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Application of the NOWPAP Common Procedure for Eutrophication Assessment in Selected Sea Areas in the NOWPAP Region

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Preface

The Northwest Pacific region includes parts of northeast China, Japan, Korea and Russian Far East. It is one of the most densely populated areas in the world, and its coastal environment is subject to significant human-induced nutrient inputs. A large number of red tides and hypoxic conditions have been reported in the coastal waters, possibly resulting from anthropogenic activities, such as the use of chemical fertilizers and the discharge of sewage. Eutrophication is an emerging environmental problem in the region. Although there is no international legislation addressing these issues, the Northwest Pacific Action Plan (NOWPAP), under the United Nations Environment Programme (UNEP), was established by China, Japan, Korea and Russia in 1994 with focus on the conservation of the marine and coastal environment in the region. Within the NOWPAP framework, the Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC) developed the NOWPAP Common Procedure, a methodology for the assessment of eutrophication status including the evaluation of land-based sources of nutrients in the NOWPAP region (NOWPAP CEARAC, 2009). To apply and evaluate the suitability of the NOWPAP Common Procedure, member states conducted case studies to assess eutrophication status in selected sea areas based on that methodology. In 2011, the results of these case studies were combined and published as "Integrated Report on Eutrophication Assessment in Selected Sea Areas in the NOWPAP Region: Evaluation of the NOWPAP Common Procedure".

Realizing the technical problems of the NOWPAP Common Procedure in its first application to the selected sea areas, the NOWPAP Common Procedure was refined and applied to each selected sea area in 2012-2013, except Changjiang River Esutary and its adjacent area in China: Jiaozhou Bay was newly selected instead. This report presents the results of eutrophication assessment in selected sea areas in the NOWPAP region based on the refined NOWPAP Common Procedure.

These studies have indirectly resulted in an interim classification of the eutrophication status in the selected sea areas, but should not be interpreted as a NOWPAP eutrophication assessment authorized by the NOWPAP member states, their provinces, prefectures or cities. Nevertheless, we hope that this report will provide a basis for discussions that will lead to the development of a unified approach to eutrophication assessment that can be used to determine the eutrophication status of the entire NOWPAP sea area and contribute to the improvement of water quality in coastal and open sea areas in the region.

The CEARAC Secretariat would like to thank the CEARAC Focal Points and the experts of case studies on eutrophication assessment in each selected sea area for their great contribution to this report.

Kazuya Kumagai
CEARAC Director

Executive summary

Almost half of the world's population lives within 100 km from a coastline. Anthropogenic activities have led to nutrient enrichment, particularly nitrogen and phosphorus, which enter sea areas through domestic and industrial wastewaters and agricultural runoff. Such nutrient enrichment can degrade marine ecosystems by eutrophication. Eutrophication often negatively impacts the marine environment by increasing red tide occurrences, by the mortality of benthos, fish and shellfish due to hypoxia and anoxia. Eutrophication is becoming a serious problem in some highly populated coastal areas within the NOWPAP region.

Due to these concerns, a decision was made to assess the status of eutrophication using a common procedure throughout the NOWPAP member states. In 2009, procedures for the assessment of eutrophication status for the NOWPAP region (the NOWPAP Common Procedure), including an evaluation of land-based sources of nutrients, was developed by the Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC). First case studies of the assessment of the eutrophication status using the NOWPAP Common Procedure were conducted in selected sea areas by experts nominated from each NOWPAP member state in 2010-2011. The NOWPAP Common Procedure was then refined (Annex C) and second case studies were conducted with the refined NOWPAP Common Procedure in 2012-2013. Rapid review of literature related to negative impacts of eutrophication and ecological modeling (Annex A) and search for available monitoring data for eutrophication assessment in each NOWPAP member state (Annex B) were also carried out by the nominated national experts.

In the refined NOWPAP Common Procedure, two steps were suggested: Screening Procedure (initial diagnosis) to detect symptoms of eutrophication with the minimum required parameters; and Comprehensive Procedure (second diagnosis) to assess the status and possible causes of eutrophication using parameters categorized by (I) degree of nutrient enrichment, (II) direct effects of nutrient enrichment, (III) indirect effects of nutrient enrichment, and (IV) other possible effects of nutrient enrichment.

This report is compiled from the case study results in each selected sea area (Annex D); Jiazhou Bay, China; Jinhae Bay, Korea; North Kyushu sea area and Toyama Bay, Japan; and the Peter the Great Bay, Russia. Case studies to assess the eutrophication status in the selected sea areas were conducted using the refined NOWPAP Common Procedure. Application of the screening procedure including use of satellite data was useful to detect symptoms of eutrophication within the selected sea areas. Combined use of the screening and comprehensive procedures was still necessary in some case studies to validate assessment results obtained by the screening procedure in the selected sea area. Newly added parameters such as dissolved oxygen (DO) at the bottom layer and transparency in the comprehensive procedure as recommended parameters improved the reliability of the assessment results. Setting common assessment values for DO at the bottom layer and chlorophyll-*a* (Chl-*a*) was suggested. A necessity to unify statistical methods to detect long-term trends was also acknowledged.

Although it is expected that the eutrophication status of the entire NOWPAP sea area will be assessed in the long run, application of the refined NOWPAP Common Procedure to the entire NOWPAP sea area may require extensive efforts in collecting and analyzing monitoring data, and it may not be fully carried out due to lack of data and resources. Therefore, trial application of the screening procedure for the whole NOWPAP region with limited parameters can be suggested as a next step. Enhancing autonomous use of the comprehensive procedure is also encouraged to help plan management actions against eutrophication in the member states.

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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 loading caused by overpopulation, run-off from industries or agricultural activities can lead to eutrophication. Eutrophication affects the marine environment in various ways. Phytoplankton grows 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, fisheries, and aquaculture by killing fish. As algal biomass decomposes, microbial processes consume the oxygen in the water, and hypoxia or anoxia can occur at the bottom of the oceans (Diaz and Rosenberg, 1995; Diaz, 2001). Hypoxic or anoxic water masses have negative effects on benthic organisms, often leading to the degradation of biodiversity in the sea.

Eutrophication was originally considered a local concern, but is now understood to be a regional and global environmental issue (Andersen and Conley, 2009). It is closely linked with increase in human population, expansion of urban areas, use of fertilizers, release of atmospheric emissions and the deposition of nitrogen, and changes in land use. Global warming can also accelerate eutrophication. Increase in water temperatures can lead to more frequent red tide events, as well as a strengthening of thermal stratification and possible acceleration of the formation of hypoxic or anoxic water masses at the bottom of the sea.

While excessive nutrient loading can result in eutrophication, the lack of nutrients can result in oligotrophication and a decrease in productivity. It is necessary to maintain an appropriate supply of nutrients to the marine ecosystem to support sustainable biological productivity (Yamamoto, 2003). Developed countries have experienced oligotrophication as the result of excessive nutrient removal by advanced sewage water treatment systems, which are not viewed favorably for sea-based alimentary products such as *Nori* (edible seaweed) aquaculture. It is therefore necessary to develop and promote a regional river basin management system to discharge appropriate amounts of nutrients for the maintenance of healthy marine ecosystems (Yanagi, 2007).

In the Northwest Pacific region, where the coastal areas of China, Japan, Korea and Russia are densely populated, eutrophication is recognized as a potential threat to coastal environments. Evidence of eutrophication can be seen in frequent occurrences of red tide (Fukuyo *et al.*, 2002; GEOHAB, 2006; NOWPAP CEARAC 2005, 2007; Miyahara *et al*., 2005; Onitsuka *et al*., 2010), the abundance of the giant jellyfish, *Nemopilema nomurai* (Kawahara *et al*., 2006; Uye, 2008; Dong, 2010), massive green tides (Hu *et al*., 2010; Liu *et al*., 2010), hypoxia or anoxia (Chen *et al*., 2007), changes in phytoplankton communities (Chen, 2000; Harashima, 2007) and loss of marine biodiversity (NOWPAP 2010). Although monitoring or management actions against eutrophication have been taken by each NOWPAP member state in accord with existing policies (NOWPAP CEARAC, 2011), collaborative monitoring of marine environments beyond national boundaries is still to be implemented. Nevertheless, due to increased agricultural and industrial activities, as well as probable changes in coastal run-off, there has been an increasing need for effective methods of assessing regional changes in water quality.

The Northwest Pacific Action Plan (NOWPAP) was adopted in 1994 by the People's Republic of China, Japan, the Republic of Korea, and the Russian Federation. It is a part of the United Nations Environment Programme (UNEP) Regional Seas Programme (RSP) launched in 1974 in the wake of the 1972 United Nations Conference on the Human Environment held in Stockholm, Sweden. The RSP aims to address the accelerating degradation of the world's oceans and coastal areas through sustainable management and use of marine and coastal environments. Today, more than 143 countries participate in 13 regional programs established under the auspices of UNEP.

In order to evaluate eutrophication, many assessment tools and methodologies have been developed. Well known examples include the Oslo-Paris Conventions for the Protection of the North Sea Comprehensive Procedures (OSPAR Commission, 2003), the Eutrophication Assessment Tool of Helsinki Commission (HELCOM, 2006), the National Oceanic and Atmospheric Administration's National Estuarine Eutrophication Assessment (Bricker *et al*., 1999) and the Assessment of Estuarine Trophic Status (Bricker *et al*., 2003). Eutrophication assessments have been conducted using each of these tools or methodologies, and assessment results have been published by their respective bodies (OSPAR Commission, 2008; HELCOM, 2009; Bricker *et al*., 2007; Wu *et al*., 2013).

Within the NOWPAP framework, the Special Monitoring & Coastal Environmental Assessment Regional Activity Centre (CEARAC) developed the NOWPAP Common Procedure (NOWPAP CEARAC, 2009). The NOWPAP member states have applied the NOWPAP Common Procedure to selected sea areas in each country, and evaluated the suitability of the methodology to the assessment of eutrophication status. The selected sea areas were the Changjiang (Yangtze) River Estuary and its adjacent area in China, the North Kyushu sea area and Toyama Bay in Japan, Jinhae Bay in Korea, and Peter the Great Bay in Russia. The aim of the assessments was to obtain results that would provide material for discussion in order to limit, or, if possible, mitigate anthropogenic eutrophication in the region.

When technical problems with the NOWPAP Common Procedure emerged during its application to the selected sea areas in the 2010-2011 biennium (NOWPAP CEARAC, 2011), CEARAC proposed refinement of the NOWPAP Common Procedure as one of the CEARAC activities for the 2012-2013 biennium at the 9th CEARAC Focal Points Meeting (FPM) in Toyama, Japan (September 6-7, 2011). The CEARAC work plan, including refinement of the NOWPAP Common Procedure, was then approved by the member states at the 16th Intergovernmental Meeting of NOWPAP (Beijing, China, December 20-22, 2011).

This report presents the assessment results of the eutrophication status in the selected sea areas of each NOWPAP member state based on the refined NOWPAP Common Procedure (Annex C).

2 Assessment methods and data

2.1 Refinement of the NOWPAP Common Procedure

Initial eutrophication assessments with the NOWPAP Common Procedure in selected sea areas of the NOWPAP member states (CEARAC 2011) revealed technical problems of the NOWPAP Common Procedure such as differences in temporal and spatial scales of assessment parameters and the criteria for classifying assessment categories and reference values. Following identification of these technical problems came work to refine the NOWPAP Common Procedure for eutrophication assessment to improve its suitability towards the assessment of the eutrophication status of the whole NOWPAP region. National experts nominated by each member state were then requested to provide comments and suggestions for refinement of the NOWPAP Common Procedure. Taking into account the received comments and suggestions from national experts, the refined NOWPAP Common Procedure was separated into two steps: "screening procedure" to preliminarily assess eutrophication by detecting symptoms of eutrophication within minimum parameters and "comprehensive procedure" to assess status and possible causes of eutrophication.

The screening procedure includes three parameters proposed for collection and analysis to detect symptoms of eutrophication. When any one of the following three are found problematic, the comprehensive procedure should be subsequently applied.

i) Nutrients input and residence times

Identifying enclosed or semi-enclosed bays in each NOWPAP member state that are susceptible to eutrophication using criteria on nutrients input and residence time, to be developed in the future.

ii) Frequencies of red tide events

Identifying spots where one or more red tide events (diatom species and flagellate species) have been recorded over the recent three years. Information on red tide events in the NOWPAP sea area can be found in reports of organizations that monitor harmful algal blooms for protection of fishery resources, literature and/or the CEARAC HAB Integrated Website.

iii) High chlorophyll-*a* (Chl-*a*) detected by satellite

Identifying high Chl-*a* area with satellite-derived Chl-*a* with the reference value of 5 μg/L in average in 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 the screening procedure are proposed on a provisional basis, to be further verified in the future based on the trial applications of the screening procedure as a specific project for the 2014-2015 biennium.

The comprehensive procedure requires collection of information and data in line with the following four categories of water quality parameters considering degree and effects of nutrient enrichment: (1) degree; (2) direct effects; (3) indirect effects; and (4) other possible effects (Table 2.1).

Table 2.1 Assessment categories for water quality parameters

Category I	Parameters that indicate degree of nutrient enrichment
Category II	Parameters that indicate direct effects of nutrient enrichment
Category III	Parameters that indicate indirect effects of nutrient enrichment
Category IV	Parameters that indicate other possible effects of nutrient enrichment

This category based assessment of eutrophication gives a comprehensive overview of the status and causes of eutrophication within the assessment area, and helps in selecting countermeasures for the mitigation of eutrophication.

2.2 Eutrophication classification with the use of the NOWPAP Common Procedure

Based on the NOWPAP Common Procedure, water quality parameter data relating to eutrophication was collected and organized into four assessment categories by degree and effects of nutrient enrichment: (1) degree; (2) direct effects; (3) indirect effects; and (4) other possible effects (Table 2.1). The collected information and data were assessed by the level of concentration or number of occurrences of an event, and trends (increasing, decreasing or no change). By assessing the combination of the level and trend, the eutrophication status was classified into one of six categories: High-Increase (HI); High-No Trend (HN); High-Decrease (HD); Low-Increase (LI); Low-No trend (LN); and Low-Decrease (LD) (Fig. 2.1). High or Low eutrophication level was determined using a reference value set for each selected sea area. The level of eutrophication for dissolved oxygen (DO) was determined in reverse to other parameters, since healthy marine environments are usually associated with high DO concentrations. Therefore the eutrophication level of DO was rated as 'Low' when the DO values were above the reference value, and 'High' when the DO values were below the reference value. In China and Japan, trends were identified using the non-parametric Mann-Kendall test (Salmi *et al*., 2002) for the time series data, whereas Korea did not apply statistical methods, and Russia followed parametric methods.

A unique feature of the NOWPAP Common Procedure is that both the level and trend assessment parameters are used to assess the eutrophication status. This is because simply looking at either the level or trend individually does not help properly assess phenomena related to changes in eutrophication over the long term. Only considering the levels of some parameters could lead to missing low eutrophication levels about to develop into high eutrophication levels. In contrast, only considering the trends of parameters will not provide information on areas needing immediate management actions. Thus, the six eutrophication classifications of the NOWPAP Common Procedure enable the planning of comprehensive management actions to address eutrophication.

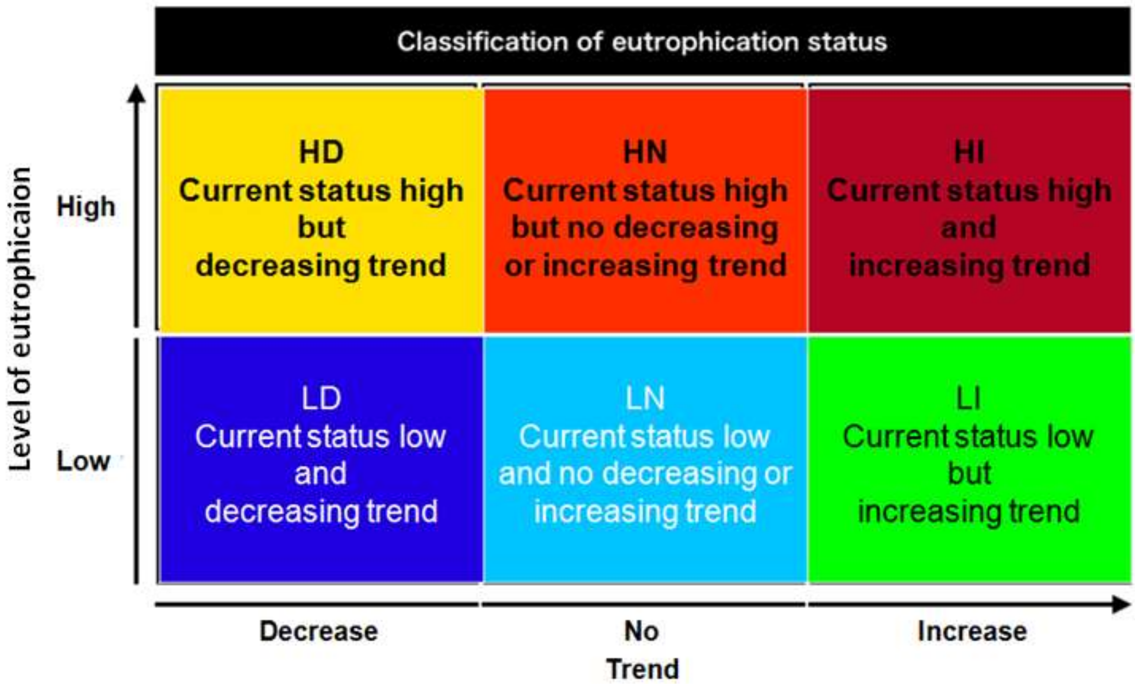

Fig. 2.1 The six classifications of eutrophication status in the NOWPAP Common Procedure, determined using a combination of the level of eutrophication and the trend of assessment parameters.

2.3 Selection of target sea areas in the NOWPAP member states

Target sea areas to test the suitability of the NOWPAP Common Procedure were defined in the 9th CEARAC Focal Points Meeting in Toyama. Jiaozhou Bay in China, the North Kyushu sea area and Toyama Bay in Japan, Jinhae Bay in Korea and Peter the Great Bay in Russia were the selected target sea areas (Fig. 2.2).

Fig. 2.2 Location of selected sea areas for case studies

2.3.1 Jiaozhou Bay in China

Jiaozhou Bay in Qingdao, is a semi-enclosed bay in the northern part of China's Yellow Sea. It is characterized by temperate waters, and is thus ice-free year round with a temperature range from 2 ℃ (minimum) in winter to 28 ℃ (maximum) in summer. The salinity is around 32 psu. A few rivers flow into the bay with a discharge of about 2×10^9 m^3/a. Jiaozhou Bay covers an area of about 390 km^2 with an average depth of 7 m, and is connected to the Yellow Sea via a narrow conduit (2.5 km). The narrow mouth gives Jiaozhou Bay an average water exchange time of about 52 days.

According to the differences in the geographical characteristics of Jiaozhou Bay and in water exchange capability (Liu, 2004), the area was sub-divided into three sub-areas (Fig. 2.3). Sub-area A represents inner Jiaozhou Bay, which has an average water exchange time of 50 days and is influenced by a large amount of riverine nutrient load. Sub-area B is the mouth of Jiaozhou Bay, which includes the narrow opening and has a shorter water exchange time of about 10 days. Sub-area C is outside Jiaozhou Bay proper and is near the coastal area of the northern Yellow Sea. Although sub-area C is not actually a part of Jiaozhou Bay, it is adjacent to it and thus, its eutrophication status was included to fully recognize the trophic status of Jiaozhou Bay. Sampling sites 1 to 7 are located in sub-area A, while sites 8 and 9 are in sub-area B; sites 10, 12, 13 are located in sub-area C.

Fig. 2.3 Map of Jiaozhou Bay and its adjacent area in China

2.3.2 North Kyushu sea area in Japan

The North Kyushu sea area was set for this case study as the sea area mainly around Fukuoka Prefecture, from the Kanmon Strait in the East to Itoshima Peninsula in the West and up to about 40km offshore. This area includes the coastal zone from Hakata Bay to Dokai Bay. Hakata Bay is adjacent to Fukuoka City, which has a population of 1.45 million. Dokai Bay is adjacent to Kitakyushu City, which has a population of 0.98 million and includes the Kitakyushu industrial zone (Fig. 2.4). Both bays have been affected by eutrophication induced by nutrient loads from anthropogenic sources. In order to restore the ecosystem in Hakata Bay, Fukuoka City developed a Hakata Bay Environmental Conservation Plan, and is implementing various environmental projects. Kitakyushu City is also actively involved in various environmental improvement projects for Dokai Bay. The water quality of both bays has improved significantly since the 1960s and 70s.

Affected by the Tsushima Current, this area is also susceptible to changes in the marine environment in the East China Sea and the Yellow Sea.

