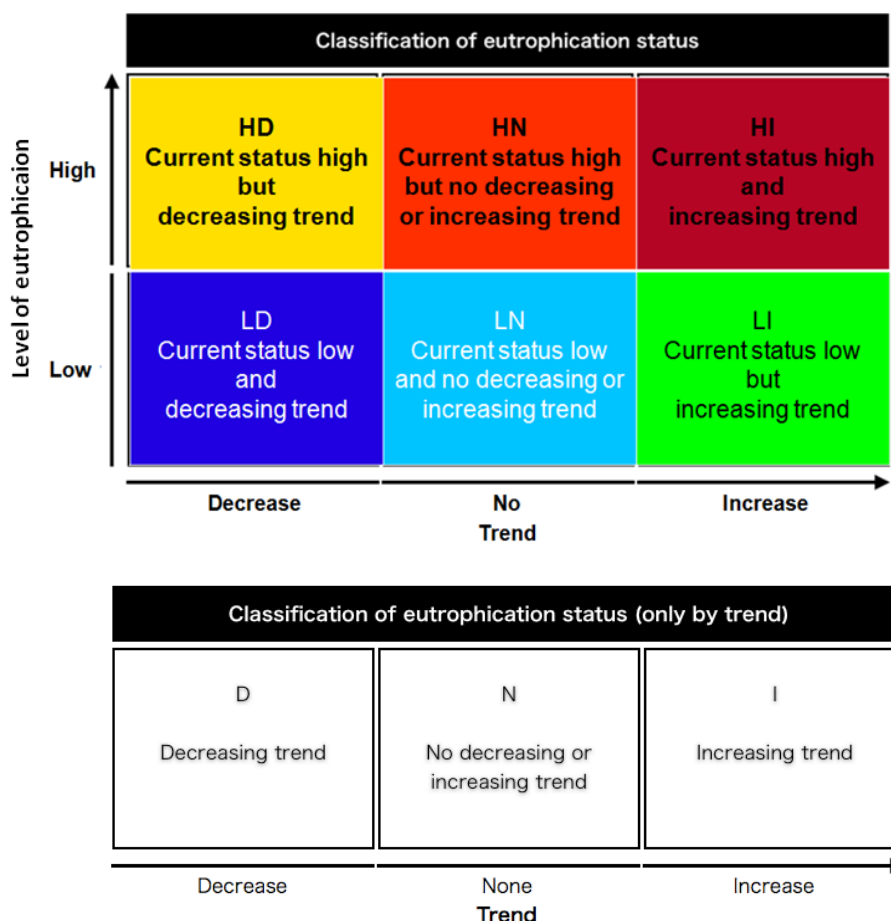


Figure 2 The classifications of the eutrophication status in the NOWPAP Common Procedure, determined using a combination of the level and the trend of assessment parameters.

1-4. Precautions

1.8. The following uncertainties should be kept in mind.

- i) The assessment results may not be applicable for use in the environmental impact assessment.
- ii) The assessment results may become less reliable/valid when scientific data/information are updated.
- iii) The assessment results may have the low degree of confidence due to insufficient data.

2. Overall structure

2.1. The NOWPAP Common Procedure is broadly separated into four parts, namely i) screening procedure, ii) comprehensive procedure, iii) results and discussion and iv) conclusion and recommendation. In the 'screening procedure', the eutrophication status will be preliminarily assessed to detect symptoms of eutrophication with the minimum required parameters after setting objectives and selecting areas for the assessment. In the 'comprehensive procedure', status and possible causes of eutrophication in selected sea is assessed with the level and trend of collected parameters categorized by degree of nutrient enrichment, direct/indirect effects of nutrient enrichment and other possible effects of nutrient enrichment. This procedure can be skipped if no symptoms of eutrophication is detected at the screening procedure. In the 'results and discussion', obtained assessment results of the screening and comprehensive procedures are described in details and are reviewed by literatures. In the 'conclusion/recommendations' part, future measures and actions to be taken against eutrophication are suggested with estimates of costs and benefits, and future issues are identified on the basis of the assessment results. Figure 3 shows the overall structure of the NOWPAP Common Procedure.

