I Preface

(Not prepared yet)

II Executive summary

(Not prepared yet)

III Table of contents

Tables

Figures

1. Introduction

Nutrients, nitrogen (N) and phosphorus (P) are essential for biological productivity in the marine environment. Eutrophication is a phenomenon caused by excessive input of nutrients, nitrogen and phosphorus, often caused by overpopulation, industries and agriculture in coastal areas or the catchment area, and it damages the environment in various ways. Phytoplankton grows by taking up nutrients, however when primary production is accelerated excessively, red tides may occur. Red tides often include the occurrence of harmful toxic plankton species which a marine life and fisheries negatively through fish kills, e.g., by suffocation or poisoning and shellfish poisoning. Also, in the process of decomposition of algal blooms and algal biomass in general, oxygen in the water is consumed by microbial processes and may take place at the at the bottom waters of the sea. Hypoxic or anoxic water masses causes negative effects to benthic organisms, which often leads to degradation of biodiversity in the sea. Eutrophication has not been just a local problem, but also a trans-boundary concern.

Eutrophication has originally been understood as being mainly of local concern but now as regional and global environmental issue. It is closely related to the problem of population increase, expansion of urban area, fertilizer use, atmospheric emissions and deposition of nitrogen, and changes in land-use. Also, as global warming proceeds, it is of concern that the effects of eutrophication expand. Increase of water temperature may increase the frequency of red tide events. It also strengthens thermal stratification and accelerate formation of hypoxic or anoxic water masses.

Although excessive nutrients may result in eutrophication too limited input of nutrients may result in oligotrophication and decrease in primary productivity. It is necessary to allow an appropriate supply of nutrients to the marine ecosystem to maintain biological productivity and the sustainable ecosystems. It has been pointed out by some developed countries dependent on high production of sea-based alimental products that oligotrophication which may occur due to excessive removal of nutrients by advanced sewage water treatment systems is not of favor. Oligotrophication reduces biological productivity in sea areas. Therefore, it is necessary to develop and promote suitable regional river basin management to discharge appropriate amounts of nutrients, aiming at maintaining healthy marine ecosystems.

In the Northwest Pacific region, coastal areas of China, Japan and Korea are densely populated and eutrophication is often perceived as a potential threat for coastal environment while eutrophication is in Russian waters is not considered as a threat.. Ability to monitor coastal systems is necessary to manage and sustain healthy coastal environments. However, the availability of continuous and synoptic water quality data, particularly in estuaries and bays is lacking, and it is difficult to characterize the changes in water quality resulting from human and natural impacts. Furthermore due to increases in agricultural and industrial activity as well as the possible changes of coastal run-off in this region, there has been an increase in the need for effective assessment methods for 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 (HELCOM, 2009, OSPAR 2009) and develop “Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region (NOWPAP Common Procedures)”.

NOWPAP member states have decided to apply the NOWPAP Common Procedures in selected sea areas of each country and to evaluate the suitability of suggested methodology for assessment of eutrophication status. Selected sea areas are Yangtze River Estuary and adjacent area in China, Northwest Kyushu sea area and Toyama Bay in Japan, Jinhae Bay in Korea and Peter the Great Bay in Russia. The aim is that the obtained assessments will provide arguments to limit or, if possible, to reduce anthropogenic eutrophication of the coastal ecosystem.

This report presents the evaluation of the eutrophication status in the selected sea areas of each NOWPAP member state based on the NOWPAP Common Procedures (NOWPAP CEARAC, 2009). In addition, technical problems in the Common Procedures have been considered by examining assessment parameters and their reference values.

2. Assessment method and data

2.-1 Eutrophication classification with the use of the NOWPAP Common Procedure

Based on the Common Procedures, water quality parameter data related to eutrophication were collected and organized in four categories by the degree of nutrient enrichment, and direct, indirect and other possible effects of nutrients enrichment (Table 2-1). Collected information and data was assessed by its status (level of concentration or occurrence of event) and trend. By the combination of status and trend, eutrophication status is classified into 6 classifications; High-Increase, High-No Trend, High-Decrease, Low-Increase, Low-No trend and Low-Increase (Fig. 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