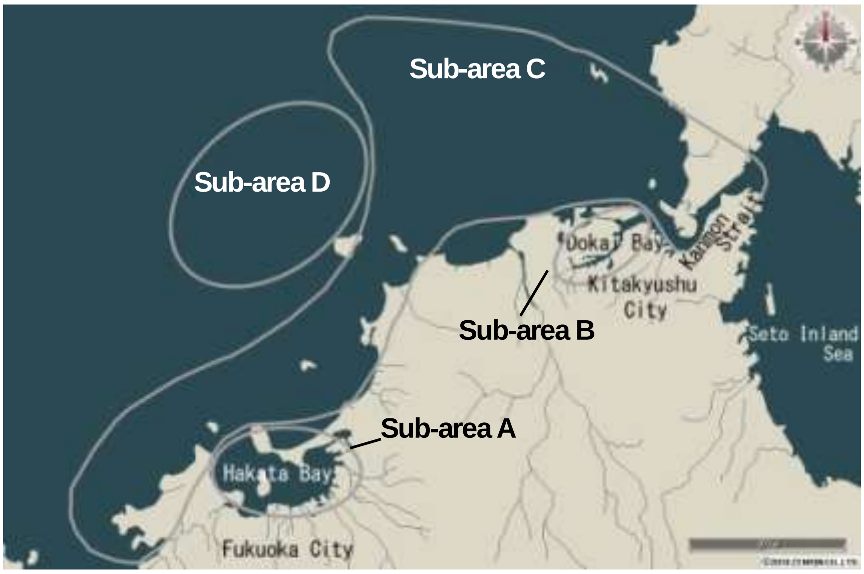

Fig. 2.4 Map of the North Kyushu sea area, Japan

Taking into account the geographical characteristics of the North Kyushu sea area and the distribution of remotely sensed Chl-*a* reported in the 2010-2011 biennium case study (CEARAC 2011), the North Kyushu sea area was divided into four sub-areas: A (Hakata Bay), B (Dokai Bay), C (intermediate area: area with low Chl-*a* concentration (<5 µg/L) but increasing trend) and D (offshore area: area with low Chl-*a* concentration but no trend). Fig. 2.4 shows the boundary of each sub-area. The Kanmon Strait which was part of Sub-Area B with Dokai bay in the 2011 CEARAC, was included as part of the intermediate area (sub-area C) for this report.

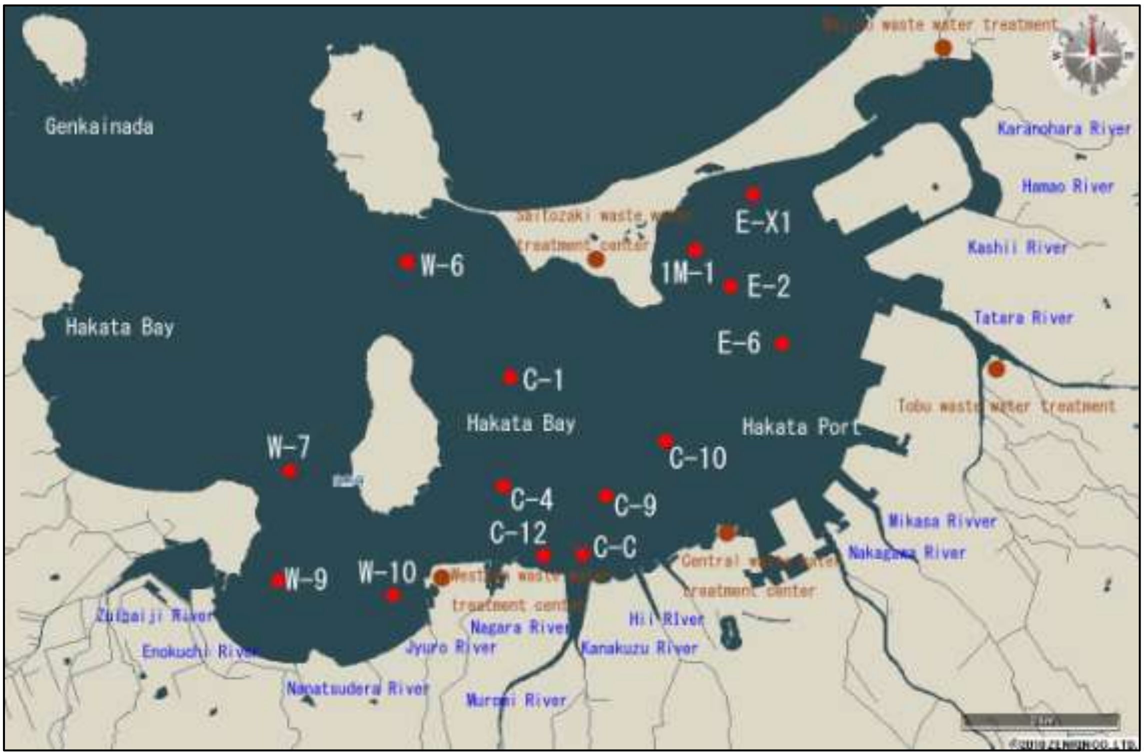

Fig. 2.5 Sub-area A (Hakata Bay) of the North Kyushu sea area

Fig. 2.6 Sub-area B (Dokai Bay) of the North Kyushu sea area

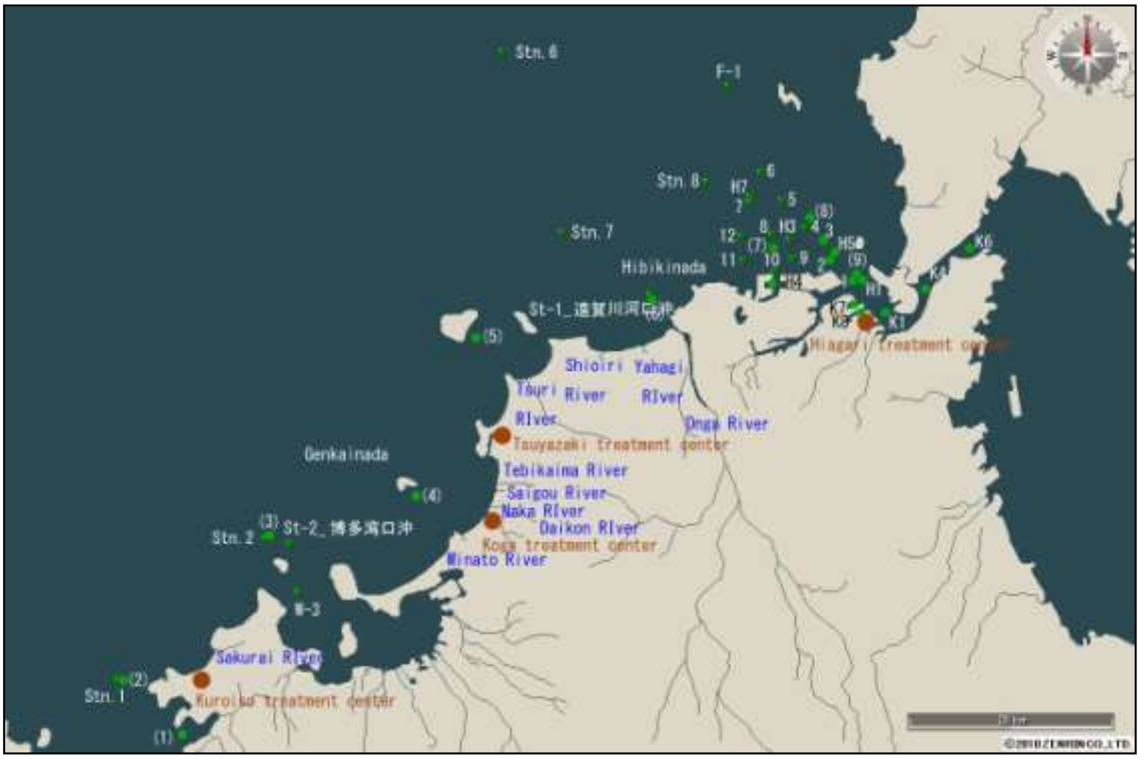

Fig. 2.7　Sub-area C (intermediate area) of the North Kyushu sea area

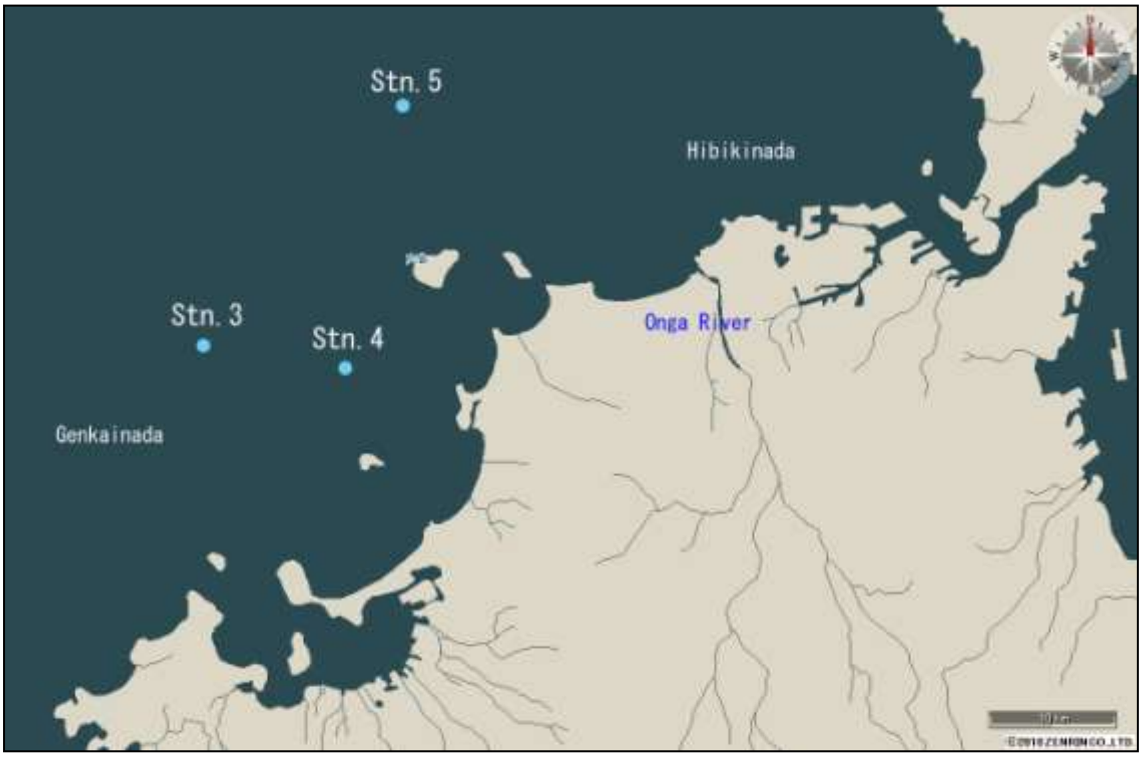

Fig. 2.8　Sub-area D (offshore area) of the North Kyushu sea area

2.3.3 Toyama Bay in Japan

Toyama Bay is fed by five Class A rivers, waterways of special importance protected by the national government, as well as by other small rivers (Fig. 2.9). The Class A rivers account for 77 % of the total river discharge into the bay (Toyama Bay Water Quality Conservation Research Committee, 2001). The daily average discharge of these rivers are: Oyabe River 46.65 m^3/s; Shou River 21.10 m^3/s; Jinzu River 147.17 m^3/s; Joganji River 16.30 m^3/s; and Kurobe River 32.48 m^3/s. The average daily discharge from these five rivers totals 263.44 m^3/s. River-based nutrients are supplied to the surface water of the bay. Nutrient loading in the river water is both natural and anthropogenic, the latter originating from sources such as industrial, domestic, and livestock activities. In terms of nutrient loading, the coastal environment of Toyama Bay has been influenced strongly by class-A rivers, particularly by the Oyabe and Jinzu rivers. In this area, phytoplankton blooms increase in summer, leading to an increase in chemical oxygen demand (COD). In order to improve the coastal environment in Toyama Bay, it is essential to understand the nutrient loading from rivers, the nutrient concentration in the sea area, and the biochemical reaction caused by nutrients.

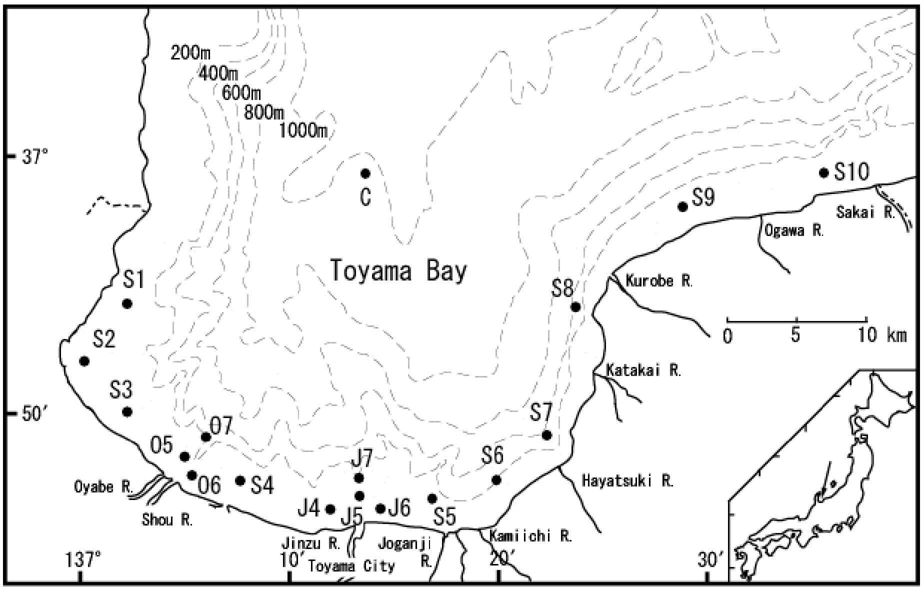

Fig. 2.9 Map of Toyama Bay in Japan

In line with the screening procedure, the eutrophication status in Toyama Bay was preliminarily assessed by detecting symptoms of eutrophication with the minimum required parameter: nutrient data and their residence time, frequency of red tide (diatom species and flagellate species) events, and high Chl-*a* detected by satellite. Nutrient data showed higher concentrations in the Oyabe and the Jinzu River basins (Kawasaki, 1985). No red tide events of diatom species and flagellate species had been recorded in Toyama Bay over the recent three years (2007 to 2009). High average Chl-*a* (> 5 μg/L) levels were detected in the Toyama Bay coastal area in the recent three years (2007 to 2009) by satellite derived Chl-*a* (Satellite Chl-*a*) data of Moderate Resolution Imaging Spectoradiometer on board the Aqua satellite (Fig. 2.10). Toyama Bay coastal areas which showed high satellite Chl-*a* and high concentration of nutrients were chosen as assessment areas for the comprehensive procedure.

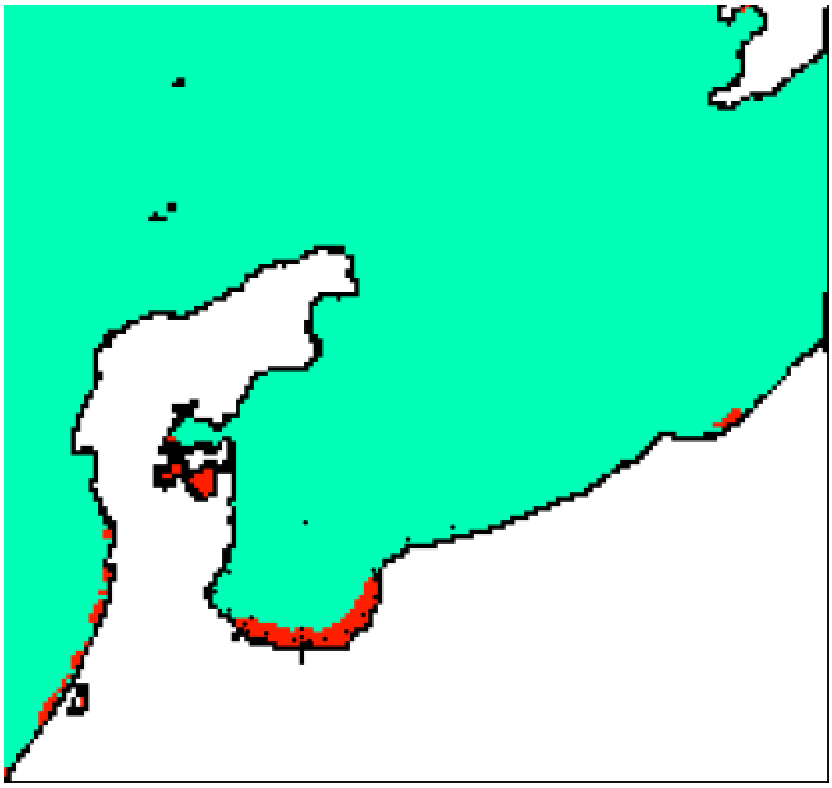

Fig. 2.10 High Chl-*a* areas detected by satellite
Black dots indicate water sampling stations by the Toyama Prefectural Government.

2.3.4 Jinhae Bay in Korea

Jinhae Bay, located in the southeastern part of Korea, was selected to be a target area for eutrophication assessment because it is within the NOWPAP geographic scope. Moreover, Jinhae Bay and its adjacent waters have been the most highly eutrophic sea area in Korea with a high frequency of red tide and hypoxia particularly during summer season, since the 1970s. Therefore, on the whole Jinhae Bay is a typical water body suitable for eutrophication assessment in Korea.

Based on the geographic and oceanographic characteristics including sea water exchanges of Jinhae Bay, two sub-areas were set for this report. Sub-area A represents inner Jinhae Bay that has relatively good sea water circulation (30-40 cm/s) (Oh *et al*, 2006) and includes several small bays such as the Jindong, Goseong, Wonmoon and Gohyun Bays. Sub-area B is the innermost part of Jinhae Bay, including Masan-Haengam Bay for which the sea surface shows a relatively calm flow (20-30 cm/s) due to their shallow water depth and unique features of a semi-closed embayment compared to sub-area A (Fig. 2.11). Nine and five sampling sites are located in sub-area A and sub-area B, respectively.

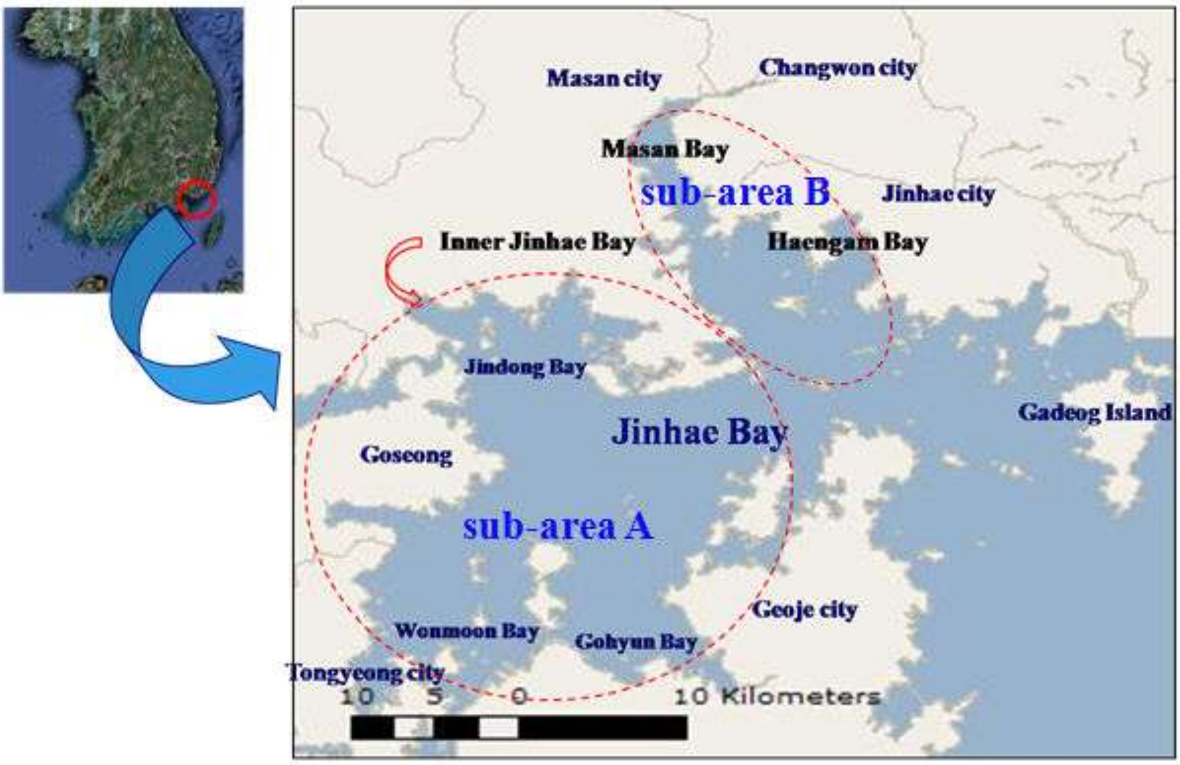

Fig. 2.11 Map of Jinhae Bay in Korea

2.3.5 Peter the Great Bay in Russia

Peter the Great Bay is situated in Far Eastern Russia. From the open sea, the boundary of the bay is drawn by connecting two points, one at the mouth of the western side of the Tumannaya River, and the other on the eastern side of the Povorotnij Cape (Fig. 2.12). The distance between these two points is about 200 km and the distance of the coastline around the bay is about 1,500 km. The total area of Peter the Great Bay is about 9,500 km^2. The bay contains about 500 km^3 of water. The Muravyov-Amursky Peninsula and a group of islands (Russky Island, Popov Island, Rejnike Island and other small islands) divide Peter the Great Bay into Amursky Bay (western part) and Ussuriisky Bay (eastern part). Vladivostok is the largest city in the Primorye Krai and it is situated on the coast of Amursky Bay and Ussuriisky Bay. It has a population of about 630,000. The main anthropogenic pressure on Peter the Great Bay is from inputs from the Razdolnaya River and the wastewaters of Vladivostok City. Within Peter the Great Bay, Amursky Bay has large rivers, such as the Razdolnaya River, and several small rivers including the Amba, Barabashevka and Narva. They discharge about 3.26 km^3/year of river water to Amursky Bay. Ussuriisky Bay has several small rivers, such as the Artemovka, Shkotovka, Sukhodol and Petrovka rivers, from which the bay receives river water input of 1.3 km^3/year. The eastern part of Peter the Great Bay is attached to Nakhodka City and several small rivers, including the Partizanskaya River that flows into the sea. The southern part of Peter the Great Bay receives an input of 1.35 km^3/year of river water.