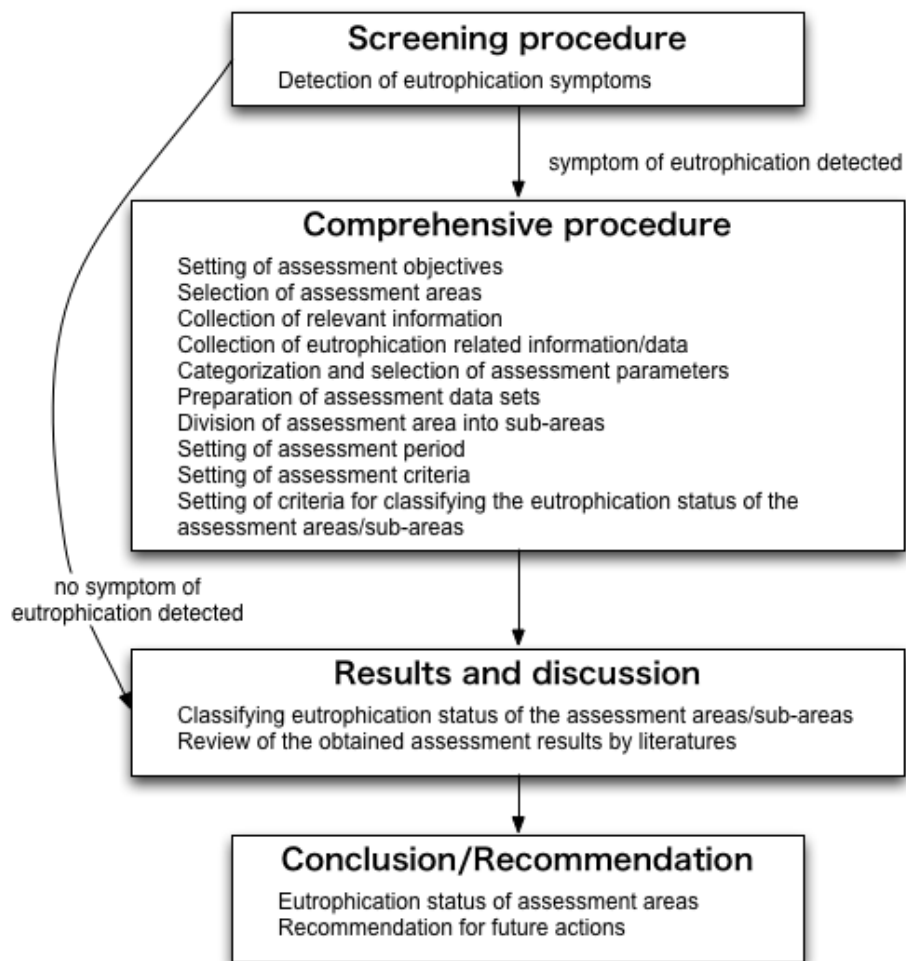


Figure 3 Overall structure of the NOWPAP Common Procedure and the flow of the eutrophication assessment.

3. Screening procedure

3-1. Detection of eutrophication symptoms*

3.1. The following minimum required parameters will be collected and analyzed to detect symptoms of eutrophication within the selected sea areas. When either one of the following three are found problematic, the comprehensive procedure should be applied to the selected sea areas.

i) Nutrients input and their residence time

Enclosed and semi-enclosed bays in each NOWPAP member state that are susceptible to eutrophication will be identified based on criteria on nutrients input and their residence time to be developed in the future.

ii) Frequencies of red tide events

One or more red tide events (diatom sp. and flagellate sp.) are recorded over the recent

three years. Information on red tide events in the NOWPAP sea areas can be referred from reports of such as organizations that monitor harmful algal blooms for protection of fishery resources, literatures and/or CEARAC HAB Integrated Website.

iii) High chlorophyll-a detected by satellite

A satellite-derived annual mean Chl-a is recorded more than 5 µg/L over the recent three years. Satellite derived Chl-a images in the NOWPAP sea area can be found at the Marine Environmental Watch web site.