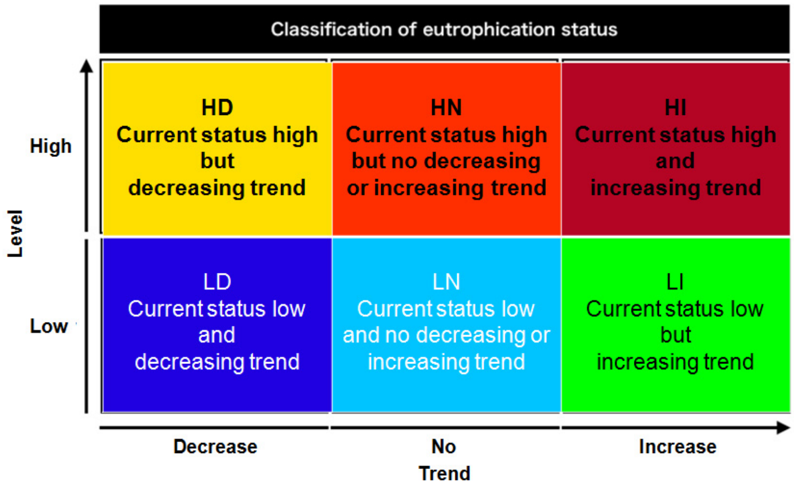

Fig. 2-1　　Classification of eutrophication status by the combination of the level of eutrophication and trend of assessment parameters in the Common Procedures.

2.-2 Selection of target sea areas in the NOWPAP member states

It was agreed at the 7th CEARAC Focal Point meeting in Toyama that each NOWPAP member state select target sea area to conduct an assessment of eutrophication status using the Common Procedures: China - Changjiang/Yangtze River Estuary and adjacent area, Korea – Jinhae Bay, Russia – Peter the Great Bay. Japan selected the Northwest Kyushu sea area and Toyama Bay. Figs. 2-2, 2-3, 2-4, and 2-5 show the location of each selected sea area.

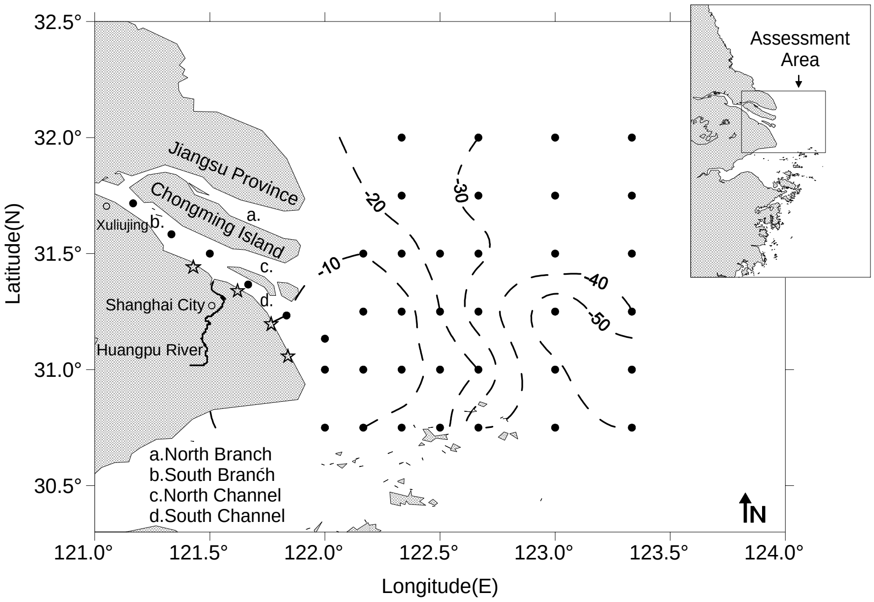

Fig. 2-2 Map of the Changjiang/Yangtze River estuary and adjacent sea, China.