For this assessment, Peter the Great Bay was divided into three sub-areas (Table 2.2), based on exisiting geographical boundaries and river inputs.

Table 2.2 Sub-areas in Peter the Great Bay

Sub-area A (Amursky Bay)	Amursky Bay is situated west of Vladivostok. The Razdolnaya River flows into the northern part of the bay. Anthropogenic pressure is highest among the three sub-areas. In winter, the northern half of sub-area A is covered with ice for about three months.
Sub-area B (Ussuriisky Bay)	An open basin located in the northeastern part of Peter the Great Bay. During winter, ice formations occur.
Sub-area C (Southern part of Peter the Great Bay)	An area of about 6,400 km^2. Depth varies from 0-150 m, with an average of about 70 m. In this sub-area, the biggest town is Nakhodka, with a population of about 180,000. The total population in this sub-area is about 200,000. Small rivers flow into this sub-area. The most distinctive feature of this sub-area is the intense exchange between the shelf water of the bay and the deep water of the sea via the down welling and upwelling processes along the steep slope.

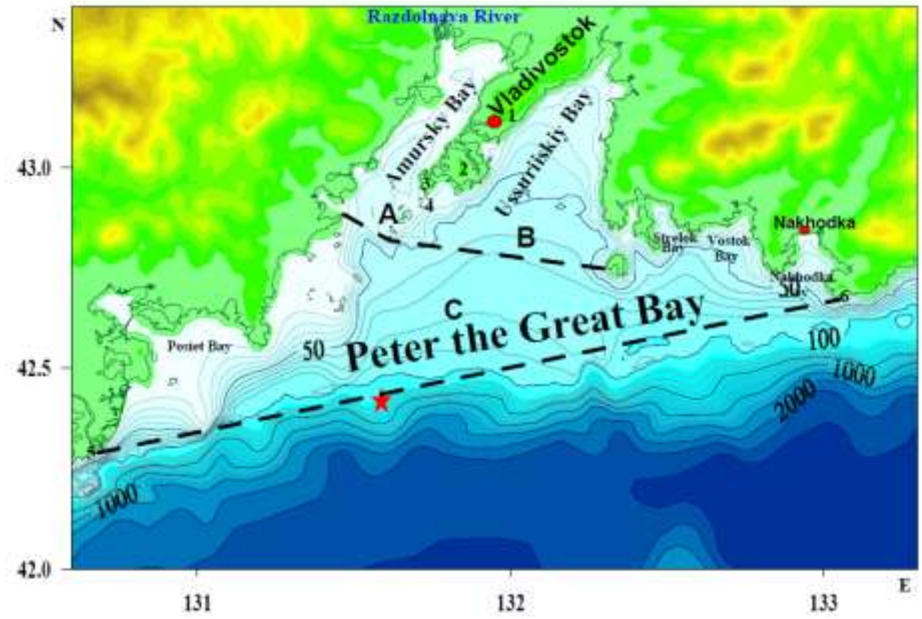

Fig. 2.12 Map of Peter the Great Bay in Russia

2.4 Data and parameters used in each selected sea area

An assessment of the eutrophication status was conducted in the selected sea areas of China, Japan, Korea and Russia. Table 2.3 lists the parameters of the four categories used in this assessment.

In Category I, all of the member states selected riverine input of total nitrogen (TN) and total phosphorus (TP) as assessment parameters. However, from 1995 to 1996, limited TN and TP input data were available for Jinhae Bay in Korea. DIN and DIP riverine input data for Jiaozhou Bay in China were available for the late 1980s, 1999, 2001, 2005, and 2008 through published research papers. In the North Kyushu sea area in Japan, the trend of TN and TP released from sewage treatment plants was used. For Peter the Great Bay in Russia, data on DIN, DIP, dissolved silicic acid (DSi), chemical oxygen demand by potassium dichromate (COD_{Cr}), suspended substance (SS) and Biochemical Oxygen Demand (BOD_5) inputs from rivers and sewage plants were used. China, Japan and Korea used monitoring data on TN and TP concentrations in the sea areas, whereas Russia did not. DIN, DIP and DIN/DIP ratio were common parameters for all of the member states; however, Japan and Korea used only winter data, whereas China and Russia used annual means.

For Category II, all of the member states used the annual mean Chl-*a* as a parameter. In addition, China, Japan and Korea used the annual maximum of Chl-*a*. In Korea, the ratio of areas with high Chl-*a* to the total area was used as a parameter. Regarding red tides, the number of occurrences was used in China, Japan and Korea. With the exception of Peter the Great Bay, red tide events were divided into two taxonomic groups: diatom species and flagellate species.

In Category III, all of the member states selected Dissolved Oxygen (DO) as a common parameter. DO at bottom layer was used in Jiazhou Bay, North Kyushu sea area, Jinhae Bay, and Peter the Great Bay. Toyama Bay in Japan used surface layer DO. Moreover, China used the annual mean of DO, Japan and Korea used the annual minimum, and Russia used both the annual mean and minimum. Fish kill incidents were used in all of the member states. Annual mean COD was also used as a parameter in China, Japan and Korea, but not in Russia. Additionally the trend of transparency was used in North Kyushu sea area in Japan.

In category IV, China, Japan and Korea used the red tide events of *Noctiluca* sp. and shellfish poisoning incidents as assessment parameters, whereas Russia used effects on benthic fauna and flora.

Table 2.3 Parameters used in the NOWPAP member states

Categories	Assessment parameters	Jiaozhou Bay, China	North Kyushu sea area, Japan	Toyama Bay, Japan	Jinhae Bay, Korea	Peter the Great Bay, Russia
Ⅰ	Riverine input of TN[1]		✓	✓	✓	
	Riverine input of TP[2]		✓	✓	✓	
	Riverine input of DIN[3]	✓				✓
	Riverine input of DIP[4]	✓				✓
	Input from direct discharge of TN		✓	✓		
	Input from direct discharge of TP		✓	✓		
	TN concentration	✓	✓	✓	✓	
	TP concentration	✓	✓	✓	✓	
	Winter DIN concentration		✓	✓	✓	
	Winter DIP concentration		✓	✓	✓	
	Winter DIN/DIP ratio		✓	✓	✓	
	Annual mean DIN concentration	✓				✓
	Annual mean DIP concentration	✓				✓
	Annual mean DSi[5] concentration					✓
	Annual mean DIN/DIP ratio	✓				✓
Ⅱ	Annual maximum of chlorophyll-*a*	✓	✓	✓	✓	✓
	Annual mean of chlorophyll-*a*	✓	✓	✓	✓	✓
	Red tide events (diatom species)	✓	✓	✓	✓	
	Red tide events (flagellate species)	✓	✓	✓	✓	
Ⅲ	Annual minimum DO[6] (surface)			✓		
	Annual minimum DO (bottom)		✓		✓	✓
	Annual mean DO (surface)					
	Annual mean DO (bottom)	✓				✓
	Fish kill incidents	✓	✓	✓	✓	
	Annual mean COD[7]	✓	✓	✓	✓	
	Transparency		✓			
Ⅳ	Red tide events (*Noctiluca* sp.)	✓	✓	✓	✓	
	Red tide events (*Mesodinium* sp.)	✓			✓	
	Shell fish poisoning incidents	✓	✓	✓	✓	
	Fish kill incidents					✓
	Benthic fauna and flora					✓

1) TN: total nitrogen

2) TP: total phosphorus

3) DIN: dissolved inorganic nitrogen

4) DIP: dissolved inorganic phosphate

5) DSi: dissolved silicic acid

6) DO: dissolved oxygen

7) COD: chemical oxygen demand

2.5 Reference values used in selected sea areas

Basic information on assessment parameters and their national standards in NOWPAP member states are included in NOWPAP CEARAC (2011). Therefore, reference values used in selected sea areas are mentioned in this report.

2.5.1 Jiaozhou Bay in China

In this study, the National Seawater Quality Standard of China (NSQS, 1997) Class II was selected as criteria for each parameter as it was suitable for aquaculture water bodies. Jiaozhou Bay is important for shell fish aquaculture and a fairly large part of the bay is covered by aquaculture farms. For TN and TP, no threshold values were assigned in NSQS (1997), and these criteria were set based on Japan environmental water quality standard Type III and Fishery Type 2. For Chl-*a* and DO, several studies on Jiaozhou Bay and Chinese coastal eutrophication assessment (Chen *et al*., 2007; Yao *et al*., 2007; Su *et al*., 2008; Xia *et al*., 2012) and some international studies (Bricker *et al*., 2003) were referenced. Therefore, 0.3 mg l^{-1} for DIN (21.4 μM), 0.03 mg l^{-1} for DIP (0.97 μM), 0.6 mg l^{-1} for TN, 0.05 mg l^{-1} for TP, 20 μg l^{-1} for maximum of Chl-*a*, 5 μg l^{-1} for mean of Chl-*a*, 2 mg l^{-1} for bottom DO, and 3 mg l^{-1} for COD were used as criteria of the assessment (Table 2.4). As for DIN/DIP ratio, the Redfield value of 16 was used in this study. Red tide events, fish kill incidents and shell fish poisoning incidents were rated as High or Low based on the occurrence of one or more incident, or no incident in the recent three years, respectively. This was based on the criteria employed in Toyama Bay in the 2011 CEARAC report (NOWPAP CEARAC, 2011).

Table 2.4 Reference values used in Jiaozhou Bay in China

Categories	Assessment parameters	Reference value	Reference
I	TN concentration	0.6 mg/L (42.9 μM)	Japan Fishery type 2
	TP concentration	0.05 mg/L (1.61 μM)	Japan Fishery type 2
	DIN concentration	0.3 mg/L (21.4 μM)	NSQS Class II
	DIP concentration	0.03 mg/L (0.97 μM)	NSQS Class II
	DIN/DIP ratio	16	Redfield ratio
Ⅱ	Maximum of chlorophyll-*a*	20 μg/L	Bricker et al., 2003
	Mean of chlorophyll-*a*	5 μg/L	Yao et al., 2007; Xia et al., 2012
	Red tide events (diatom species)	1 event/3 years	CEARAC Report 2011
	Red tide events (flagellate species)	1 event/3 years	CEARAC Report 2011
Ⅲ	DO at bottom layer	2 mg/L	Bricker et al., 2003
	COD	3 mg/L	NSQS Class II
	Fish kill incidents	1 event/3 years	CEARAC Report 2011
IV	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	3 event/3 years	CEARAC Report 2011
	Shell fish poisoning incidents	1 event/3 years	CEARAC Report 2011

2.5.2 North Kyushu sea area and Toyama Bay in Japan

For the case studies in Japan (the North Kyushu sea area and Toyama Bay), reference values for TN and TP concentrations and COD were set using the environmental quality standards for water pollution decided by the Ministry of the Environment, Japan (1971). It is noted that three different environmental water quality standards (Types II-IV) are applied depending on the type of water use in the North Kyushu sea area (Table 2.5), but only Type II was applied for the case study in Toyama Bay (Table 2.6). Since there are no water quality standards for winter DIN and DIP concentrations in Japan, their reference values were set from the TN and TP concentration standards through a regression analysis. The Redfield ratio of 16 was used as the ratio of winter DIN to DIP. The reference value for Chl-*a* was set based on Bricker and others (2003). For setting a DO reference value, the Fisheries water quality standard was applied. Red tide (diatom species and flagellate species) events were rated as 'High' when one or more incidents occurred over the past three years, and 'Low' if no incidents had occurred. Red tides of *Noctiluca* sp. were rated as 'High' when three or more incidents occurred over the past three years, and 'Low' if there had been less than three. This criterion was applied because conversion of oceanographic currents aggregates *Noctiluca* sp. regardless of the occurrence of eutrophication. In other words, there is a risk of misinterpreting *Noctiluca* sp. occurrences as a sign of eutrophication if the criterion of 'one or more events over the past three years,' is applied. If one or more incidents of abnormal fish kills and shellfish poisoning occurred in the last three years, their status was rated as 'High.' Assessment parameters were evaluated by comparing either the mean of the past three years, or the number of incidents to the reference value.

Table 2.5 Reference values used in the North Kyushu sea area, Japan

Categories	Assessment parameters	Reference value	Reference
Ⅰ	Riverine input of TN	None	None
	Riverine input of TP	None	None
	Input from direct discharge of TN	None	None
	Input from direct discharge of TP	None	None
	TN concentration	0.3 mg/L 0.6 mg/L 1.0 mg/L	Environmental quality standards for water pollution, Type II Environmental quality standards for water pollution, Type III Environmental quality standards for water pollution, Type IV
	TP concentration	0.03 mg/L 0.05 mg/L 0.09 mg/L	Environmental quality standards for water pollution, Type II Environmental quality standards for water pollution, Type III Environmental quality standards for water pollution, Type IV
	Winter DIN concentration	0.170 mg/L 0.338 mg/L 0.562 mg/L	Correspond to 'Environmental quality standards for water pollution, Type II' Correspond to 'Environmental quality standards for water pollution, Type III' Correspond to 'Environmental quality standards for water pollution, Type IV'
	Winter DIP concentration	0.010 mg/L 0.017 mg/L 0.029 mg/L	Correspond to 'Environmental quality standards for water pollution, Type II' Correspond to 'Environmental quality standards for water pollution, Type III' Correspond to 'Environmental quality standards for water pollution, Type IV'
	Winter DIN/DIP ratio	16	Redfield ratio
Ⅱ	Annual maximum of chlorophyll-*a*	20 μg/L	Bricker et al., 2003
	Annual mean of chlorophyll-*a*	5 μg/L	Bricker et al., 2003
	Red tide events (diatom species)	1 event/3 year	None
	Red tide events (flagellate species)	1 event/3 year	None
Ⅲ	DO at bottom layer	4.3 mg/L 3.6 mg/L	Fisheries water quality standard Yanagi, 1989
	Fish kill incidents	1 event/3 year	None
	COD	3.0 mg/L	Environmental quality standards for water pollution, Type B
	Transparency	None	None
Ⅳ	Red tide events (*Noctiluca* sp.)	3 event/3 years	None
	Shell fish poisoning incidents	1 event/3 year	None

Table 2.6　Reference values used in Toyama Bay in Japan

Categories	Assessment parameters	Reference value	Reference
Ⅰ	Riverine input of TN	None	None
	Riverine input of TP	None	None
	Input from direct discharge of TN	None	None
	Input from direct discharge of TP	None	None
	TN concentration	0.3 mg/L	Environmental quality standards for water pollution, Type II
	TP concentration	0.03 mg/L	Environmental quality standards for water pollution, Type II
	Winter DIN concentration	0.144 mg/L	Set based on the relationship between TN and DIN
	Winter DIP concentration	0.017 mg/L	Set based on the relationship between TP and DIP
	Winter DIN/DIP ratio	16	Redfield ratio
Ⅱ	Annual maximum of chlorophyll-*a*	20 µg/L	Bricker et al., 2003
	Annual mean of chlorophyll-*a*	5 µg/L	Bricker et al., 2003
	Red tide events (diatom species)	1 event/year	None
	Red tide events (flagellate species)	1 event/year	None
Ⅲ	Annual minimum DO	6.0 mg/L	Fisheries water quality standard
	Fish kill incidents	1 event/year	None
	COD	3.0 mg/L	Environmental water quality standard Type B
Ⅳ	Red tide events (*Noctiluca* sp.)	3 event/3 years	None
	Shell fish poisoning incidents	1 event/year	None

2.5.3 Jinhae Bay in Korea

For the reference values, background values were used in this case study. Therein, water quality data in Gijang Coast was applied as a contrast with Jinhae Bay and Masan-Haengam Bay. The Gijang coast, about ten kilometers east of Busan city, receives a relatively small effect from anthropogenic activities and is influenced more by the open sea than coastal sea. Accordingly, the place has relatively constant salinities (33 psu) almost all year round due to the strong influence of the Tsushima Warm Current, a branch of Kuroshio Current. Painting *et al*. (2005) reported that a target area meets 'ecological quality objectives' when assessment parameters do not exceed 150 % (or 67 %[1] for DO) of background values. Following the standard suggested by Painting *et al.* (2005), this report classified eutrophication into two levels: 'high' when the value of the current status exceeds 150 % (67 % for DO) of background values and 'low' when the value of current status is lower than 150% of background values. The reference value of DO was set to 4 mg/L (67 % of the back ground concentration of 6 mg/L based on OSPAR, 2005). As for DIN/DIP ratio, the Redfield ratio of 16 was used in this study. Red tide events, fish kill incidents and shell fish poisoning incidents were rated as High or Low based on the occurrence of one or more incident, or no incident in the past three years, respectively. This criteria was based on CEARAC Report in 2011. Details are listed in Table 2.7.

Table 2.7 Reference values used in Jinhae Bay in Korea

Categories	Assessment parameters	Reference value	Reference
Ⅰ	Riverine input of TN	20 mg/L	Chang et al., 2012
	Riverine input of TP	2 mg/L	Chang et al., 2012
	TN concentration	0.4 mg/L	Background value in Gijang area
	TP concentration	0.04 mg/L	Background value in Gijang area
	Winter DIN concentration	0.2 mg/L	Background value in Gijang area
	Winter DIP concentration	0.02 mg/L	Background value in Gijang area
	Winter DIN/DIP ratio	16	Redfield ratio
Ⅱ	Annual maximum of chlorophyll-*a*	15 μg/L	Background value in Gijang area
	Annual mean of chlorophyll-*a*	4 μg/L	Background value in Gijang area
	Red tide events (diatom species)	1 event/3 years	CEARAC Report 2011
	Red tide events (flagellate species)	1 event/3 years	CEARAC Report 2011
Ⅲ	DO at bottom layer	4 mg/L	OSPAR, 2005
	Fish kill incidents	1 event/3 years	CEARAC Report 2011
	COD	1.5 mg/L	Background value in Gijang area
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	3 event/3 years	CEARAC Report 2011
	Shell fish poisoning incidents	1 event/3 years	CEARAC Report 2011

[1] The DO reference value was set based on the formula: Reference value = background value × 100/150

2.5.4 Peter the Great Bay in Russia

Reference values of DIN, DIP and DSi concentration were calculated based on stoichiometric relations of the Redfield ratio, and concentrations were set based on the minimum necessary DO in seawater. A reference value for DIN/DIP ratio was not set. For Chl-*a* concentration, the reference value was set at 8 µg/L (OECD, 1982). The reference value of DO was set at 76 µM, which is the mean of 2 mg/L (63 µM) (Diaz, 2001) and 2 ml/L (89 µM) (Breitburg *et al*., 2009), the defined threshold values for hypoxia. Details are in Table 2.8.