*The parameters and criteria for screening procedure are proposed on a provisional basis and they will be further verified in the future based on the trial applications of the screening procedure proposed as a specific project for the 2014-2015 biennium.

4. Comprehensive procedure

4.1. If the symptoms of eutrophication is detected at the screening procedure, the comprehensive procedure should be applied to assess the status and causes of eutrophication in selected sea areas.

4-2. Setting of assessment objectives

4.2. State objectives of the assessment taking into account the assessment results in the screening procedure.

4.3. In order to facilitate the understanding of the assessment results, clarify the preconditions and limitations involved in the assessment.

4-3. Selection of assessment areas

4.4. The NOWPAP member states should select and decide the areas for applying comprehensive procedure, among the areas where the evidence of eutrophication is detected in the screening procedure, taking into account their geographic units.

4-4. Collection of relevant information

4.5. Collect information on the assessment area that is necessary and relevant to the eutrophication assessment such as: i) environmental monitoring/survey data* (e.g. Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), nutrient concentration, red tides, marine flora/fauna, shellfish poisoning); ii) pollutant sources (e.g. municipal, industrial, agricultural wastewater, marine aquaculture, atmospheric deposition); iii) supplementary information (e.g. oceanography, meteorology, catchment area population, wastewater management, fishery status, coastal recreation). The list of relevant information will be updated as further experiences are gained through the application of the NOWPAP Common Procedure.

*: Information on methodology on monitoring/survey (e.g. method of field measurement and chemical analysis) should also be collected to confirm data reliability.

4.6. Collect eutrophication related information/data from organizations such as:

- i) Organizations that monitor water quality for environmental conservation purposes
- ii) Organizations that monitor harmful algal blooms for protection of fishery resources
- iii) Organizations that monitor shellfish poisoning for food safety
- iv) Organizations that have supporting environmental information (e.g. physical biogeochemical, meteorological data, etc.

4.7. Organize the collected environmental monitoring/survey information into a tabular format. Table 1 is an example of a tabular format.

Table 1 An Example of tabular format for organizing collected environmental monitoring/survey information.

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameter	Survey frequency	No. of survey points

4.8. Select the most appropriate environmental monitoring/survey program for the eutrophication assessment.

4.9. The following environmental monitoring/survey programs should not be used in the assessment procedure:

- i) Monitoring/surveys conducted at very limited frequency that seasonal changes cannot be monitored
- ii) Programs that monitor/survey environmental parameters that are not directly related to eutrophication
- iii) Monitoring/surveys that are not conducted at regular locations and frequency
- iv) Monitoring/surveys that are not conducted for monitoring water quality and aquatic organisms
- v) Monitoring/surveys that employ uncommon analytical methods

4-5. Categorization and selection of assessment parameters

4.10. From the selected environmental monitoring/survey programs, categorize all eutrophication related parameters used in the assessment areas into the following four assessment categories:

- i) Category I Parameters that indicate the degree of nutrient enrichment
- ii) Category II Parameters that indicate direct effects of nutrient enrichment
- iii) Category III Parameters that indicate indirect effects of nutrient enrichment
- iv) Category IV Parameters that indicate other possible effects of nutrient enrichment

4.11. After the categorization process, select the assessment parameter(s) from each assessment category (Category I - IV) that are applicable in the comprehensive procedure on the basis of their data reliability and continuity (e.g. data collected at fixed locations and/or at regular frequencies). In principle, all surveyed/monitored parameters related to eutrophication should be selected in the assessment procedure. The selected assessment parameters should also have established assessment methods.