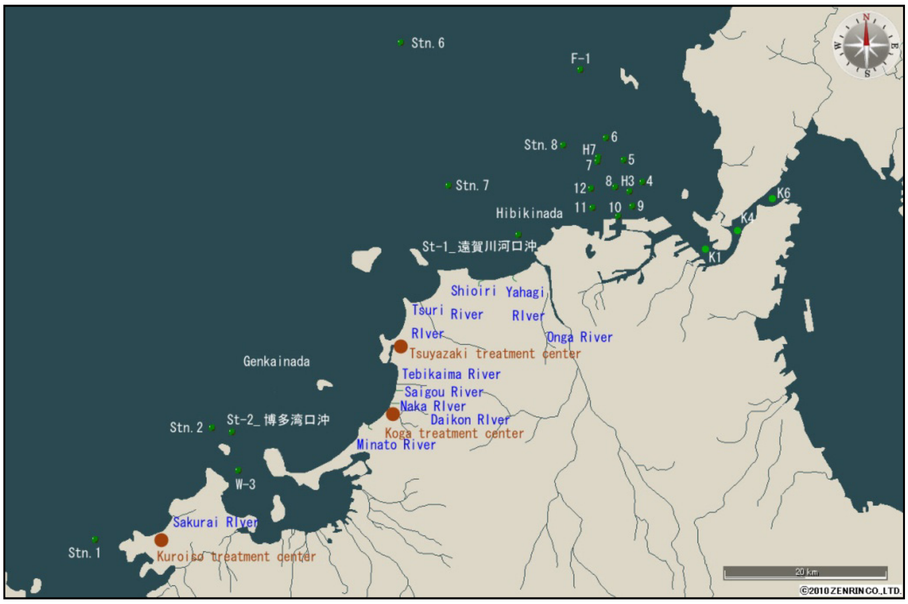

Fig. 2-3 Map of the Northwest Kyushu sea area, Japan.

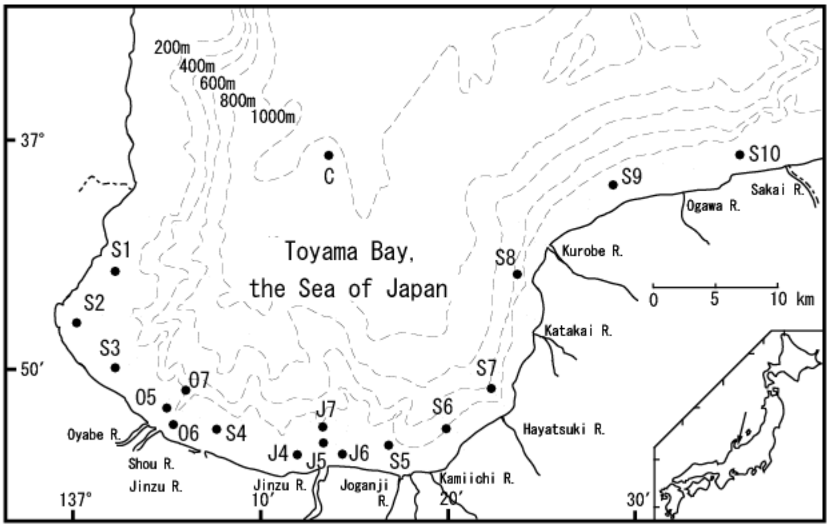

Fig. 2-4 Map of Toyama Bay, Japan.