Table 2.8 Reference values used in Peter the Great Bay in Russia

Categories	Assessment parameters	Reference value	Reference
Ⅰ	Riverine input of DIN	none	none
	Riverine input of DIP	none	none
	DIN concentration	33.4 µM (0.47 mg/L)	Winter
		24.3 µM (0.34 mg/L)	Spring, Autumn
		18.3 µM (0.26 mg/L)	Summer
	DIP concentration	2.1 µM (0.065 mg/L)	Winter
		1.5 µM (0.046 mg/L)	Spring, Autumn
		1.1 µM (0.034 mg/L)	Summer
	DSi concentration	35.5 µM (0.997 mg/L)	Winter
		25.8 µM (0.725 mg/L)	Spring, Autumn
		19.4 µM (0.545 mg/L)	Summer
	DIN/DIP ratio	none	none
Ⅱ	Annual mean of chlorophyll-*a*	8 µg/L	OECD, 1982
	Annual maximum of chlorophyll-*a*	8 µg/L	OECD, 1982
Ⅲ	Annual mean of DO at bottom layer	none	none
	Annual minimum of DO at bottom layer	76 µM (2.4 mg/L)	Diaz, 2001
		89 µM (2ml/L)	Breitburg et al., 2009
Ⅳ	Fish kill incidents	none	none
	Benthic fauna and flora	none	none

2.6 Assessment data used in selected sea areas

2.6.1 Jiaozhou Bay in China

In Jiaozhou Bay in China, assessment data were prepared based on the information summarized in Table 2.9.

Table 2.9 Assessment data in Jiaozhou Bay and its adjacent area in China

Category	Assessment parameters	Spatial and temporal conditions
Ⅰ	Riverine input of DIN	Annual input
	Riverine input of DIP	Annual input
	TN concentration	Annual mean
	TP concentration	Annual mean
	DIN concentration	Annual mean
	DIP concentration	Annual mean
	DIN/DIP ratio	Annual mean
Ⅱ	Chlorophyll-*a* concentration	Annual maximum
	Chlorophyll-*a* concentration	Annual mean
	Red tide events (diatom species)	Annual occurences
	Red tide events (flagellate species)	Annual occurences
Ⅲ	DO at bottom layer	Annual mean
	COD	Annual mean
	Fish kill incidents	Annual occurences
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	Annual occurences
	Shellfish poisoning incidents	Annual occurences

2.6.2 North Kyushu sea area and Toyama Bay in Japan

In the North Kyushu sea area and Toyama Bay in Japan, the assessment data were prepared based on the information summarized in Table 2.10 and Table 2.11.

Table 2.10 Assessment data in the North Kyushu sea area, Japan

Category	Assessment parameters	Spatial and temporal conditions
Ⅰ	Riverine input of TN	Annual mean
	Riverine input of TP	Annual mean
	Input from direct discharge of TN	Annual mean
	Input from direct discharge of TP	Annual mean
	TN concentration	Annual mean
	TP concentration	Annual mean
	Winter DIN concentration	Seasonal (Jan-Mar) mean
	Winter DIP concentration	Seasonal (Jan-Mar) mean
	Winter DIN/DIP ratio	Seasonal (Jan-Mar) mean
Ⅱ	Chlorophyll-*a* concentration	Annual maximum Annual mean
	Red tide events (diatom species)	Annual occurences
	Red tide events (flagellate species)	Annual occurences
Ⅲ	DO at bottom layer	Annual minimum
	Fish kill incidents	Annual occurences
	COD	Annual mean
	Transparency	-
Ⅳ	Red tide events (*Noctiluca* sp.)	Annual occurences
	Shellfish poisoning incidents	Annual occurences

Table 2.11 Assessment data in Toyama Bay in Japan

Category	Assessment parameters	Spatial and temporal conditions
Ⅰ	Riverine input of TN	Annual mean
	Riverine input of TP	Annual mean
	Input from direct discharge of TN	Annual mean
	Input from direct discharge of TP	Annual mean
	TN concentration	Annual mean
	TP concentration	Annual mean
	Winter DIN concentration	Seasonal (Jan-Mar) mean
	Winter DIP concentration	Seasonal (Jan-Mar) mean
	Winter DIN/DIP ratio	Seasonal (Jan-Mar) mean
Ⅱ	Chlorophyll-*a* concentration	Annual maximum Annual mean
	Red tide events (diatom species)	Annual occurences
	Red tide events (flagellate species)	Annual occurences
Ⅲ	DO at surface layer	Annual minimum
	Fish kill incidents	Annual occurences
	COD	Annual mean
Ⅳ	Red tide events (*Noctiluca* sp.)	Annual occurences
	Shellfish poisoning incidents	Annual occurences

2.6.3 Jinhae Bay in Korea

In Jinhae Bay in Korea, the assessment data were prepared based on the information as summarized in Table 2.12.

Table 2.12 Assessment data in Jinhae Bay in Korea

Category	Assessment parameters	Spatial and temporal conditions
Ⅰ	Riverine input of TN	Annual mean
	Riverine input of TP	Annual mean
	TN concentration	Annual mean
	TP concentration	Annual mean
	Winter DIN concentration	Seasonal mean
	Winter DIP concentration	Seasonal mean
	Winter DIN/DIP ratio	Seasonal mean
Ⅱ	Chlorophyll-*a* concentration	Annual maximum Annual mean
	Red tide events (diatom species)	Annual occurences
	Red tide events (flagellate species)	Annual occurences
Ⅲ	DO at bottom layer	Annual minimum
	COD at bottom layer	Annual mean
	Fish kill incidents	Number of occurrences per year
Ⅳ	Red tide events (*Noctiluca* sp.and *Mesodinium* sp.)	Number of occurrences per year
	Shellfish poisoning incidents	Number of occurrences per year

2.6.4 Peter the Great Bay in Russia

In Peter the Great Bay in Russia, the assessment data were prepared based on the information summarized in Table 2.13.

Table 2.13 Assessment data in Peter the Great Bay in Russia

Category	Assessment parameters	Spatial and temporal conditions
Ⅰ	Riverine input of DIN	Annual mean
	Riverine input of DIP	Annual mean
	DIN concentration	Annual mean
	DIP concentration	Annual mean
	DSi concentration	Annual mean
	DIN/DIP ratio	Annual mean
Ⅱ	Chlorophyll-*a* concentration	Annual mean Annual maximum
Ⅲ	DO at bottom layer	Annual mean Annual minimum
Ⅳ	Fish kill incidents	Annual occurences
	Benthic fauna and flora	-

3 Eutrophication status in selected sea areas of the NOWPAP region

3.1 Jiaozhou Bay in China

3.1.1 Sub-area A (Inner Jiaozhou Bay)

Category I parameters: both DIN and DIP inputs from rivers showed an increasing trend between the end of 1990s and 2008. TN and TP concentrations demonstrated no trend between 1997 and 2009. Both DIN and DIP concentrations showed an increasing trend. The DIN/DIP ratio showed a decreasing trend.

Category II parameters: both the annual maximum and mean Chl-*a* showed no trend between 1997 and 2009.

Category III parameters: DO values at bottom layer were higher than the reference value of 2 mg/L, identified as “L” in Table 3.1 to indicate the low level of eutrophication and showed an increasing trend between 2001 and 2006, identified as “D” in Table 3.1 to indicate the decreasing trend of eutrophication. No fish kill incidents were observed between 1997 and 2009. The COD showed no trend between 1997 and 2009.

Category IV parameters: Observed red tide events (*Noctiluca* sp.) were less than the reference value of three events in three years from 1997 to 2009. No shellfish poisoning incidents were observed from the 1970s to 2009.

In sub-area A (Inner Jiaozhou Bay), both DIN and DIP inputs from rivers showed an increasing trend. No red tide events (*Noctiluca* sp. and *Mesodinium* sp.) had been recorded since 2001. Assessment results corresponding to the categories for Inner Jiaozhou Bay are summarized in Table 3.1

In sub-area A (Inner Jiaozhou Bay), TN concentrations at most sites in the recent three years were higher than the reference value. DIN concentrations were higher than the reference concentration in the last three years and showed an increasing trend for all sampling sites from 1997 to 2009. Red tide events (diatom species) often occurred before 2004 but no events have been recorded since, showing a decreasing trend. One red tide event (flagellate species) was recorded in the last three years. Assessment results corresponding to the categories for Sub-area A (Inner Jiaozhou Bay) are summarized in Table 3.1

Table 3.1 Assessment results of each assessment category in sub-area A (Inner Jiaozhou Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of DIN	×	×	×	×	I	The end of 1980s-2008	I	HI
	Riverine input of DIP	×	×	×	×	I	The end of 1980s-2008	I	
	TN concentration	H	1997-2009	×	×	N	1997-2009	HN	
	TP concentration	H	1997-2009	×	×	N	1997-2009	HN	
	DIN concentration	H	1997-2009	×	×	I	1997-2009	HI	
	DIP concentration	H	1997-2009	×	×	I	1997-2009	HI	
	DIN/DIP ratio	H	1997-2009	×	×	D	1997-2009	HD	
Ⅱ	Annual maximum of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	LN
	Annual mean of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	
	Red tide events (diatom species)	×	×	L	1997-2009	D	1997-2009	LD	
	Red tide events (flagellate species)	×	×	H	1997-2009	N	1997-2009	HN	
Ⅲ	DO at bottom layer	L	2001-2006	×	×	D	2001-2006	LD	LN
	Fish kill incidents	×	×	L	1997-2009	N	1997-2009	LN	
	COD	L	1997-2009	×	×	N	1997-2009	LN	
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	×	×	L	1997-2009	N	1997-2009	LN	LN
	Shell fish poisoning incidents	×	×	L	1997-2009	N	1997-2009	LN	

3.1.2 Sub-area B (Mouth of Jiaozhou Bay)

Category I parameters: both TN and TP concentrations showed no trend between 1997 and 2009. DIN concentrations showed no trend while DIP concentrations showed an increasing trend. The DIN/DIP ratio showed a decreasing trend.

Category II parameters: both the annual maximum and mean Chl-*a* showed no trend between 1997 and 2009. Red tide events showed no trend and their occurrence was low between 1997 and 2009.

Category III parameters: DO values at the bottom layer were higher than the reference value of 2 mg/L, identified as "L" in Table 3.2 to indicate the low level of eutrophication and showed an increasing trend between 2001 and 2006, identified as "D" in Table 3.2 to indicate the decreasing trend of eutrophication. Fish kill incidents showed no trend between 1997 and 2009. The COD showed no trend between 1997 and 2009.

Category IV parameters: observed red tide events (*Noctiluca* sp. and *Mesodinium* sp.) were less than the reference value of three events in three years between 1997 and 2009. No shellfish poisoning incidents were observed between 1997 and 2009.

In sub-area B (Mouth of Jiaozhou Bay), TN concentrations at most sites in the last three years were lower than the reference value. DIN concentrations were lower than the reference concentrations in the last three years and showed no obvious trend for all sampling sites from 1997 to 2009. No red tide events (diatom species) had been recorded since 1997. Assessment results corresponding to the categories for Sub-area B (Mouth of Jiaozhou Bay) are summarized in Table 3.2

Table 3.2 Assessment results of each assessment category in sub-area B (Mouth of Jiaozhou Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of DIN	×	×	×	×	×	×	×	LN
	Riverine input of DIP	×	×	×	×	×	×	×	
	TN concentration	L	1997-2009	×	×	N	1997-2009	LN	
	TP concentration	H	1997-2009	×	×	N	1997-2009	HN	
	DIN concentration	L	1997-2009	×	×	N	1997-2009	LN	
	DIP concentration	H	1997-2009	×	×	I	1997-2009	HI	
	DIN/DIP ratio	L	1997-2009	×	×	D	1997-2009	LD	
Ⅱ	Annual maximum of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	LN
	Annual mean of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	
	Red tide events (diatom species)	×	×	L	1997-2009	N	1997-2009	LN	
	Red tide events (flagellate species)	×	×	L	1997-2009	N	1997-2009	LN	
Ⅲ	DO at bottom layer	L	2001-2006	×	×	D	2001-2006	LD	LN
	Fish kill incidents	×	×	L	1997-2009	N	1997-2009	LN	
	COD	L	1997-2009	×	×	N	1997-2009	LN	
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	×	×	L	1997-2009	N	1997-2009	LN	LN
	Shell fish poisoning incidents	×	×	L	1997-2009	N	1997-2009	LN	

3.1.3 Sub-area C (Outside of Jiaozhou Bay)

Category I parameters: both TN and TP concentrations showed no trend between 1997 and 2009. The DIN/DIP ratio showed a decreasing trend.

Category II parameters: both the annual maximum and mean Chl-*a* showed no trend between 1997 and 2009. Red tide events (diatom species) showed an increasing trend and high occurrence while red tide events (flagellate species) showed no trend and low occurrence between 1997 and 2009.

Category III parameters: DO values at the bottom layer were higher than the reference value of 2 mg/L, identified as "L" in Table 3.3 to indicate the low level of eutrophication and showed an increasing trend between 2001 and 2006, identified as "D" in Table 3.3 to indicate the decreasing trend of eutrophication. Fish kill incidents showed no trend between 1997 and 2009. The COD showed no trend between 1997 and 2009.

Category IV parameters: Observed red tide events (*Noctiluca* sp. and *Mesodinium* sp.) were greater than the reference value of three events in three years between 1997 and 2009. No shellfish poisoning incidents were observed between 1997 and 2009.

In sub-area C (Outside of Jiaozhou Bay), TN concentrations at most sites in the recent three years were higher than the reference value. DIN concentrations were lower than the reference concentrations in the last three years and showed no obvious trend for all sampling sites from 1997 to 2009. Red tide (diatom species) began to occur at a high frequency in the past five years, showing an increasing trend. Assessment results corresponding to the categories for sub-area C (Outside of Jiaozhou Bay) are summarized in Table 3.3

Table 3.3 Assessment results of each assessment category in sub-area C (Outside of Jiaozhou Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of DIN	×	×	×	×	×	×	×	HN
	Riverine input of DIP	×	×	×	×	×	×	×	
	TN concentration	H	1997-2009	×	×	N	1997-2009	HN	
	TP concentration	H	1997-2009	×	×	N	1997-2009	HN	
	DIN concentration	L	1997-2009	×	×	N	1997-2009	LN	
	DIP concentration	H	1997-2009	×	×	I	1997-2009	HI	
	DIN/DIP ratio	L	1997-2009	×	×	D	1997-2009	LD	
Ⅱ	Annual maximum of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	LN
	Annual mean of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	
	Red tide events (diatom species)	×	×	H	1997-2009	I	1997-2009	HI	
	Red tide events (flagellate species)	×	×	L	1997-2009	N	1997-2009	LN	
Ⅲ	DO at bottom layer	L	2001-2006	×	×	D	2001-2006	LD	LN
	Fish kill incidents	×	×	L	1997-2009	N	1997-2009	LN	
	COD	L	1997-2009	×	×	N	1997-2009	LN	
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	×	×	H	1997-2009	N	1997-2009	HN	HN-LN
	Shell fish poisoning incidents	×	×	L	1997-2009	N	1997-2009	LN	

3.2 North Kyushu sea area in Japan

3.2.1 Sub-area A (Hakata Bay)

Category I parameters: both TN and TP inputs from the rivers showed a decreasing trend. TN and TP inputs from the sewage treatment plants showed no trend. TN concentration satisfied the reference value but showed an increasing trend at many stations. TP concentration satisfied the reference value and showed a decreasing trend at all stations. Winter DIN concentration was above the reference value and showed an increasing trend at many stations. On the other hand, winter DIP concentrations were below the reference value at all stations. Consequently, the winter DIN/DIP ratio was higher than the Redfield ratio.

Category II parameters: annual maximum and mean Chl-*a* concentrations showed no trend despite the fact that they were above the reference values at all stations. Diatom and flagellate red tides were also confirmed.

Category III parameters: DO did not satisfy the reference value at two stations, but the ratio of stations that satisfied the reference values (i.e. was higher than the reference value, therefore indicating a low level of eutrophication) was dominant. While COD at some stations were above the reference value, all stations showed no trend. Transparency also showed no trend.

Category IV parameters: *Noctiluca* sp. red tide was observed, but at limited frequency. No shellfish poisoning incidents were confirmed.

In sub-area A (Hakata Bay), the concentration of nitrogen and phosphorus should be balanced by adjusting the level of nitrogen and phosphorus inputs. The number of diatom and flagellate red tides should also be reduced. Assessment results corresponding to the categories for sub-area A (Hakata Bay) are summarized in Table 3.4.

Table 3.4 Assessment results of each assessment category in sub-area A (Hakata Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	D	1985-2010	D	LD-LI
	Riverine input of TP	×	×	×	×	D	1985-2010	D	
	Input from direct discharge of TN	×	×	×	×	N	1995-2010	N	
	Input from direct discharge of TP	×	×	×	×	N	1995-2010	N	
	TN concentration	L	1978-2010	×	×	I	1978-2010	LI	
	TP concentration	L	1978-2010	×	×	D	1978-2010	LD	
	Winter DIN concentration	H	1978-2010	×	×	I	1978-2010	HI	
	Winter DIP concentration	L	1978-2010	×	×	N	1978-2010	LN	
	Winter DIN/DIP ratio	H	1978-2010	×	×	I	1978-2010	HI	
Ⅱ	Annual maximum of chlorophyll-*a*	H	1981-2010	×	×	N	1981-2010	HN	HN
	Annual mean of chlorophyll-*a*	H	1981-2010	×	×	N	1981-2010	HN	
	Red tide events (diatom species)	×	1978-2010	H	×	N	1978-2010	HN	
	Red tide events (flagellate species)	×	1978-2010	H	×	N	1978-2010	HN	
Ⅲ	DO at bottom layer	L	1978-2010	×	×	N	1978-2010	LN	LN
	Fish kill incidents	×	×	L	1970s-2010	N	1970s-2010	LN	
	COD	L	1978-2010	×	×	N	1978-2010	LN	
	Transparency	×	×	×	1978-2010	N	1978-2010	N	
Ⅳ	Red tide events (*Noctiluca* sp.)	×	×	L	1978-2010	N	1978-2010	LN	LN
	Shell fish poisoning incidents	×	×	L	1970s-2010	N	1970s-2010	LN	

3.2.2 Sub-area B (Dokai Bay)

Category I parameters: both TN and TP inputs from the rivers showed a decreasing trend. TN and TP inputs directly discharged from factories and sewage treatment plants into Dokai Bay showed a decreasing trend. Although TN concentrations were above the reference value, TP concentrations satisfied the reference value at all stations and both parameters showed decreasing trends. Winter DIN/DIP concentration was not assessed due to lack of data.

Category II parameters: Annual maximum and mean of Chl-*a* concentrations exceeded the reference values at all stations, and occurrences of diatom red tides were confirmed. The occurrence of flagellate red tide was not confirmed.

Category III parameters: DO satisfied the reference value (i.e. was higher than the reference value, therefore indicating a low level of eutrophication) at four of the seven stations. While COD exceeded the reference value at one of four stations, COD levels decreased at stations where high levels were recorded in the past, thus confirming improvement in water quality. Improvement in transparency was confirmed.

In sub-area B (Dokai Bay), transparency was improved and with a decreasing trend in COD. Assessment results corresponding to the categories for sub-area B (Dokai Bay) are summarized in Table 3.5.

Table 3.5 Assessment results of each assessment category in sub-area B (Dokai Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	D	1987-2010	D	LD
	Riverine input of TP	×	×	×	×	D	1987-2010	D	
	Input from direct discharge of TN	×	×	×	×	D	1995-2010	D	
	Input from direct discharge of TP	×	×	×	×	D	1995-2010	D	
	TN concentration	L	1978-2010	×	×	D	1978-2010	LD	
	TP concentration	L	1978-2010	×	×	D	1978-2010	LD	
	Winter DIN concentration	×	×	×	×	×	×	-	
	Winter DIP concentration	×	×	×	×	×	×	-	
	Winter DIN/DIP ratio	×	×	×	×	×	×	-	
Ⅱ	Annual maximum of chlorophyll-*a*	H	1986-2010	×	×	N	1986-2010	HN	HN
	Annual mean of chlorophyll-*a*	H	1986-2010	×	×	N	1986-2010	HN	
	Red tide events (diatom species)	×	×	H	1978-2010	N	1978-2010	HN	
	Red tide events (flagellate species)	×	×	L	1978-2010	N	1978-2010	LN	
Ⅲ	DO at bottom layer	L	1994-2010	×	×	N	1994-2010	LN	LD-LN
	Fish kill incidents	×	×	L		N	1970s-2010	LN	
	COD	L	1978-2010	×	×	D	1978-2010	LD	
	Transparency	×	×	×	×	D	1978-2010	D	
Ⅳ	Red tide events (*Noctiluca* sp.)	×	×	L	1978-2010	N	1978-2010	LN	LN
	Shell fish poisoning incidents	×	×	L	1970s-2010	N	1970s-2010	LN	

3.2.3 Sub-area C (Kyushu intermediate area)

Category I parameters: both TN and TP inputs from rivers showed a decreasing trend from 1985 to 2010. TN inputs from direct discharge showed a decreasing trend from 1995 to 2010 while TP inputs from direct discharge showed an increasing trend. TN and TP inputs were the highest from the Hiagari Treatment Center, which discharges into the sub-area C. Both TN and TP concentrations were below the reference values, and there was no trend detected from 1978 to 2010.

Category II parameters: annual maximum and mean Chl-*a* were above the reference values and flagellate red tide was observed.