4.12. If certain parameters are to be excluded from the assessment procedure although data of the parameter is available, the reasons must be clearly stated.

4.13. Although the final selection of assessment parameters is subject to the decision of each member state, the use of the following parameters shown in Table 2 are highly recommended. The appropriateness of the selected assessment parameters should be reevaluated as further experiences are gained through the application of the NOWPAP Common Procedure.

Table 2 Recommended set of assessment parameters

Category		Assessment parameter	Units
I	Degree of nutrient enrichment	Riverine input: total nitrogen and phosphorus (T-N and T-P)	t/year
		Input from direct discharge : (T-N and T-P)	t/year
		Total nitrogen/Total phosphorus (T-N, T-P)	mg/L
		Winter dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) concentrations	mg/L
		Winter N/P ratio (DIN/DIP)	-
II	Direct effects of nutrient enrichment	Chlorophyll-a concentration (field data)	ug/L
		Red-tide events (diatom species)	event/year
		Red-tide events (flagellate species)	event/year
III	Indirect effects of nutrient enrichment	Dissolved oxygen (DO) at bottom layer	mg/L
		Abnormal fish kill incidents	event/year
		Chemical oxygen demand (COD)	mg/L
		Transparency	m
IV	Other possible effects of nutrient enrichment	Red-tide events (<i>Noctiluca</i> sp.)	event/year
		Shellfish poisoning incidents	event/year

4-6. Preparation of assessment data sets

4.14. In order to understand the inter-annual trends of eutrophication, the assessment should be conducted with data that represents changes in time series (e.g. annual mean, annual max, annual number of events, seasonal mean). However, raw data may also be used if they are considered more appropriate. It is recommended to carefully analyze raw data to make reasonable statistical analysis. Descriptions of changes in sampling and analytical methods, such as sampling number, sampling time and location, preservation, and measurement procedure, is necessary for reasonable interpretation of data.

4.15. Select monitoring/survey data to be applied for each assessment parameter taking into account the reliability and continuity of data.

4.16. Prepare data sets for each assessment parameter at all survey/monitoring sites taking into account the seasonal variation of each parameter.

4-7. Division of assessment area into sub-areas

4.17. If it is necessary to understand and assess the causes and direct/indirect effects of eutrophication at more localized scales, an assessment area may be divided into sub-areas.

4.18. When dividing an assessment area into sub-areas, factors such as the locations of riverine input and monitoring, fishery activities, underwater topography, salinity distribution, ocean currents and red-tide events should be considered. Information derived by remote sensing techniques should also be taken into account, if applicable.

4-8. Setting of assessment period

4.19. After organizing all of the collected data in chronological order, set the assessment period objectively in accordance with the assessment objectives and availability of reliable data.

4.20. In addition to the assessment period set in 4.11 above, most recent ten years should also be set as a standard assessment period for comparison with other assessment areas in the NOWPAP region.

4-9. Setting of assessment criteria

4.21. The eutrophication status of a selected assessment area is determined based on a set of assessment criteria. Detailed explanations are provided in the following sections.

4-9-1. Eutrophication identification tools and setting of criteria for each assessment parameter

4.22. The eutrophication status of each parameter is assessed by identifying its current status and/or trend by using a combination of the following three identification tools. Selection of the identification tools should be based on set identification criteria*.

*Identification criteria: Criteria for selecting the identification tools for the assessment.

i) Identification by comparison (identifying the current status): The eutrophication status is

identified by comparing the obtained assessment value (e.g. annual mean value) to reference values obtained from historical data, ecological modeling or expert judgments. This identification tool is used for assessment parameters that are expressed by concentration or ratio (e.g. N/P ratio).

ii) Identification by occurrence (identifying the current status): The eutrophication status is identified by occurrence or non-occurrence of eutrophication-related events. This identification tool is used for assessment parameters that are expressed by number or frequency of events (e.g. red tides).

iii) Identification by trend (identifying the trend): The eutrophication status is identified by identifying the trend. This identification tool is used for all assessment parameters with reasonably long time series. The Mann-Kendall test should be used to detect the trend statistically.