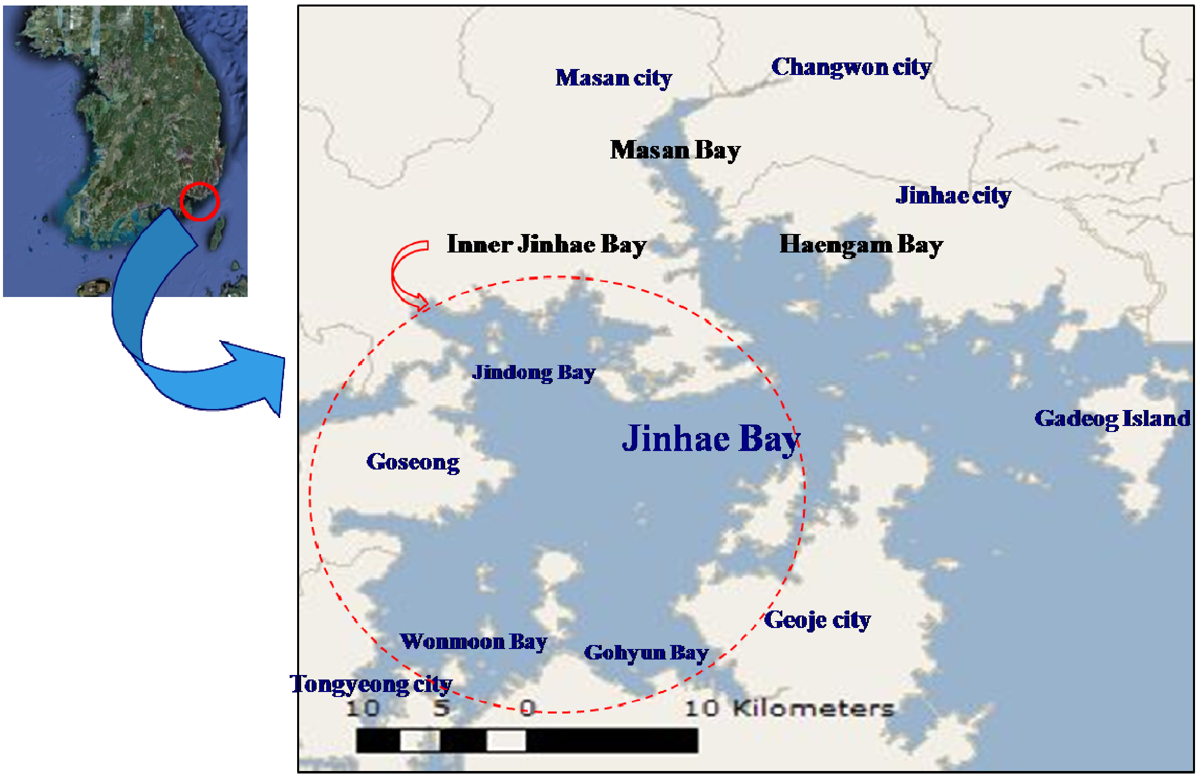

Fig. 2-5 Map of Jinhae Bay, Korea.

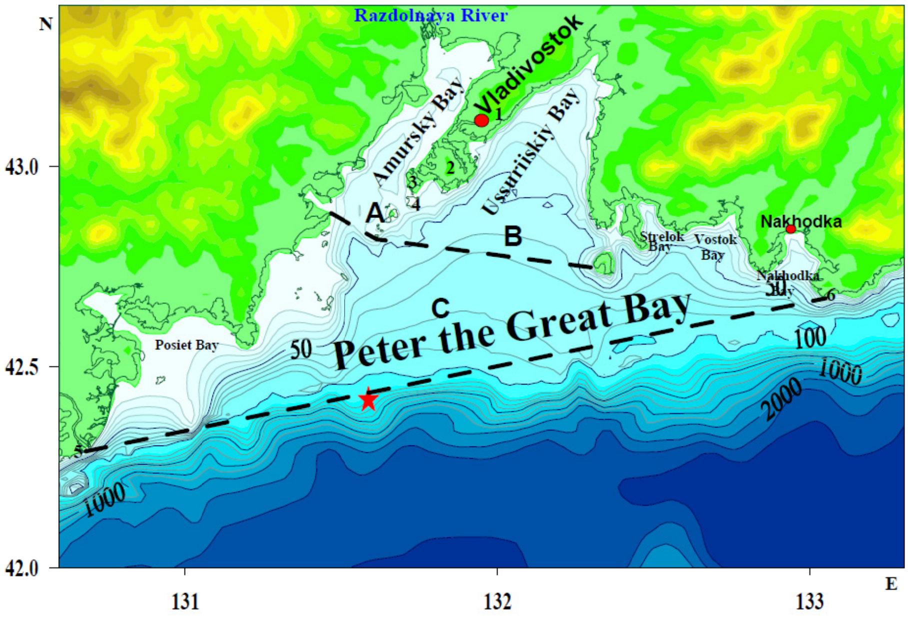

Fig. 2-6 Map of the Peter the Great Bay, Russia.

2.-3 Data and parameters used in each selected sea area

An assessment of eutrophication status was conducted in the selected sea areas in China, Japan, Korea and Russia. Table 2-2 shows the list of parameters of the four categories used for this assessment.