Category III parameters: DO satisfied the reference value (i.e. was higher than the reference value, therefore indicating a low level of eutrophication) at all stations and COD was below the reference value. No trend was confirmed at most stations. Transparency showed no trend.

Category IV parameters: *Noctiluca* red tide occurred twice in the most recent three years. No shellfish poisoning incidents were confirmed.

In sub-area C (Kyushu intermediate area), concentrations of TN, TP, winter DIN and winter DIP were low. However, the area may be influenced by other sea areas as there were flagellate and *Noctiluca* red tides. Assessment results corresponding to the categories for sub-area C (Kyushu intermediate area) are summarized in Table 3.6.

Table 3.6 Assessment results of each assessment category in sub-area C (Kyushu intermediate area)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	N	1985-2010	N	LN
	Riverine input of TP	×	×	×	×	N	1985-2010	N	
	Input from direct discharge of TN	×	×	×	×	D	1995-2010	D	
	Input from direct discharge of TP	×	×	×	×	I	1995-2010	I	
	TN concentration	L	1978-2010	×	×	N	1978-2010	LN	
	TP concentration	L	1978-2010	×	×	N	1978-2010	LN	
	Winter DIN concentration	L	1978-2010	×	×	N	1978-2010	LN	
	Winter DIP concentration	L	1978-2010	×	×	D	1978-2010	LD	
	Winter DIN/DIP ratio	H	1978-2010	×	×	I	1978-2010	HI	
Ⅱ	Annual maximum of chlorophyll-*a*	L	1975-2010	×	×	N	1975-2010	LN	LN-HN
	Annual mean of chlorophyll-*a*	H	1975-2010	×	×	N	1975-2010	HN	
	Red tide events (diatom species)	×	×	L	1978-2010	N	1978-2010	LN	
	Red tide events (flagellate species)	×	×	H	1978-2010	I	1978-2010	HI	
Ⅲ	DO at bottom layer	L	1978-2010	×	×	N	1978-2010	LN	LN
	Fish kill incidents	×	×	L		N	1970s-2010	LN	
	COD	L	1978-2010	×	×	N	1978-2010	LN	
	Transparency	×	×	×	×	N	1978-2010	N	
Ⅳ	Red tide events (*Noctiluca* sp.)	×	×	L	1978-2010	N	1978-2010	LN	LN
	Shell fish poisoning incidents	×	×	L	1970s-2010	N	1970s-2010	LN	

*Parameter identification of the winter DIN/DIP ratio was not used for class identification, because winter DIN concentration and winter DIP concentration were lower than reference concentrations.

3.2.4 Sub-area D (Kyushu offshore area)

Category I parameters: there are no rivers or sewage treatment plants that discharge water directly into sub-area D. Therefore, no assessment of Category I was conducted.

Category II parameters: the level of annual maximum Chl-*a* concentration was below the reference value, and no trend was detected in the annual maximum or mean Chl-*a*. The number of flagellate red tide events exceeded the reference value, and there was no trend. The number of diatom red tide events did not exceed the reference value, and there was no trend observed.

Category III parameters: DO satisfied the reference value (i.e. was higher than the reference value, therefore indicating a low level of eutrophication) and increasing trends - indicating a decreasing trend (labelled as “D” in Table 3.7) of eutrophication- were identified at all stations. No fish kill events were observed. COD was below the reference value, and no trend was detected. No trend was also detected in transparency.

Category IV parameters: *Noctiluca* red tide occurred only once in 2009 in the recent three years. No shellfish poisoning incidents was observed.

In sub-area D (Kyushu offshore area), with the exception of flagellate red tide, all parameters were classified as either ‘LN’ or ‘N’. Therefore, eutrophication does not appear to be a major issue in sub-area D. Assessment results corresponding to the categories for sub-area D (Kyushu offshore area) area are summarized in Table 3.7.

Table 3.7 Assessment results of each assessment category in sub-area D (Kyushu offshore area)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	×	×	-	-
	Riverine input of TP	×	×	×	×	×	×	-	
	Input from direct discharge of TN	×	×	×	×	×	×	-	
	Input from direct discharge of TP	×	×	×	×	×	×	-	
	TN concentration	×	×	×	×	×	×	-	
	TP concentration	×	×	×	×	×	×	-	
	Winter DIN concentration	×	×	×	×	×	×	-	
	Winter DIP concentration	×	×	×	×	×	×	-	
	Winter DIN/DIP ratio	×	×	×	×	×	×	-	
Ⅱ	Annual maximum of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	LN
	Annual mean of chlorophyll-*a*	×	×	×	×	N	1997-2009	N	
	Red tide events (diatom species)	×	×	L	1978-2010	N	1978-2010	LN	
	Red tide events (flagellate species)	×	×	H	1978-2010	N	1978-2010	HN	
Ⅲ	DO at bottom layer	L	1997-2009	×	×	D	1997-2009	LD	LN
	Fish kill incidents	×	×	L		N	1970s-2010	LN	
	COD	L	1997-2009	×	×	N	1997-2009	LN	
	Transparency	×	×	×	×	N	1997-2009	N	
Ⅳ	Red tide events (*Noctiluca* sp.)	×	×	L	1978-2010	N	1978-2010	LN	LN
	Shell fish poisoning incidents	×	×	L	1970s-2010	N	1970s-2010	LN	

3.3 Toyama Bay in Japan

Category I parameters: total TN input from all of the Class-A rivers did not show any trend. However, total TN input showed increasing trends in the Jinzu River and decreasing trend in the Oyabe River. Due to its size and location (the biggest and flow into the innermost section of the bay) of the Jinzu River, a significant influence over the Toyama Bay is considered. On the other hand, total TP input from all of the Class-A rivers and TP concentration showed a decreasing trend. Almost all the mean concentrations of TN, winter DIN and winter DIP of the recent three years were below respective reference value, and there was no trend.

Category II parameters: the annual maximum Chl-*a* concentrations of the recent three years in most stations were below the reference value, however the annual mean Chl-*a* concentrations in all stations were above the reference value and there was no trend. There were no diatom red tide events in the recent three years, showing a decreasing trend. In addition, there were no flagellate red tides in the recent three years, and there were no trend.

Category III parameters: no trend was shown at seven of the nine stations, and reference values were satisfied at all stations (i.e. DO was higher than the reference value, therefore indicating a low level of eutrophication). An increasing trend of COD was detected at five stations, although reference values were still satisfied at all stations.

Category IV parameters: There was only one *Noctiluca* red tide event in 2007. No shellfish-poisoning incidents were confirmed.

In Toyama Bay coastal area, all categories were classified as 'Low eutrophication status and No trend'. However, among Category I parameters, it is suggested to reduce TN input since N/P ratio was higher than the reference value. Among Category II parameters, annual mean Chl-*a* showed high eutrophication status. Therefore, it is required to improve the status by reducing nutrient enrichment. Among Category III parameters, an increasing trend of COD and decreasing trend of DO (i.e. an increasing trend of eutrophication) were also identified in some stations, and continuous monitoring of these parameters are necessary in order to manage eutrophication. Assessment results corresponding to the categories for the Toyama Bay coastal area are summarized in Table 3.8.

Table 3.8 Assessment results of each assessment category (Toyama Bay coastal area)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	N	1985-2009	N	
	Riverine input of TP	×	×	×	×	D	1985-2009	D	
	Input from direct discharge of TN	×	×	×	×	×	×	-	
	Input from direct discharge of TP	×	×	×	×	×	×	-	
	TN concentration	L	1997-2009	×	×	N	1997-2009	LN	LN
	TP concentration	L	1997-2009	×	×	D	1997-2009	LD	
	Winter DIN concentration	L	2000-2009	×	×	N	2000-2009	LN	
	Winter DIP concentration	L	2000-2009	×	×	N	2000-2009	LN	
	Winter DIN/DIP ratio	H	2000-2009	×	×	N	2000-2009	HN*	
Ⅱ	Annual maximum of chlorophyll-*a*	L	1997-2009	×	×	N	1997-2009	LN	LN
	Annual mean of chlorophyll-*a*	H	1997-2009	×	×	N	1997-2009	LH	
	Red tide events (diatom species)	×	×	L	1966-2009	D	1966-2009	LD	
	Red tide events (flagellate species)	×	×	L	1966-2009	N	1966-2009	LN	
Ⅲ	DO at surface layer	L	1976-2009	×	×	N	1976-2009	LN	LN
	Fish kill incidents	×	×	L	1985-2009	N	1985-2009	LN	
	COD	L	1976-2009	×	×	N	1976-2009	LN	
Ⅳ	Red tide events (*Noctiluca* sp.)	×	×	L	1966-2009	N	1966-2007	LN	LN
	Shell fish poisoning incidents	×	×	L	1994-2009	N	1994-2007	LN	

*Parameter identification of the winter DIN/DIP ratio was not used for Class identification, because winter DIN concentration and winter DIP concentration were lower than reference concentrations.

3.4 Jinhae Bay in Korea

3.4.1 Sub-area A (Jinhae Bay)

Category I parameters: riverine input of TN and TP into sub-area A showed a decreasing trend. Both TN and TP concentrations showed a decreasing trend, and a higher value than the reference value. Winter DIN and DIP had lower values than the reference value, and a decreasing trend. A decreasing trend for DIN/DIP ratio was also observed, with the value slightly higher than the reference.

Category II parameters: maximum Chl-*a* value was higher than the reference value, and there was no trend. Mean Chl-*a* also showed a higher value than the reference without any trend. Red tide events by diatom species were lower than the reference value (one event), and there was a decreasing trend. Meanwhile, the number of flagellate red tide events was higher than the reference value (one event), and there was no trend.

Category III parameters: COD concentrations at the bottom layer were higher than the reference value, showing a decreasing trend. However, the COD level was considered to not be very high considering the range (1.08-2.24). There were no reports of fish kill incidents during 1993 to 2011.

Category IV parameters: the number of red tide events by *Noctiluca scintillans* and *Mesodinium rubrum* were few with a total of three events recorded (2002, 2006, and 2008). For shellfish poisoning incidents in Jinhae Bay, Paralitic Shellfish Poisoning (PSP) occurs from March to May reportedly from the shellfish monitoring program targeted at more than 20 regular sampling stations within Jinhae Bay. However, there were only a few PSP incidents exceeding the regulatory level (80 ug/100 g meats), and there have been no official reports on patients suffering from PSP intoxication in Jinhae Bay since 2001.

In sub-area A (Jinhae Bay), nutrient enrichment showed a decreasing trend. However, the nutrient concentration of TN and TP were still higher than the reference value even though DIN and DIP concentrations were lower than the reference value during recent years. Assessment results corresponding to the categories for sub-area A (Jinhae Bay) are summarized in Table 3.9.

Table 3.9 Assessment results of each assessment category in sub-area A (Jinhae Bay) in Korea

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	D	1995-1996	D	HD
	Riverine input of TP	×	×	×	×	D	1995-1996	D	
	TN concentration	H	2002-2011	×	×	D	2002-2011	HD	
	TP concentration	H	2002-2011	×	×	D	2002-2011	HD	
	Winter DIN concentration	L	2002-2011	×	×	D	2002-2011	LD	
	Winter DIP concentration	L	2002-2011	×	×	D	2002-2011	LD	
	Winter DIN/DIP ratio	H	2002-2011	×	×	D	2002-2011	HD	
Ⅱ	Annual maximum of chlorophyll-*a*	H	2002-2011	×	×	N	2002-2011	HN	HN
	Annual mean of chlorophyll-*a*	H	2002-2011	×	×	N	2002-2011	HN	
	Red tide events (diatom species)	×	×	L	2001-2011	D	2001-2011	LD	
	Red tide events (flagellate species)	×	×	H	2001-2011	N	2001-2011	HN	
Ⅲ	DO at bottom layer	H	2002-2011	×	×	N	2002-2011	HN	HN
	Fish kill incidents	×	×	L	1979-2011	N	1979-2011	LN	
	COD	H	2002-2011	×	×	D	2002-2011	HD	
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	×	×	L	2001-2011	N	2001-2011	LN	LN
	Shell fish poisoning incidents	×	×	L	1980-present	N	1980-present	LN	

3.4.2 Sub-area B (Masan-Haengam Bay)

Category I parameters: riverine input of TN and TP into sub-area B showed a decreasing trend. Both TN and TP concentrations showed a decreasing trend, with values higher than the reference values. Winter DIN and DIP showed lower values than the reference, and a decreasing trend. A decreasing trend for DIN/DIP ratio was observed. The value was slightly higher than the reference.

Category II parameters: Maximum Chl-*a* showed a higher value than the reference value, and there was no trend. Mean Chl-*a* also showed a higher value than the reference value without any trend. The number of red tide events by diatoms were lower than the reference value (one event), and there was a decreasing trend. Meanwhile, the number of red tide events by flagellates was higher than reference value (one event).

Category III parameters: COD concentrations at the bottom layer were higher than the reference value and showed a decreasing trend. However, it was regarded that the COD level was not high considering their ranges (1.52-2.65). There were no reports of fish kill incidents during 1993 to 2011.

Category IV parameters: the number of red tide events by *Noctiluca scintillans* and *Mesoninium rubrum* was low with only one event recorded (2009).

In sub-area B (Masan-Haengam Bay) where Masan and Changwon mega cities are located nearby, TP concentration was relatively higher than in sub-area A. Assessment results corresponding to the categories for sub-area B (Masan-Haengam Bay) are summarized in Table 3.10.

Table 3.10 Assessment results of each assessment category in sub-area B (Masan-Haengam Bay) in Korea

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of TN	×	×	×	×	D	1995-1996	D	HD
	Riverine input of TP	×	×	×	×	D	1995-1996	D	
	TN concentration	H	2002-2011	×	×	D	2002-2011	HD	
	TP concentration	H	2002-2011	×	×	D	2002-2011	HD	
	Winter DIN concentration	L	2002-2011	×	×	D	2002-2011	LD	
	Winter DIP concentration	L	2002-2011	×	×	D	2002-2011	LD	
	Winter DIN/DIP ratio	H	2002-2011	×	×	D	2002-2011	HD	
Ⅱ	Annual maximum of chlorophyll-*a*	H	2002-2011	×	×	N	2002-2011	HN	HD
	Annual mean of chlorophyll-*a*	H	2002-2011	×	×	N	2002-2011	HN	
	Red tide events (diatom species)	×	×	L	2001-2011	D	2001-2011	LD	
	Red tide events (flagellate species)	×	×	H	2001-2011	D	2001-2011	HD	
Ⅲ	DO at bottom layer	H	2002-2011	×	×	N	2002-2011	HN	HN
	Fish kill incidents	×	×	L	1979-2011	N	1979-2011	LN	
	COD	H	2002-2011	×	×	D	2002-2011	HD	
Ⅳ	Red tide events (*Noctiluca* sp. and *Mesodinium* sp.)	×	×	L	2001-2011	N	2001-2011	LN	LN
	Shell fish poisoning incidents	×	×	L	1980-present	N	1980-present	LN	

3.5 Peter the Great Bay in Russia

3.5.1 Sub-area A (Amursky Bay)

Category I parameters: DIN, DIP and DSi concentrations were higher than reference values and showed an increasing trend.

Category II parameters: Annual mean concentration of Chl-*a* was lower than the reference value while annual maximum concentration of Chl-*a* was higher than the reference value.

Category III parameters: Both mean and minimum DO at the bottom layer were lower than the reference values, indicating a high level of eutrophication. .

Category IV parameters: Fish kill incidents were at a low frequency, and no trend was identified.

Sub-area A (Amursky Bay), had a high eutrophic status and an increasing trend toward eutrophication. Assessment results corresponding to the categories for sub-area A (Amursky Bay) are summarized in Table 3.11.

Table 3.11 Assessment results of each assessment category in sub-area A (Amursky Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of DIN	H	2000-2010	×	×	I	2000-2010	HI	HI
	Riverine input of DIP	H	2000-2010	×	×	I	2000-2010	HI	
	DIN concentration	H	2000-2010	×	×	I	2000-2010	HI	
	DIP concentration	H	2000-2010	×	×	I	2000-2010	HI	
	DSi concentration	H	2000-2010	×	×	I	2000-2010	HI	
	DIN/DIP ratio			×	×				
Ⅱ	Annual mean of chlorophyll-*a*	L	2000-2010	×	×	I	2000-2010	LI	LI-HN
	Annual maximum of chlorophyll-*a*	H	2000-2010	×	×	N	2000-2010	HN	
Ⅲ	Annual mean of DO at bottom layer	H	2000-2010	×	×	D	2000-2010	HD	HD-HN
	Annual minimum of DO at bottom layer	H	2000-2010	×	×	N	2000-2010	HN	
Ⅳ	Fish kill incidents	×	×	L		N		LN	LN
	Benthic fauna and flora								

3.5.2 Sub-area B (Ussuriisky Bay)

Category I parameters: in the winter time, there are very low concentrations of DIN, DIP and DSi for surface and bottom layers.

Category II parameters: annual mean and maximum Chl-*a* in the surface layer were lower than the reference value and showed no trend between 2008 to 2011.

Category III parameters: Annual mean values of DO were higher than the reference value (i.e. indicating a low level of eutrophication). On the other hand, annual minimum values of DO were lower than the reference value (i.e. indicating a high level of eutrophication). Both annual mean and minimum DO values showed no trend.

Category IV parameters: Fish kill incidents were not observed in sub-area B.

In sub-area B (Ussuriisky Bay), nutrient loads per square into sub-area B (Ussuriisky Bay) are significantly less. It can be concluded that the eutrophication status of sub-area B is considered low. Assessment results corresponding to the categories for sub-area B (Ussuriisky Bay) are summarized in Table 3.12.

Table 3.12 Assessment results of each assessment category in sub-area B (Ussuriisky Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of DIN	L	2003-2011	×	×	N	2003-2011	LN	LN
	Riverine input of DIP	L	2003-2011	×	×	N	2003-2011	LN	
	DIN concentration	L	2003-2011	×	×	N	2003-2011	LN	
	DIP concentration	L	2003-2011	×	×	N	2003-2011	LN	
	DSi concentration	L	2003-2011	×	×	N	2003-2011	LN	
	DIN/DIP ratio			×	×				
Ⅱ	Annual mean of chlorophyll-*a*	L	2003-2011	×	×	N	2003-2011	LN	LN
	Annual maximum of chlorophyll-*a*	L	2003-2011	×	×	N	2003-2011	LN	
Ⅲ	Annual mean of DO at bottom layer	L	2003-2011	×	×	N	2003-2011	LN	LN-HN
	Annual minimum of DO at bottom layer	H	2003-2011	×	×	N	2003-2011	HN	
Ⅳ	Fish kill incidents	×	×	×	×	×	×	—	—
	Benthic fauna and flora								

3.5.3 Sub-area C (southern part of Peter the Great Bay)

Category I parameters: DIN, DIP and DSi for surface and bottom layers are lower than the reference values.

Category II parameters: annual mean Chl-*a* in the surface layer was lower than the reference value and there was no trend between 2000 and 2010, while annual maximum Chl-*a* was higher than the reference value with no trend.

Category III parameters: DO concentration was higher than the reference value (indicating a low level of eutrophication) with no trend.

Category IV parameters: Fish kill incidents were not been observed in sub-area C.

In sub-area C (southern part of Peter the Great Bay), variations of nutrients and DO concentrations are minimal. The area contains the maximum Secci disk depth. Currently, the ecosystem behavior of most of sub-area C is close to the natural character. Assessment results corresponding to the categories for sub-area C (southern part of Peter the Great Bay) are summarized in Table 3.13.

Table 3.13 Assessment results of each assessment category in sub-area C (southern part of Peter the Great Bay)

Categories	Assessment parameters	Comparison		Occurrence		Trend		Parameter identification	Class identification
Ⅰ	Riverine input of DIN	L	2000-2010	×	×	N	2000-2010	LN	LN
	Riverine input of DIP	L	2000-2010	×	×	N	2000-2010	LN	
	DIN concentration	L	2000-2010	×	×	N	2000-2010	LN	
	DIP concentration	L	2000-2010	×	×	N	2000-2010	LN	
	DSi concentration	L	2000-2010	×	×	N	2000-2010	LN	
	DIN/DIP ratio			×	×				
Ⅱ	Annual mean of chlorophyll-*a*	L	2000-2010	×	×	N	2000-2010	LN	LN-HN
	Annual maximum of chlorophyll-*a*	H	2000-2010	×	×	N	2000-2010	HN	
Ⅲ	Annual mean of DO at bottom layer	L	2000-2010	×	×	N	2000-2010	LN	LN
	Annual minimum of DO at bottom layer	L	2000-2010	×	×	N	2000-2010	LN	
Ⅳ	Fish kill incidents	×	×	×	×	×	×	—	—
	Benthic fauna and flora								

4 Evaluation of the Refined NOWPAP Common Procedure

Improvements in the refined NOWPAP Common Procedure were evaluated based on the results of the case studies in member states.

- Addition of the screening procedure

The refined NOWPAP Common Procedure recommends the implementation of the screening procedure prior to the comprehensive procedure to detect symptoms of eutrophication within selected sea areas.