4.23. The rationale to set identification criteria must be stated clearly and objectively.

4-9-2. Setting of criteria for classifying the eutrophication status of assessment parameter

4.24. Apply identification tools to assess the eutrophication status of each assessment parameter.

4.25. Table 3 shows the identification tools applied to each assessment parameter as an example.

Table 3 Example of identification tools to be applied to each assessment parameter

Category	Assessment parameter	units	Assessment value	Identification tools ¹⁾			Remarks
				Comparison	Occurrence	Trend	
I	Riverine input (T-N, T-P)	t/year	Annual mean			✓	
	Input from direct discharge (T-N, T-P)	t/year	Annual mean			✓	
	Total nitrogen/Total phosphorus (T-N, T-P)	mg/L	Annual mean	✓		✓	
	Winter DIN/DIP concentration	mg/L	Winter mean	✓		✓	
	Winter N/P ratio (DIN/DIP)		Winter mean	✓		✓	
II	Chlorophyll-a concentration (field data)	ug/L	Annual max. Annual mean	✓		✓	
	Red-tide events (diatom species)	event/year	Annual occurrences		✓	✓	
	Red-tide events (flagellate species)	event/year	Annual occurrences		✓	✓	
III	Dissolved oxygen (DO) at bottom layer	mg/L	Annual minimum	✓		✓	
	Abnormal fish kill incidents	event/year	Annual occurrences		✓	✓	
	Chemical oxygen demand	mg/L	Annual mean	✓		✓	

	(COD)						
	Transparency	m	Annual mean	✓		✓	
IV	Red-tide events (<i>Noctiluca</i> sp.)	event/year	Annual occurrences		✓	✓	
	Shellfish poisoning incidents	event/year	Annual occurrences		✓	✓	

- 1) Comparison: Comparison with reference values
 Occurrences: Occurrence or non-occurrence of eutrophication-related events
 Trend: degree of increasing/decreasing

4-9-3. Setting of criteria for classifying the eutrophication status of assessment categories

4.26. Determine the eutrophication status of the assessment category (I~IV) by setting assessment category classification criteria.

4.27. Classify the eutrophication status of each assessment category by comprehensively analyzing the identification results of each assessment parameters in the category. However, if the identification results are contradictory among the assessment parameters, this assessment category can be excluded from the assessment procedure with its reasons stated.

4-10. Setting of criteria for classifying the eutrophication status of the assessment areas/sub-areas

4.28. Set assessment criteria to comprehensively assess the eutrophication status of the assessment areas/sub-areas by making a diagnosis on the classification results of each assessment parameter and category.

5. Results and discussion

5-1. Classifying the eutrophication status of the assessment areas/sub-areas

5.1. The eutrophication status of each assessment area/sub-area should be assessed on the basis of the identification results of the assessment data and classification results of each parameter and category.

5.2. Identify the eutrophication status of each monitoring site based on the set identification criteria.

5.3. Classify each assessment parameter based on the identification results of the assessment data. If there are multiple monitoring sites in each assessment area/sub-area, the identification results from all the monitoring sites should be taken into account.

5.4. Classify each assessment category based on the classification results of assessment parameters.

5.5. The eutrophication status of each area/sub-area should be assessed based on the classification results of each assessment parameter and category.

5.6. Explain diagnostically classification results of each assessment parameter and category.

5-2. Review of the obtained assessment results by literatures

5.7. The assessment report should have all necessary information required for the objective review of the assessment results.

5.8. It is recommended to review the obtained assessment results with published literatures on eutrophication in the assessment areas.

6. Conclusion and recommendations

6.1. Based on the assessment results, provide recommendations for future actions.

6.2. The results of each classification process should be clearly presented, so that policy makers etc. can consider appropriate monitoring and/or countermeasures against eutrophication.