Case studies that adopted the screening procedure were Jiaozhou Bay in China, Toyama Bay in Japan, Jinhae Bay in Korea, and Peter the Great Bay in Russia.

Jiaozhou Bay in China was categorized as potentially eutrophic by frequent red tide events in the screening procedure, but showed relatively low ecological effects in the comprehensive procedure in recent years. This suggests that it is important to validate the results of the screening procedure by analyzing the occurrence of eutrophication from multilateral viewpoints in the comprehensive procedure. The screening procedure applied in Jinhae Bay in Korea also showed high nutrients input, high Chl-*a* concentrations, and frequent red tide events from the 1980s. However, adoption of the comprehensive procedure concluded that there were no problems in the sea area regarding indirect effects of nutrient loads on the ecosystem or other effects. From these examples, it can be seen that the combined use of the screening and comprehensive procedures is effective to comprehend the potential and degree of eutrophication.

In Toyama Bay in Japan, the screening procedure was adopted to narrow down the target sea areas by selecting high Chl-*a* concentration areas using three years of Chl-*a* concentration observed by satellite. By using this method, the coastal area of Toyama Bay was selected as a target area of the case study for the comprehensive procedure, and the assessment process became efficient. Follow up assessment results by the comprehensive procedure were in agreement with existing literature, revealing that it is possible to conduct a reliable preliminary assessment of eutrophication with the screening procedure.

In Peter the Great Bay in Russia, area screening was carried out by reviewing existing literature for the following parameters: 1) an unacceptable deviation in trophic structure of Peter the Great Bay; 2) land based sources of nutrients; and 3) seasonal hypoxia of bottom waters and related nutrient concentrations. A preliminary assessment of the eutrophication level of Peter the Great Bay according to these parameters was deemed valuable. However, none of these assessment parameters are included in the preliminary assessment procedure of the NOWPAP Common Procedure, and it is necessary to unify the methods with other NOWPAP sea areas to conduct the preliminary assessment for the whole NOWPAP area.

- Revision of the assessment parameters in the comprehensive procedure

The NOWPAP Common Procedure showed the assessment parameters of Toyama Bay as an example, but the refined NOWPAP Common Procedure recommended set of assessment parameters by adding direct (discharge except riverine input) load, number of red tide events (flagellate species), bottom layer DO, and transparency used in the case studies in the 2012-2013 biennium.

➢ Addition of direct nutrient loads

In the refined NOWPAP Common Procedure direct nutrient loads of TN and TP were added as assessment parameters for the North Kyushu sea area in Japan.

In the 2011 case study for the North Kyushu sea area, only the nutrient load from sewage treatment plants was considered whereas in the 2013 case study a detailed assessment including the nutrient load from factories was conducted. As a result, the TN assessment result in the 2011 case study was N (no increase or decreasing trend), but changed to D (decreasing trend) in the 2013 assessment. Addition of load from factories is appropriate to accurately quantify nutrient load to sub-area B (Dokai Bay) because TN input from factories is more than ten times as much as that from sewage treatment plants. On the other hand, there was no change in the assessment results for TP, because the TP loading level from factories is low.

In conclusion, direct nutrient load is an important assessment parameter to understand the load especially in sea areas with many factories, and it is a necessary assessment parameter for coastal cities in NOWPAP sea area undergoing rapid industrialization.

- Addition of red tide species

In the refined NOWPAP Common Procedure, red tide species in assessment parameters were separated into two groups: diatom species and flagellate species. This revision reflects the opinion from a Korean expert that assessment by multiple species is ideal due to the change in composition of red tide species in Korea. Korea and China adopted the addition of red tide species in assessment parameters with the refined NOWPAP Common Procedure. In Toyama Bay and the North Kyushu sea area, diatom red tide and flagellate red tide were already been evaluated separately in the 2011 case study.

A separate assessment of diatom and flagellate as red tide species in Jinhae Bay showed that while diatom red tide events are in a decreasing trend and below the reference value, flagellate red tide events continued and were above the reference value. A separate assessment of diatom and flagellate in sub-area A of China's Jiaozhou Bay revealed that while the events of diatom red tides decreased after 2004 in the area, the events of flagellate red tide were recorded there, with an occurrence of one in 2008 that reached the criteria of "High" status specified by the NOWPAP Common Procedure.

Thus, by separating the red tide species into diatom and flagellate, it was observed that the status of diatom red tide events improved but that of flagellate red tide did not. Flagellate red tide species are known to occur due to changes in the composition of nutrients (Oh, *et al.*, 2005).

- Change of DO from surface to bottom layer

In the refined NOWPAP Common Procedure, the depth of DO as an assessment parameter was changed from surface to bottom. This change reflected the opinions from experts in NOWPAP member states that low oxygen levels are likely to occur in the bottom layer and affect organisms there. For the case study sea areas, bottom layer DO data was used in the assessment with the exception of Toyama Bay, where insufficient length of observation was recorded. Some case studies also followed the suggestion to use the annual minimum value as the DO assessment value.

For the case study of Jiaozhou Bay, improvement in the annual mean value of bottom layer DO was observed. In Jinhae Bay, the annual minimum DO value at the bottom layer in August was lower than the background value taken at Gijiang coast, and the assessment results indicated a more accurate reflection of the eutrophication level.

Bottom layer DO levels were also used in the North Kyushu sea area, considering that organisms that are more likely to be affected by low oxygen levels exist. The DO assessment results in sub-area D of the North Kyushu sea area was HN for surface layer DO in the 2011 assessment, while it was LD using bottom layer DO in the 2013 assessment (eutrophication level of DO was rated as 'Low' when the DO values were above the reference value, and 'High' when the DO values were below the reference value). In the 2013 assessment based on the bottom layer, DO levels improved. Results of bottom layer DO measurements were consistent with the classification results of the other assessment parameters in sub-area D that were mainly classified as L. Therefore, using the bottom layer DO as an assessment parameter was considered to accurately reflect the eutrophication status.

In Peter the Great Bay, they used bottom layer DO data in summer and confirmed the occurrence of anoxic waters.

- Addition of transparency

Transparency was added as an assessment parameter in the refined NOWPAP Common Procedure. This addition reflected Korean opinions that decreased transparency has often been observed in Korea due to increase in phytoplankton biomass, and that transparency could be one of the direct or indirect effects of nutrients enrichment. Russia also commented the same. In Japan, the Ministry of the Environment is also considering the inclusion of transparency in environmental standards.

However, both case studies in Korea and Russia have not employed transparency as an assessment parameter, while the North Kyushu sea area has. For the North Kyushu sea area, the number of assessment parameters in Category III increases by the addition of transparency. In Dokai Bay, the reliability of assessment results in Category III was strengthened, because an increasing trend of transparency was seen in correspondence with a decreasing trend of COD. Transparency has been monitored since the 18^{th} century due to its easy survey method (Falkowski *et al*., 1992), and Japan has long-term observation data. Therefore, use of transparency as one of the assessment parameters in NOWPAP areas is expected in the future.

On the other hand, for areas that are originally turbid such as the Ariake Sea, increase of red tide events may occur when transparency became higher. There is a possibility of this incident also happening in the coastal areas of China and Korea, as reported in the Saemangeum coastal area of Korea that experienced an increase in Chl-*a* concentration in clearer water after dyke construction (Min *et al*., 2008). Therefore, it is necessary to take this into consideration when conducting an assessment using transparency.

- Other revisions in the comprehensive procedure

In the refined NOWPAP Common Procedure, all assessment parameters in the comprehensive assessment procedure as well as some of the methods for obtaining assessment and reference values were reevaluated.

➢ Method for obtaining assessment values

The refined NOWPAP Common Procedure recommends the use of seasonal means and raw data for assessment parameters in addition to the annual mean or annual maximum value. This change reflects comments from the NOWPAP member states that the annual minimum value should be referenced because bottom layer DO value is lowest in summer and affects organisms greatly. For this case study, Japan, Korea, and Russia employed the annual minimum of bottom layer DO, while China used the annual mean value. China also used the annual mean value for DIN and DIP while other countries used winter mean values. However, there was no explanation as to why they used the annual mean as the bottom layer DO assessment value. When using assessment values other than those recommended in the refined NOWPAP Common Procedure, it is advisable to state the reasons.

- Method for obtaining reference values

A common set of reference values is not created because it is preferable to establish their own reference values in each case study area based on their marine environments such as the carrying capacity of ecosystems. The reference values for TN, TP, DIN, DIP and COD are the environmental standards of each country or 150 % (67 % for only DO) of the background values. On the other hand, red tides, fish kills incidents, and shellfish poisoning incidents were evaluated based on the number of events. Mostly the reference values in the CEARAC Report 2011 were used, such as one event in recent three years (for diatom and flagellate red tide, fish kill incidents, and shell fish poisoning), or three events in three years (for *Noctiluca* red tide).

For reference values for bottom layer DO, there were a variety of values used in case studies. China used reference values of eutrophication threshold in literature, Korea used 4 mg/L (67 % of the OSPAR Common Procedure value 6 mg/L), Japan used fisheries water standards and values in literature, and Russia used the mean of literature values. It may be possible to unify the reference value for bottom layer DO because regardless of environmental carrying capacity, oxygen levels below a certain value directly lead to death of benthic organisms. Therefore, a discussion of establishing a common reference value for DO in NOWPAP sea area is needed in the future.

For the annual mean of Chl-*a*, Korea used 150 % of the background value, while Russia used the OECD index of 8 μg/L. China and Japan's North Kyushu sea area and Toyama Bay used 5μg/L taken from Bricker (2003). Since 5 μg/L adopted in China and Japan appropriately assessed the status of eutrophication in China and Japan, this value could be used for the satellite Chl-*a* data in the screening procedure. Nevertheless, the value of the threshold may require adjustment when this methodology is applied to other areas. The threshold value should be determined reflecting the level of Chl-*a*, which causes undesirable conditions in each assessment area. If the assessment area is limited to enclosed bays or estuaries, the threshold values can be determined at a local level by local experts taking into account sources of nutrients and carrying capacity of environment in each enclosed bay and estuary. In contrast, if the assessment covers a large area such as the entire NOWPAP sea area, the determination of such threshold values needs further discussion among scientists at national and international levels taking into account a wide variety of nutrient sources as well as seasonal and interannual variability of Chl-*a*.

- Assessment period and statistical method for trend classification

The assessment period for detecting trend depends on the number of years of available data to be collected. It was 13, 25 to 36, 10 to 43, 2 to 33 and 9 to 11 in Jiazhou Bay, North Kyushu sea area, Toyama Bay, Jinhae Bay and Peter the Great Bay, respectively. For the statistical method of trend detection, China and Japan used the Mann-Kendall test, Korea used linear regression due to lack of data points, and Russia also used linear regression. It was possible to use Man-Kendall in Russia and Korea because the trend can be calculated with only four data points if the significance level is set at 10 %.

In the future, it is recommended to use Man-Kendall for detection of trend because it may be possible to compare the results in different case study areas.

5 Conclusion and recommendations

5.1 Conclusion

Case studies to assess the eutrophication status in the selected sea areas were conducted using the refined NOWPAP Common Procedure. Application of the screening procedure including use of satellite data was useful to detect symptoms of eutrophication within the selected sea areas. Combined use of the screening and comprehensive procedures was still necessary in some case studies to validate assessment results obtained by the screening procedure in the selected sea areas. Newly added parameters such as DO at the bottom layer and transparency in the comprehensive procedure as recommended parameters improved the reliability of the assessment results. Setting common assessment values for DO at the bottom layer and Chl-*a* was suggested. Necessity to unify statistical methods to detect long-term trends was also acknowledged.

5.2 Recommendations to address eutrophication in the NOWPAP region

In the refined NOWPAP Common Procedure, there are two steps in assessing the eutrophication status: screening procedure (initial diagnosis) to detect symptoms of eutrophication with the minimum required parameters; and comprehensive procedure (second diagnosis) to assess the status and possible causes of eutrophication using the existing four categories (degree of nutrient enrichment, direct effects of nutrient enrichment, indirect effects of nutrient enrichment, and other possible effects of nutrient enrichment). As all of the currently selected sea areas have shown symptoms of eutrophication in the past and/or currently, the comprehensive procedure was subsequently applied to each selected sea area.

Although it is expected that the eutrophication status of the entire NOWPAP sea area will be assessed in the long run, application of the refined NOWPAP Common Procedure to the entire NOWPAP sea area may require extensive efforts in collecting and analyzing monitoring data, and it may not be fully carried out due to lack of data and resources.

Therefore, trial application of the screening procedure for the whole NOWPAP region with limited parameters can be suggested as a next step to identify and visualize potential eutrophic zones in the NOWPAP region. Enhancing autonomous use of the comprehensive procedure is suggested to help plan management actions against eutrophication in the member states.

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List of acronyms

ADEOS-I: Advanced Earth Observing Satellite-I

BOD_5: Biochemical Oxygen Demand

CCICED: China Council for International Cooperation on the Environment and Development

CEARAC: Special Monitoring and Coastal Environmental Assessment Regional Activity Centre

COD: Chemical Oxygen Demand

COD_{Cr}: Chemical Oxygen Demand by Potassium Dichromate

DIN: Dissolved Inorganic Nitrogen

DINRAC: Data and Information Network Regional Activity Centre

DIP: Dissolved Inorganic Phosphate

DO: Dissolved Oxygen

DSi: Dissolved Silicic acid

FPM: Focal Points Meeting

HABs: Harmful Algal Blooms

HD: High-Decrease

HELCOM: The Baltic Marine Environment Protection Commission (Helsinki Commission)

HI: High Increase

HN: High-No Trend

ICARM: Integrated Coastal and River Basin Management

JAXA: Japan Aerospace Exploration Agency

Low-Decrease

LI: Low-Increase

LN: Low-No Trend

MEP: The Ministry of Environmental Protection of the People's Republic of China

MODIS: Moderate Resolution Imaging Spectroradiometer

MODIS-A: MODIS on board Aqua

MPCs: Maximum Permissible Concentrations

N: Nitrogen

NASA: National Aeronautics and Space Administration

NPEC: Northwest Pacific Region Environmental Cooperation Center

NOAA: National Oceanic and Atmospheric Administration

NOWPAP: Northwest Pacific Action Plan

NOWPAP Common Procedure: Procedures for the assessment of eutrophication status including evaluation of land based source of nutrients for the NOWPAP region

NSQS: National Seawater Quality Standard of China

OBPG: NASA Ocean Biology Processing Group

OCTS: Ocean Color and Temperature Scanner

OSPAR: Convention for the Protection of the Marine Environment of the North-East Atlantic (originally the Oslo and Paris Conventions)

P: Phosphorus

POMRAC: Pollution Monitoring Regional Activity Centre

PSP: Paralytic Shellfish Poisoning

RAP MALI: The NOWPAP Regional Action Plan on Marine Litter

RAC: Regional Activity Center

RSP: UNEP Regional Seas Programme

ROSHYDROMET: The Russian Federal Service on Hydrometeorology and Environmental Monitoring
SeaWiFS: Sea-viewing Wide Field-of-view Sensor
SS: Suspended Substance
TMS: Tele-Monitoring System
TN: Total Nitrogen
TP: Total Phosphorus
TPLCS: Total Pollutant Load Control System
TWPLMS: Total Water Pollution Loading Management System
UNEP: United Nations Environment Programme
WG3: Working Group 3 on Harmful Algal Blooms
WG4: Working Group 4 on Remote Sensing
YSLME: Yellow Sea Large Marine Ecosystem

Annex A List of literature related to negative impact of eutrophication and ecological modeling

China

Literature	Findings	Language
Zhao, Q., 2010.The seasonal variation of nutrient and comparison of several eutrophication assessment method in Qingduizi Bay. Master's Thesis. Liaoning Normal University.	Qingduizi Bay is located in Liaoning Province and the East of Liaodong Peninsula. Using OSPAR Common procedure, the Qingduizi Bay was rated as "problem sea area", although some of the indicators in type II and type III were unavailable.	Chinese
Wu, J. H., Wang, N. B., Zhang, Y. F., 2013. Distribution and variation of dissolved oxygen in Dalian Bay and its relationship with the nutrients in summer. Marine Science Bulletin.32 (1): 66-71.	Dalian Bay is adjacent to the city of Dalian, and the investigation indicated that the DO was 5.66-8.59 mg/L in the surface (average:7.66) and 4.58-8.25 mg/L in the bottom layers (average: 7.12). An decreasing trend was observed from the nearshore to offshore.	Chinese
Qiu, C. X., Shao, M. H., Li, Y. N., 2005. Assessment on the status of ecology and environment in Dalian Bay. Journal of Dalian Maritime University. 31 (1): 77-80.	In the investigation of Dalian Bay, the ranges of cell abundance of phytoplankton were 2.8-45.0 $\times 10^4$ cells/L with an average of 19.3. The bay was rated as eutrophic according to nutrient index method.	Chinese
Zhang, Z. F., Zong, H. M., Wang, Y., et al., 2012. The distribution and their correlation of Bio-active P and Chl-*a* in the Dalian Bay. Environmental Chemisty. 31(4): 554-555.	The investigation held in four seasons in 2010 indicated that the annual mean Chl-*a* concentration were 7.12-10.4 µg/L for 4 sites inner the bay and 4.20 for 1 site in the mouth of the bay.	Chinese
Hu, Y. Y., Wang, J. Y., Zong, H. M., et al., 2011. Development of Pressure and State assessment method for coastal eutrophication and application in Liaodong Bay. Scientific Research of Conference on Environmental Pollution and Public Health. (CEPPH2011)	Liaodong Bay is in the north of Bohai Sea. The methodology used both index of pressure and symptoms-based evaluation of state. The trophic status of Liaodong Bay was rated as Moderate Low (equal to Good in ASSETS). No hypoxia was recorded. 1 to 2 occurrences of Red tide events were recorded each year from 2001 to 2006.	Chinese

Literature	Findings	Language
Zhang, Q. L., Zhang, X. L., Wang, X., et al., 2009. Assessment of eutrophication in southeast of Liaodong Bay. Coastal Engineering. 28(1): 38-43.	Using 4 seasons investigation data in 2006, the southeast of Liaodong Bay was rated as "Potential Problem Area"	Chinese
Wu, Z. X., Yu, Z. M., Song, X. X., et al. 2013. Application of an integrated methodology for eutrophicaion assessment: A case study in the Bohai Sea. Chinese Journal of Oceanology and Limnology. 31(5). (Volume In progress)	In this study, the trophic status in Bohai Bay and Laizhou Bay in 2007 and 2008 were assessed using a symptom-based method, which integrate both water quality and ecological effects indicators. The results showed that the north Bohai Bay was rated as "Bad,5" or"Poor,4", while west Laizhou Bay was also rated as "Poor,4". Red tide events in Bohai Bay were frequent in recent 10 years.	English
Zhang, J. H., Wang, W., Han, T. T., 2012. The distributions of dissolved nutrients in spring of Sungo (Sanggou) Bay and potential reason of outbreak of red tide. Journal of Fisheries of China. 36 (1) :132-139.	Sungo Bay was in the east of Shandong Peninsula. Red tide events in Sungo Bay were rare before and began to occur in recent 2 years. The coverage is wide and duration was almost 40 years long.	Chinese
Yao, Y. and Shen, Z. l.2004. Assessment of seawater eutrophication in the Jiaozhou Bay. Marine Science. 28(6): 14-22.	North of Jiaozhou Bay was rated as eutrophic using fuzzy logic method, with indicators of nutrients, DO and Chl-*a*.	Chinese
Wu, Z. X., Yu, Z. M., Song, X. X., et al. 2013.An intergrated methodology for eutrophication assessment based on both water quality and ecological response: a case study in typical coastal areas of Shandong Peninsula. (In press)	Several Bays and coastal areas along the Shandong Peninsula were assessed based on an integrated method which considered eutrophication symptoms. The Sishili Bay and Dingzi Bay in Yantai, the Jiaozhou Bay in Qingdao were three Bays with most serious eutrophic conditions, with categories of "poor,4". Coastal areas of the city of Rizhao and Huangdao were areas with "good, 2" trophic status.	Chinese
Shen, Z. L., 2001. Historical changes in nutrient structure and its influences on phytoplantkon composition in Jiaozhou		English

Literature	**Findings**	**Language**
Liu, Y. H., Song, X. K., Jin, Y., et al. 2012. Occurrence characteristics of akashiwo sanguine bloom caused by land source rainwater. Acta Ecologica Sinica. 32 (15):4836-4843.	Sishili Bay was adjacent to the city of Yantai in Shandong Peninsula. Land source rainwater has contributed to a high frequency of red tide events in this bay. During the red tide events, the Chl-*a* concentrations could reach 44.4-70.2μg/L in the surface layer.	Chinese
Qian, Y., Zhang, Y., Liu, J. T., 2008. The investigation of red tide disaster and its causation in coastal waters of Haizhou Bay. Tansactions of Oceanology and Limnology. 3:191-196.	Haizhou Bay is adjacent to the city of Lianyungang in Jiangsu Province. Occurrence of red tide was also frequent in this Bay, with 7 times from 2004 to 2006. The bay has been set as an important monitoring district for red tide.	Chinese
Xiao, Y. J., Ferrerira, J. G., Bricker, S. B., et al. 2007. Trophic assessment in Chinese coastal systems: review of methods and application to the Changjiang (Yangtze) estuary and Jiaozhou Bay. Estuaries Coasts, 30 (6):901-918.	Jiaozhou Bay was rated as “Good, 2” using ASSETS method, considering its top-down control of filter shellfish. These effects had resulted in a low susceptibility of Jiaozhou Bay.	English
Dong, K. S., Wang, Y., Yang, Z., et al., 2007. Characteristics of chlorophyll-*a* distribution in Jiaozhou Bay in summer and winter. Periodical of ocean university of China. 37 (sup:II): 127-130.	According to the investigation data in 2006 and 2007, the average Chl-*a* in different sampling sites ranges from 2.11 – 5.93μg/L.	Chinese
Sun, P. X., Wang, Z. L., Zhan, R., et al., 2005. Study on Dissolved inorganic nitrogen distributions and eutropchication in the Jiaozhou Bay. Advances in marine science. 23 (4): 466-471.	The assessment results indicated that the north and east of Jiaozhou Bay were the eutrophic areas using nutrient index method.	Chinese

Japan

Literature	Findings	Language
Hamada, K., Ueda, N., Yamada, M., Tada, K., and Montani, S. (2010) Oxygen-deficient water volume and marine lower trophic processes in Dokai Bay after large decreases in nutrient concentrations	In Dokai Bay, no change was observed after achieving environmental standard in concentration of Chl-*a* and quality and quantity of particulate organic substances while concentration of nitrogen drastically decreased. No change was observed in the scale of oxygen depleted water body while its duration is considered to be shorter. As a result, it became clear that changes of scale are small in low trophic production process and oxygen depleted water body in the bay before and after environmental standards were achieved.	Japanese
Kim, H., Yoo, S., and Oh, I.S. (2007) Relationship between phytoplankton bloom and wind stress in the sub-polar frontal area of the Japan/East Sea.	The relation between phytoplankton bloom and wind was analyzed using simple model of light and nutrients. As a result, it was considered that the beginning of blooming was related to the past record of wind.	English
Nagata, H. and Nakura, N. (1993) Seasonal changes of river discharge and chlorophyll-*a* concentration in Toyama Bay, Southern Japan Sea. Bull Jpn Sea Natl Fish Res Inst 43:55–68 (In Japanese with English abstract)	In order to understand the characteristics of plankton productivity in Toyama Bay, nutrient concentration, chlorophyll-*a* stocks, and zooplankton biomass were routinely measured by the Toyama and Ishikawa Prefectural Fisheries Experiment Stations from 1981 to 1983. Based on the results, the Bay area was divided into three sub-areas and the trend of each area was analyzed.	Japanese
Ohnishi, M., Ishizaka, J., Kasahara, H., Nagata, H., Shirayama, H., Uchiyama, I., and Terauchi, G. (2007) Chlorophyll-*a* distribution in Toyama Bay, Japan, during 1998 and 1999 as observed by Ocean color satellite. Oceanogr Jpn 16:7–22 (In Japanese with English abstract)	In order to show the usefulness of ocean color satellite data, chlorophyll-*a* concentrations in Toyama Bay, Japan, during 1998 and 1999 were observed by an ocean color satellite sensor, SeaWiFS, and were analyzed. The result indicates that the high satellite chlorophyll during summer was related to the input of nutrients by freshwater, such as river flow. Anti-cyclonic flow patterns were observed with the short-term changes of the satellite chlorophyll distribution, and inflow of the Tsushima warm current could have sporadically carried out the high satellite chlorophyll water from the head of the bay to its outside.	Japanese
Onitsuka, G. and Yanagi, T. (2005) Differences in Ecosystem Dynamics between the Northern and Southern Parts of the Japan Sea: Analyses with Two Ecosystem Models.	The ecosystem activity difference in north and south of the Sea of Japan was analyzed using “NPZD model” and “COM9 model” (ecosystem model composed of NH4, NO3, 2 species of phytoplankton, 3 species of zooplankton, DON, and PON). As a result, it was considered that the difference of blooming timing was related to nutrient concentrations in surface water and phytoplankton.	English

Literature	Findings	Language
Onitsuka, G., Yanagi, T., and Yoon, J.H. (2007) A numerical study on nutrient sources in the surface layer of the Japan Sea using a coupled physical-ecosystem model.	Nutrient source of surface of the Sea of Japan was estimated using "NPZD model". As a result, it was considered that huge nutrient source in south of the Sea of Japan is located in the east coast of Korea; and nutrient flux flowing through Tsushima-Korea strait affects nutrient concentrations at the coastal area of the Sea of Japan and productivity in the Sea of Japan.	English
Terauchi, G. and Ishizaka, J. (2007) Eutrophication monitoring by satellite remote sensing in Toyama Bay.	The Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region (NOWPAP) was adopted as a part of the Regional Seas Programme of the United Nations Environmental Programme (UNEP). Northwest Environmental Cooperation Center (NPEC), designated as a Special Monitoring & Coastal Environmental Assessment Regional Activity Centre of NOWPAP, conducted a case study to evaluate the usefulness and limitation of remote sensing between 1998 and 2003 with support from the Ministry of the Environment of Japan. The findings indicate that satellite remote sensing could be a useful tool for monitoring the environment in the coastal area of Toyama Bay as a supplementary technique to compensate for the lower monitoring frequency of monthly shipboard measurement.	Japanese
Tian, T., Hao, W., Jian, S., and Changsoo, C. (2005) Simulations of annual cycle of phytoplankton production and the utilization of nitrogen in the Yellow Sea.	Seasonal change of phytoplankton and nutrient use in Yellow Sea were analyzed using ecosystem model. As a result, it became clear that in Yellow Sea, phosphorus is the limiting factor to the primary production; and nutrients' elution from bottom sediments largely affects primary production.	English
Wei, H., Sun, J., Moll, A., and Zhao, L. (2004) Phytoplankton dynamics in the Bohai Sea - observations and modeling.	To figure out phytoplankton blooming in eutrophicated Bohai Sea, "ECOHAM model" (nutrients, phytoplankton, bottom detritus) was used. As a result, it was shown that the change of phytoplankton was highly influenced by water temperature, nutrients, light, and especially transparency. Blooming in spring ends at depletion of nutrients and blooming in autumn is caused by land-based nutrient inputs and the elution from sea bottom.	English
Yanagi, T., Onitsuka, G., Hirose, N., and Yoon J.H. (2001) A Numerical Simulation on the Mesoscale Dynamics of the Spring Bloom in the Sea of Japan.	Phytoplankton blooming in the Sea of Japan was simulated using "NPZD model" (ecosystem model composed of nutrients, phytoplankton, and detritus). As a result, it was considered that blooming in spring in the Sea of Japan is related to water temperature and limited by depletion of DIN.	English

Literature	Findings	Language
Yanagi, T. and Ishii, D. (2009) Generation and disappearance mechanism of hypoxia in the head of Hakata Bay	As a result of the analysis of field survey in the head of Hakata Bay area, it was considered that phytoplankton density in the surface layer rapidly increased due to huge nutrient inputs by heavy rain in summer and the shallow bottom layer became aphotic zone by self-shading effects. It became clear that oxygen consumption in the bottom layer due to the settlement of organic matters from surface layer and lowering of oxygen supply accompanied by the development of stratification form oxygen depleted water body in the bottom layer in the head of the bay area. It is considered that reduction of nutrient loads from land is the most effective to reduce the oxygen depleted water body in the head of the Hakata Bay area.	Japanese
Zhao, L. and Guo, X. (2008) An ecosystem model in the East China Sea – model description and seasonal variations.	The objectives are to reproduce the seasonal variation and spatial distribution of chlorophyll-*a* and nutrients in the East China Sea with a fully coupled biophysical 3-D model. Results showed that the model is able to reproduce the observed spatial and seasonal variability.	English

Korea

Literature	**Language**
Lee DI, Park CK, Cho HS (2005). Ecological modeling for water quality management of Kwangyang Bay, Korea. Journal of Environmental Management 74: 327-337.	English
Lee D-I, Choi J-M, Lee Y-G, Lee M-O, Lee W-C, Kim J-K (2008). Coastal environmental assessment and management by ecological simulation in Yeoja Bay, Korea. Estuarine, Coastal and Shelf Science 80: 495-508.	English
Lim H-S, Diaz RJ, Hong J-S, Schaffner LC (2006). Hypoxia and benthic community recovery in Korean coastal waters. Marine Pollution Bulletin 52: 1517-1526.	English
Park K, Jung H-S, Kim H-S, Ahn S-M (2005). Three-dimensional hydrodynamic-eutrophication model (HEM-3D): application to Kwang-Yang Bay, Korea. Marine Environmental Research 60: 171-193.	English
APHA, 1999. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, DC.	English
Cho H. Y. and J. W. Chae. 1998. Analysis of the Characteristics of the pollutant load in Chinhae-Masan Bay. Journal of Korean Society of Coastal and Ocean Engineers. 10(3): 132-140 (in Korean).	Korean
Kim J. H. 1984. Seawater exchange in Chinhae bay Pukyong Nat'l Univ. MS Thesis. 36 pp (in Korean).	Korean
Lee J. H. 1998. Policy issues and management framework of Chinhae Bay, Republic of Korea. Ocean & Coastal Management. 38: 161-178.	English
Lee I. C., Y. J. Oh and H. T. kim. 2008. Annual variation in oxygen-deficient water mass in jinhae bay, Korea. J. of. kor. Fish. soc. 41(2): 134-139 (in Korean).	Korean
MOMAF. 2002. Improving coastal environment of Coastal Environmental Management Area (CEMA) (In Korean).	Korean
Nam J.H., D. S Kang, J. S. Yoon, A. A. Yoon, J. Y. Choi, H. J. Choi, H. H. Lim and J. D. kim. 2005. Management Strategies for the Coastal Environment of the Masan-Chinhae Bay. Proceeding of the workshop on ecosystem management of interrelated river basins, esturies and coastal sea. 104-112 pp.	English
Oh H. T., W. C. Lee. S. E. Park, S. J. Hong, R. H. Jung and J. S. Park. 2006. Marine ecosystem response to nutrient input reduction in Jinhae Bay, South Korea. Journal of Environmental Sciences. 9: 819-827.	English
OSPAR, 2001. Draft common assessment criteria and their application within the comprehensive procedure of the common procedure. Meeting of the Eutrophication Task Group, London, 9–11 October 2001. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.	English
OSPAR, 2005. Revised common procedure for the identification of the eutrophication status of the OSPAR Maritime Area. Ref. Numb. 2005-3. OSPAR Commission.	English
Painting S. J., M.J. Devlin, S.I. Rogers, D.K. Mills, E.R. Parker, H.L. Rees. 2005. Assessing the suitability of OSPAR EcoQOs for eutrophication vs ICES criteria for England and Wales. Marine Pollution Bulletin 50: 1569–1584.	English

Literature	Language
Park S. C., K. W. Lee and Y. I. Song. 1995. Acoustic characters and distribution pattern of modern fine-grained deposits in a tide-dominated coastal bay: Jinhae bay, Southeast Korea. Geo-Marine Letters. 15: 77-84.	English
Redfield A.C. 1934. On the proportions of organic derivatives in sea water and their relation to the composition of plankton. In: Daniel, R.J. (Ed.), James Johnstone Memorial Volume. University of Liverpool Press, Liverpool, UK, pp. 176-192.	English
Shin S. Y, C I Lee, S-C. Hwang and K. D. Cho. 2004. Relationship between pollution factors and environmental variation in waters around Masan Bay. Journal of the Korean Society of Marine Environment and Safety. 10(2): 69-79 (in Korean).	Korean
Smayda, T.J. 1990. Novel and nuisance phytoplankton blooms in the sea: evidence of a global epidemic. In: Grane´ li, E., Sundstrom, B., Edler, L., Anderson, D. (Eds.), Toxic Marine Phytoplankton. Elsevier, pp. 29-40.	English
Oh HT, Lee WC, Koo JH, Park SE, Hong SJ, Jung RH, Park JS (2006) Marine Ecosystem Response to Nutrient Input Reduction in Jinhae Bay, South Korea J Environ Sciences 15(9): 819-827	English
Cho C-H (1991). Mariculture and eutrophication in Jinhae Bay, Korea. Marine Pollution Bulletin 23: 275-279.	English
Chang WK, Ryu J, Yi Y, Lee W-C, Lee C-W, Kang D et al (2012). Improved water quality in response to pollution control measures at Masan Bay, Korea. Marine Pollution Bulletin 64: 427-435.	English
Lim H-S, Diaz RJ, Hong J-S, Schaffner LC (2006). Hypoxia and benthic community recovery in Korean coastal waters. Marine Pollution Bulletin 52: 1517-1526.	English

Russia

Literature	Language
Andersen J.H., Schlüter L., and Ærtebjerg G. (2006) Coastal eutrophication: recent developments in definitions and implications for monitoring strategies. J. Plankton Research, 28, 621-628.	English
Anikiev V.V. (1987) Short-scale of geochemical processes and pollution of ocean. Moscow. Nauka. 192 p.	English
Belan T.A. (2003) Benthos abundance pattern and species composition in conditions of pollution in Amursky Bay (Peter the Great Bay, Sea of Japan). Marine Pollution Bulletin, 46, 1111–1119.	English
Belan, T.A., Tkalin A.V., Lishavskaya T.S. (2003) The present status of bottom ecosystems of Peter the Great Bay (the Sea of Japan). Pacific Oceanography, 1, 158–167.	English
Belan T.A., Moshchenko A.V. (2005) Polychaete taxocenes variability associated with sediment pollutionloading in the Peter the Great Bay (East Sea/Japan Sea). Ocean Science Journal, 40, 1-10.	English
Belan T.A., Belan L.S. (2006) Composition and Quantitative Distribution of Macrozoobenthos in Amursky Bay. Okeanology, 46, 685-694. (Rus.).	Russian
Boyarova M.D., Lukyanova O.N. (2012) Persistent organochlorine pesticides in bivalve mollusks and fish from Peter the Great Bay, pp 334-345. Current Ecological State of Peter the Great Bay, Sea of Japan. Ed. N.K. Khristoforova. Vladivostok: Far Eastern Federal Univ. Press. (Rus.).	Russian
CEARAC 2011. Integrated report on eutrophication assessment in selected sea area in the NOWPAP region: evaluation of the NOWPAP Common Procedure. 28, 2011, pp 111. ISBN 978-4-9902809-5-6.	English
Dolganova N.T. (2005) Plankton researches in TINRO: history, directions, results. Izv. TINRO, 141, 209–228.	English
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Annex B List of available monitoring data for eutrophication assessment in each NOWPAP member state

China

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey points
Jiaozhou Bay	Jiaozhou Bay Marine Ecosystem Research Station	Routine monitoring of ecological quality of the Jiaozhou Bay.	To understand the ecological quality and status of Jiaozhou Bay under longterm human pressures.	1981-	COD, nutrient, petroleum, heavy metals, PCB, BHC, DDT, diversity index, pollutant sources, red tide.	4-12 times/year	12
Shuangtaizi estuary ecological monitoring district	State Oceanic Administration and Liaoning Marine and Fishery bureau	Monitoring of ecological quality of the estuary	To understand the status of the ecosystem health.	2004-	Marine chemistry, Biodiversity, hydrodynamics, and pollutants.	Not reported	Not reported
Yellow River estuary ecological monitoring district	State Oceanic Administration and Shandong Marine and Fishery bureau	Monitoring of ecological quality of the estuary	To understand the status of the ecosystem health.	2004-	Marine chemistry, Biodiversity, hydrodynamics, and pollutants.	Not reported	Not reported
Bohai Bay ecological monitoring district (Not in the scope of NOWPAP region)	State Oceanic Administration and Tianjin, Shandong Marine and Fishery bureau	Monitoring of ecological quality of the bay.	To understand the status of the ecosystem health.	2004-	Marine chemistry, Biodiversity, hydrodynamics, and pollutants.	Not reported	Not reported

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey points
Laizhou Bay ecological monitoring district	State Oceanic Administration and Shandong Marine and Fishery bureau	Monitoring of ecological quality of the bay.	To understand the status of the ecosystem health.	2004-	Marine chemistry, Biodiversity, hydrodynamics, and pollutants.	Not reported	Not reported
Subei shoal ecological monitoring district	State Oceanic Administration and Jiangsu Marine and Fishery bureau	Monitoring of ecological quality of the coastal area.	To understand the status of the ecosystem health.	2004-	Marine chemistry, Biodiversity, hydrodynamics, and pollutants.	Not reported	Not reported
Beidaihe River estuary ecological monitoring district	State Oceanic Administration and Hebei Marine and Fishery bureau	Monitoring of ecological quality of the estuary	To understand the status of the ecosystem health.	2004-	Marine chemistry, Biodiversity, hydrodynamics, and pollutants.	Not reported	Not reported
Tianjin Civic Sea area	Tianjin City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO, pH.	2/annual	Not reported
Tianjin Civic Sea area	Tianjin City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Tianjin Civic Sea area	Tianjin City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey points
Tianjin Civic Sea area	Tianjin City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported
Tianjin Civic Sea area	Tianjin City Ocean administration	Monitoring of water quality of the coastal bathing beaches	To understand the status of water quality of the coastal bathing beaches	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/week	Not reported
Weifang Civic Sea area	Weifang City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported
Weifang Civic Sea area	Weifang City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Weifang Civic Sea area	Weifang City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Weifang Civic Sea area	Weifang City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported
Qinhuangdao Civic Sea area	Qinhuangdao City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported

Survey area	**Governing organization**	**Survey title**	**Aim**	**Survey period**	**Main survey parameters**	**Survey frequency**	**No. of survey points**
Qinhuangdao Civic Sea area	Qinhuangdao City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Qinhuangdao Civic Sea area	Qinhuangdao City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Qinhuangdao Civic Sea area	Qinhuangdao City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported
Qinhuangdao Civic Sea area	Qinhuangdao City Ocean administration	Monitoring of water quality of the coastal bathing beaches	To understand the status of water quality of the coastal bathing beaches	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/week	Not reported
Dongying Civic Sea area	Dongying City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported
Dongying Civic Sea area	Dongying City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Dongying Civic Sea area	Dongying City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey points
Dongying Civic Sea area	Dongying City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported
Chuangzhou Civic Sea area	Chuangzhou City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported
Chuangzhou Civic Sea area	Chuangzhou City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Chuangzhou Civic Sea area	Chuangzhou City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Chuangzhou Civic Sea area	Chuangzhou City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported
Huludao Civic Sea area	Huludao City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported
Huludao Civic Sea area	Huludao City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey points
Huludao Civic Sea area	Huludao City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Huludao Civic Sea area	Huludao City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported
Huludao Civic Sea area	Huludao City Ocean administration	Monitoring of water quality of the coastal bathing beaches	To understand the status of water quality of the coastal bathing beaches	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/week	Not reported
Yingkou Civic Sea area	Yingkou City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported
Yingkou Civic Sea area	Yingkou City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Yingkou Civic Sea area	Yingkou City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Yingkou Civic Sea area	Yingkou City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported

Survey area	Governing organization	Survey title	Aim	Survey period	Main Survey parameters	Survey Frequency	No. of survey points
Jinzhou Civic Sea area	Jinzhou City Ocean administration	Monitoring of environmental quality of the sea waters	To understand the status of environmental quality of the sea waters	1972-	COD, TN, TP, DIN, DIP, DO , pH.	2/annual	Not reported
Jinzhou Civic Sea area	Jinzhou City Ocean administration	Monitoring of land-based water discharge outlets into the sea and the water quality of adjacent sea areas.	To understand the status of water quality of the sea areas adjacent to the land-based waste water discharge.	2003-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Jinzhou Civic Sea area	Jinzhou City Ocean administration	Monitoring of water quality of the marine aquaculture zones	To understand the status of water quality of the marine aquaculture zones	2004-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual	Not reported
Jinzhou Civic Sea area	Jinzhou City Ocean administration	Monitoring of water quality of the HABs surveillance zones	To understand the status of water quality of the HABs surveillance zones	2001-	COD, TN, TP, DIN, DIP, DO, pH.	1/annual 1/month	Not reported

Note: The city of Tianjin, Tangshan and Chuangzhou is adjacent to the Bohai Bay, and may not belong to the scope of NOWPAP region.

Japan

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey sites
North Kyushu Sea Area	Environmental Conservation Section, Environmental Bureau, Fukuoka Prefecture	Water quality survey of public waters	Regular monitoring of water quality status	1978-present (chlorophyll-*a*: 1981-present, DIN: 1978-1999, 2001-present)	Ph, BOD, COD, SS, DO, Coliform bacteria, general bacteria、n-Hex, TN, TP, NH_4-N, NO_2-N, NO_3-N, PO_4-P, chlorophyll-*a*, TOC, Transparency, etc.	1-25/year	2012：5,378
Dokai Bay	Environmental Bureau, Kitakyushu City	Survey of Kitakyushu City Institute of Environmental Sciences	Monitoring of hypoxic water	DO: 1994-2000, 2004, 2006-2010 TN and TP (direct input from plants): 1998, 2004-2010	TN and TP, direct input from plants	1-14 / year	DO: 8 TN and TP (direct input from plants): 24
Hakata Bay	Environmental Bureau, Fukuoka City	Measures and survey results of Hakata Bay	Water quality conservation of Hakata Bay	DO:2002- COD, TN , TP:1981-	DO (Shallow sea area), COD, TN , TP	DO：6-25 / year COD, TN , TP: 12 / year	DO :9-10 COD, TN , TP：8
Toyama Bay	Toyama Pref. (Environmental Conservation Division)	Water quality survey of public waters (Water quality survey of sea water)	Monitoring of water quality status	1976 - present (TN, TP: 1997-)	DO, COD, TN, TP	1/month	23 (Coastal: 10 Jinzu: 7 Oyabe: 6)
Toyama Bay	Toyama Pref. (Environmental Conservation Division)	Survey of water quality conservation measures of Toyama Bay (Complementary survey)	Understanding of eutrophication status in Toyama Bay sea area	1997-	DIN,DIP,chlorophyll-*a*, TN, TP	1/month	9
Other coastal areas in the NOWPAP region	Local governments facing to NOWPAP sea area	Water quality survey of public waters (Water quality survey of sea water)	Monitoring of water quality status	1976 - present	Eutrophication items (COD, TN, TP, etc)		

Survey area	**Governing organization**	**Survey title**	**Aim**	**Survey period**	**Main survey parameters**	**Survey frequency**	**No. of survey sites**
Sea areas around Japan (coastal waters to offshore)	Ministry of Environment	Monitoring survey of ocean environment	Monitoring of seawater pollution status	Chlorophyll-*a* and DO: 1998, 2001, 2004 DIN and DIP: 1996, 1998, 2001, 2004	Water temp., salinity, DO, nutrients, chlorophyll-*a*, pheophytin, boron, fluorine, etc.	1/year	42
Toyama Bay	Toyama Pref. (Environmental Conservation Division)	Basic research on a prediction model	Accuracy improvement of a prediction model by organizing data of nutrients from rivers	2005-	Estimate of input loads (TN, TP) (1985-2004)	2005 ONLY	
Hibiki sea, Genkai sea	Fukuoka Fisheries and Marine Technology Research Center	Fixed-line survey of shallow waters	Monitoring of ocean status between Nansei Islands and west of Japan Sea	1972-present (TN and TP: 1995-1997, chlorophyll- *a*: 1975-present)	NH_4-N, NO_2-N, NO_3-N, PO_4-P, DO, COD, chlorophyll-*a*, transparency	1-12/year	13
North Kyushu Sea Area	Kyushu Fisheries Coordination Office, Fisheries Agency	Red-tide survey	Recording of red-tide incidents	1978-present	Red-tide status and duration, damage to fisheries	When red tide occurs	—
Toyama Bay	Toyama Prefectural Agricultural, Forestry and Fisheries Research Center, Fisheries Research Institute	Red-tide survey	Survey of red-tide events and report of related information	1966-	Extent of occurrence, types of phytoplankton, density	When red tide occurs	
Toyama Bay	Toyama Prefectural Agricultural, Forestry and Fisheries Research Center, Fisheries Research Institute	Comprehensive environmental survey of fishing ground in Toyama Bay	Understanding of fishing ground environment inside Toyama Bay	2006	DIN,DIP, Chlorophyll-*a*, TN, TP, DO	4 / year	36

Korea

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameter	Survey frequency	No. of point
Busan-Jinhae Bay	Headquarter/NFRDI	Coastal Environment Monitoring	To monitor the status of water quality and ecosystem health	1972-	W.T., Salinity, COD, SS, pH, DO, Chl-*a*, TN, TP, DIN, DIP, SiO_2, heavy metal, PCBs, TBT, PAHs, Dioxin	6/year (4/year before 2009)	44
East coast	East Sea Regional Fisheries Research Institute/ NFRDI	Coastal Environment Monitoring	To monitor the status of water quality and ecosystem health	1972-	W.T., Salinity, COD, SS, pH, DO, Chl-*a*, TN, TP, DIN, DIP, SiO_2, heavy metal, PCBs, TBT, PAHs, Dioxin	6/year (4/year before 2009)	36
West coast	West Sea Regional Fisheries Research Institute/ NFRDI	Coastal Environment Monitoring	To monitor the status of water quality and ecosystem health	1972-	W.T., Salinity, COD, SS, pH, DO, Chl-*a*, TN, TP, DIN, DIP, SiO_2, heavy metal, PCBs, TBT, PAHs, Dioxin	6/year (4/year before 2009)	42
Southeast coast	Southeast Sea Regional Fisheries Research Institute /NFRDI	Coastal Environment Monitoring	To monitor the status of water quality and ecosystem health	1972-	W.T., Salinity, COD, SS, pH, DO, Chl-*a*, TN, TP, DIN, DIP, SiO_2, heavy metal, PCBs, TBT, PAHs, Dioxin	6/year (4/year before 2009)	34
Southwest coast	Southwest Sea Regional Fisheries Research Institute/ NFRDI	Coastal Environment Monitoring	To monitor the status of water quality and ecosystem health	1972-	W.T., Salinity, COD, SS, pH, DO, Chl-*a*, TN, TP, DIN, DIP, SiO_2, heavy metal, PCBs, TBT, PAHs, Dioxin	6/year (4/year before 2009)	58
East coast	East Sea Regional Fisheries Research Institute/ NFRDI	Red tide Monitoring	To monitor changes of phytoplankton	1979-	W.T., Salinity, Chl-*a*, nutrient, phytoplankton species	8/year	14

Survey area	**Governing organization**	**Survey title**	**Aim**	**Survey period**	**Main survey parameter**	**Survey frequency**	**No. of point**
West coast	West Sea Regional Fisheries Research Institute/ NFRDI	Red tide Monitoring	To monitor changes of phytoplankton	1979-	W.T., Salinity, Chl-*a*, nutrient, phytoplankton species	8/year	30
Southeast coast	Southeast Sea Regional Fisheries Research Institute/ NFRDI	Red tide Monitoring	To monitor changes of phytoplankton	1979-	W.T., Salinity, Chl-*a*, nutrient, phytoplankton species	10/year	32
Southwest coast	Southwest Sea Regional Fisheries Research Institute/ NFRDI	Red tide Monitoring	To monitor changes of phytoplankton	1979-	W.T., Salinity, Chl-*a*, nutrient, phytoplankton species	8/year	20
Southeast coast	Southeast Sea Regional Fisheries Research Institute/ NFRDI	Monitoring of Harmful Algal Blooms by Cochlodinium species	To monitor bloom dynamics of fish killing species	2000-	Hydrodynamics, nutrient, succession of phytoplankton species	8-10/year (June-October)	12
Southwest coast	Southwest Sea Regional Fisheries Research Institute/ NFRDI	Monitoring of Harmful Algal Blooms by Cochlodinium species	To monitor bloom dynamics of fish killing species	2000-	Hydrodynamics, nutrient, succession of phytoplankton species	8-10/year (June-October)	18
East Sea	East Sea Regional Fisheries Research Institute/ NFRDI	Serial Oceanographic observation	To understand the status of marine environment and ecology for offshore	1961-	Hydrodynamics, nutrient, phytoplankton, zooplankton	4/year	69
Yellow Sea	West Sea Regional Fisheries Research Institute/ NFRDI	Serial Oceanographic observation	To understand the status of marine environment and ecology for offshore	1961-	Hydrodynamics, nutrient, phytoplankton, zooplankton	4/year	52
South Sea	Southwest Sea Regional Fisheries Research Institute/ NFRDI	Serial Oceanographic observation	To understand the status of marine environment and ecology for offshore	1961-	Hydrodynamics, nutrient, phytoplankton, zooplankton	4/year	44

Survey area	**Governing organization**	**Survey title**	**Aim**	**Survey period**	**Main survey parameter**	**Survey frequency**	**No. of point**
East China Sea	Headquarter/NFRDI	Serial Oceanographic observation	To understand the status of marine environment and ecology for offshore	1995-	Hydrodynamics, nutrient, phytoplankton, zooplankton	4/year	32

Russia

A list of available monitoring data related to assessment of eutrophication of Peter the Great Bay in Russia

There are two organizations which carry out environmental monitoring on Peter the Great Bay (PGB) and keep information about this. These are:

1) Prymorsky Center on Hydrometeorology and Environmental Monitoring (PCHEM) was established in 1937. Main goal of the organization is environmental monitoring of atmosphere, hydrosphere and soils.
2) Far Eastern Regional Hydrometeorological Research Institute (FERHRI) was established in 1950. Main goals are development of methods of monitoring systems, modeling for forecasting of environmental changes, carrying out of marine observations.

Both organizations are under umbrella of ROSHYDROMET (FEDERAL SERVICE ON HYDROMETEOROLOGY AND MONITORING OF ENVIRONMENT). ROSHYDROMET is under Russian Government.

However main problem in reconstruction of historical data regarding to eutrophication of Peter the Great Bay is that, row data and annual reports of these observations were unavailable in the open access publications at Soviet time (up to 1991).

Annual reports of the State Oceanographic Institute (SOI), which are available in open access publications and Reviews of Goshydromet, give general information only about contaminations and ecological state of PGB. There is no more detail information than those in publications of the Annual reports of FSBIPAHEM.

There are scientific organizations, which carry out ecological investigations of the PGB. These are:

1. Pacific Scientific Research Fisheries Center (TINRO-Centre) was established in 1925;
2. Far Eastern Federal University (FEFU) was established in 1899;
3. Pacific Geographical Institute Far Eastern Branch of Russian Academy of Sciences (PGI) was established in 1971;
4. A.V. Zhirmunsky Institute of Marine Biology Far Eastern Branch of Russian Academy of Sciences (IMB) was established in 1970
5. V.I.Il`ichev Pacific Oceanological Institute Far Eastern Branch of Russian Academy of Sciences (POI) was established in 1973.

Some institutes contain monitoring centers/laboratory inside itself. These are Harmful Algal Monitoring Center established in 2007 (IBM FEB RAS), Pollution Monitoring Regional Activity Center formed in 1999 (PGI FEB RAS). However main goal of these five organizations is scientific research. These organizations published some books, which are very important for undeserving of how ecosystem of PGB is going.

So there are no regular monitoring data available related to assessment of eutrophication of Peter the Great Bay in Russia and adjacent area. That is why we may use only data obtained by the scientific research in Peter the Great Bay and adjacent area.

Survey Area	Governing Organization	Aim	Survey Period	Main survey parameters	No. of Survey points
North West of Far Eastern Sea (FES) Research Vessel (R/V) “Gordienko”	Far Eastern Regional Hydrometeorological Research Institute (FERHRI)		14.04-23.04 1999		76
FES R/V “REVELLE”	Scripps Institution Oceanography		24.06-15.07 1999		113
FES R/V “Khromov”	FERHRI		22.07-13.08 1999		89
North West of FES R/V “Khromov”			03 2000		81
North of FES R/V “Gagarinsky”	Pacific Oceanological Institute Far Eastern Branch of Russian Academy of Sciences (POI FEB RAS)		12.10-11.03 2000		63
North West of FES R/V “Khromov”	FERHRI		24.02-28.02 2001		52
North of FES R/V “Gagarinsky”	POI FEB RAS	Hydrophysics Hydrochemistry	16.04-06.06 2001	CTD, Nutrients Chl, Oxygen	68
West of FES R/V “Gagarinsky”			12.04-16.04 2002		24
North West of FES R/V “Lavrentjev”			26.02-08.03 2003		66
North West of FES R/V “Gagarinsky”			14.11-24.11 2003		50
West of FES R/V “Lavrentjev”			03.05-19.05 2004		49
North West of FES R/V “Lavrentjev”			16.03-24.03 2005		34
			15.10-01.11 2005		62
West of FES R/V “Lavrentjev”			09.07-19.07 2009		38
North West of FES R/V “Gagarinsky”			05.11-08.11 2009		47

Survey Area	Governing Organization	Aim	Survey Period	Main survey parameters	No. of Survey points
North of FES R/V "HakuhoMaru"	Toyama University	Hydrophysics Hydrochemistry	06-07 2010	CTD, Nutrients, pH, TA, Chl, Oxygen	10
North West of FES R/V "Gagarinsky"	POI FEB RAS		29.09-07.10 2011		140
North West of FES R/V "Lavrentjev"			27.10-08.11 2011		111
North West of FES R/V "Gagarinsky"			18.04-19.04 2012		30

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

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. Phytoplanktons 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 are 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.

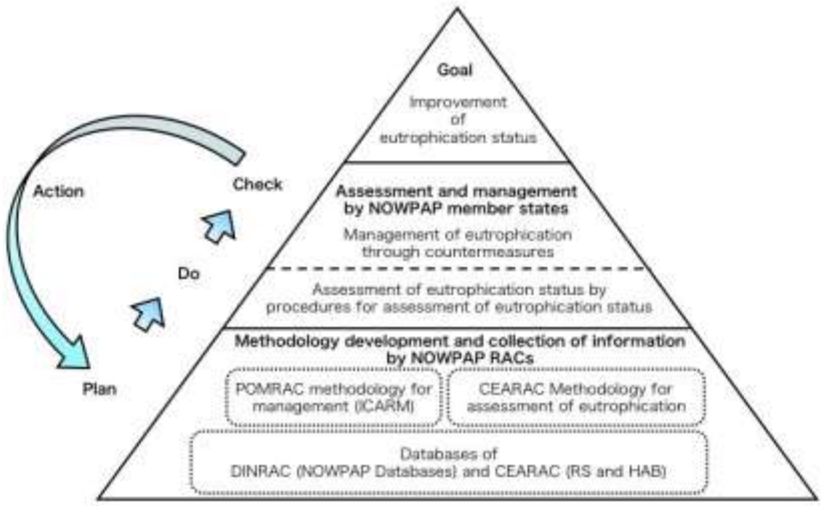

Figure 1　Concept of the NOWPAP Common Procedures.
RACs are regional activity centers of NOWPAP. CEARAC: Special Monitoring and Coastal Environment Assessment Regional Activity Centre, DINRAC: Data and Information Network Regional Activity Centre and POMRAC: Pollution Monitoring Regional Activity Centre.

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'.

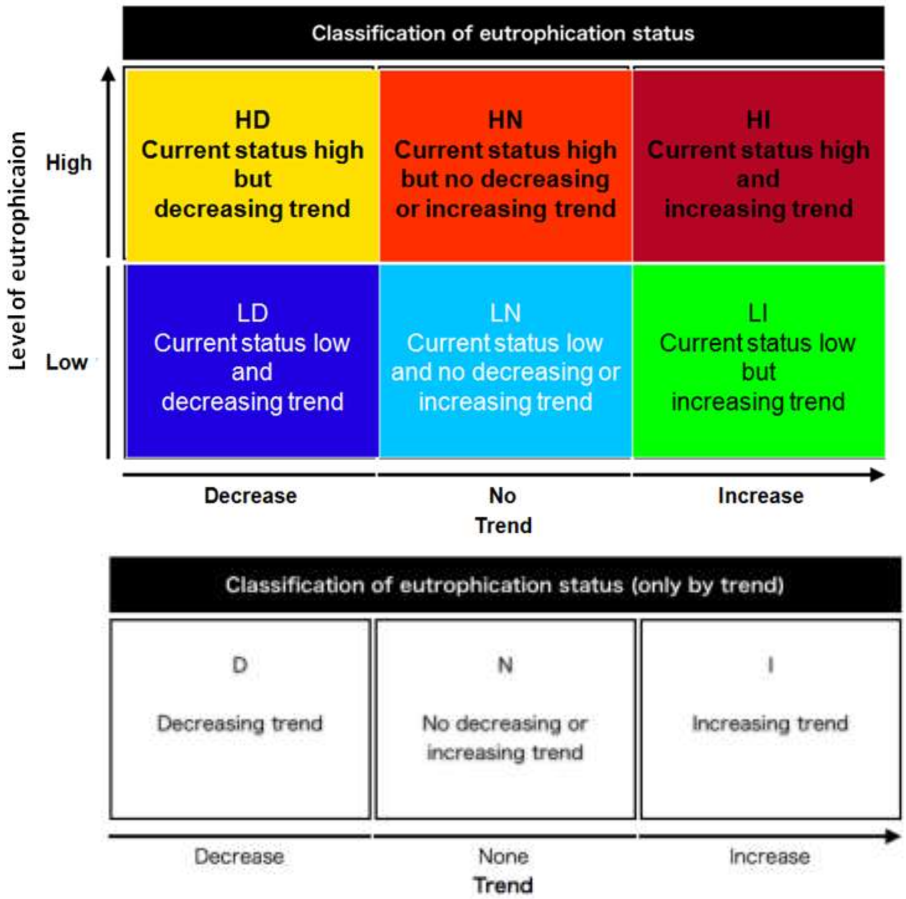

Figure 2 The classifications of the eutrophication status in the NOWPAP Common Procedure, determined using a combination of the level and the trend of assessment parameters.

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 are 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.

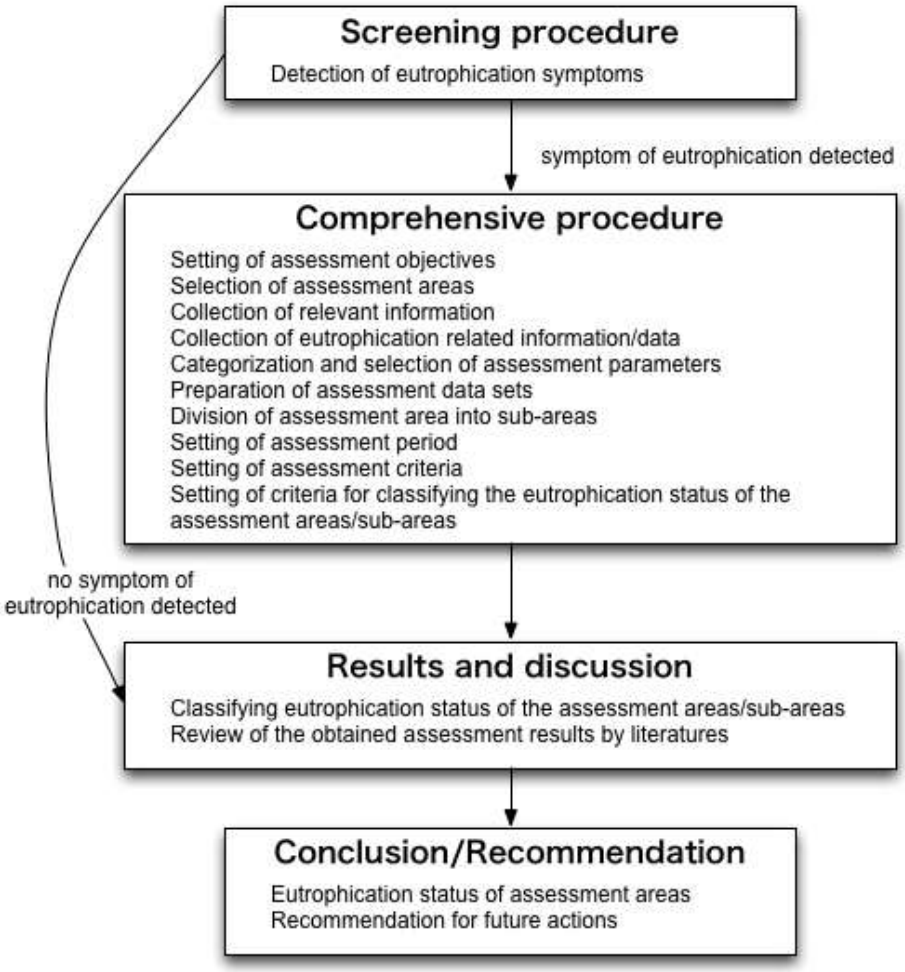

Figure 3 Overall structure of the NOWPAP Common Procedure and the flow of the eutrophication assessment.

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 *u*g/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 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)	*u*g/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 (*Noctiluca* 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 (COD)	mg/L	Annual mean	✓		✓	
	Transparency	m	Annual mean	✓		✓	
IV	Red-tide events (*Noctiluca* 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.

Annex D Results of eutrophication assessment in each selected sea areas

- Jiaozhou Bay, China
- North Kyushu sea area, Japan
- Toyama Bay, Japan
- Jinhae Bay, Korea
- Peter the Great Bay, Russia