In Category I, all four countries selected riverine input of total nitrogen (TN) and total phosphorus (TP) as assessment parameters. However, only limited data on TN and TP inputs were available in Jinhae Bay, Korea from 1995 to 1996. In riverine input data on Yangtze River, China, data on TN and TP inputs covered only 5 years (2006-2010), but DIN and DIP input data was available for a longer period longer data (1963-1997). For the Northwest 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 of TN, TP, DIN, DIP, DSi, Chemical Oxygen Demand (COD)$_{,}$, Suspended Sediment (SS) and Biological Oxygen Demand (BOD)$_5$ inputs from rivers and sewage plants was used in this assessment. Japan and Korea used monitoring data on TN and TP concentrations in the sea areas, yet China and Russia didn’t. All four countries had common parameters of DIN, DIP and DIN/DIP ratio, however with differences in the sampling season, Japan and Korea used winter data and China and Russia used annual means.

For Category II, all countries used the annual mean of chlorophyll-*a* concentration as one parameter. In addition, China, Japan and Russia used the annual maximum of chlorophyll-*a* concentration. In Korea, the ratio of area with high chlorophyll-*a* to the total area was used as a parameter. In relation to information on red tides, the number of occurrences was used in China, Japan and Korea. In Japan, red tide incidents were divided into three taxonomy groups: diatom sp., dinoflagellate sp. and *Noctiluca* sp. The first two were in Category II and the last one was included in Category IV in Japan.

In Category III, all countries selected DO as a common parameter. However, their samples were different in terms of the depth of DO observation. In Russia, DO in both the surface and the bottom layers were used. On the other hand, China, Japan and Korea selected only the surface layer. Further, China and Korea used the annual mean of DO, while Japan and Russia used the annual minimum in the surface layer. Fish kill incidents were used in all countries except China. The annual mean of COD was also used as a parameter in China, Japan and Korea, but not in Russia.

In category IV, Japan and Korea used the red tide events of *Noctiluca* sp. and shell-fish poisoning incidents as assessment parameters, and Russia used kills of benthos and fishes. On the other hand,,China didn’t use any assessment parameters in this category.

Table 2-2 Parameters used in the NOWPAP member states.

Categories	Assessment parameters	Yangtze River Estuary and adjacent area, China	Northwest Kyushu sea area, Japan	Toyama Bay, Japan	Jinhae Bay, Korea	Peter the Great Bay, Russia
I	Riverine input of TN	✓	✓	✓	✓	✓
	Riverine input of TP	✓	✓	✓	✓	✓
	Riverine input of DIN	✓				✓
	Riverine input of DIP	✓				✓
	Sewage plant input of TN		✓			
	Sewage plant input 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 concentration					✓
	Annual mean DIN/DIP ratio	✓				✓
Ⅱ	Annual maximum of chlorophyll-*a*	✓	✓	✓		✓
	Annual mean of chlorophyll-*a*	✓	✓	✓	✓	✓
	Ratio of area with high chlorophyll-*a* concentration to the total area				✓	
	Red tide events	✓				
	Red tide events (diatom sp.)		✓	✓	✓	
	Red tide events (dinoflagellate sp.)		✓	✓		
Ⅲ	Annual minimum DO (surface)		✓	✓		✓
	Annual minimum DO (bottom)					✓
	Annual mean DO (surface)	✓			✓	
	Annual mean DO (bottom)				✓	
	Fish kill incidents		✓	✓	✓	✓
	Annual mean COD	✓	✓	✓	✓	
Ⅳ	Red tide events (*Noctiluca* sp.)		✓	✓	✓	
	Shell fish poisoning incidents		✓	✓	✓	
	Zoo-Phytobenthos					✓
	Kill fishes					✓

2.-4 National standards in NOWPAP member states

2.-4-1 Standards in China

The State Environmental Protection Administration is responsible for all surface waters (lakes, reservoirs and rivers), underground water, coasts and near shore seawater, and wastewater discharge. It monitors water quality, biology, sediments and discharge volumes. This authority provides national laws and regulations, such as the Environmental Protection Law and the Water Pollution Prevention Law. Monitoring units at every administrative level carry out routine monitoring tasks and additional tasks mandated by supervisory requirements.

There are four levels of environmental monitoring in China: (1) China National Environmental Monitoring Center; (2) environmental monitoring centers in different provinces or municipalities governed by the central government; (3) environmental monitoring centers in municipalities governed by the provincial government; and (4) environmental monitoring centers of the counties and the district of municipalities.

Environmental water quality standards in China are shown in Table 2-3.

Table 2-3 Environmental water quality standards in China.

Category	Assessment parameter	Environmental water quality standard	Grade
I	DIN concentration	0.2 mg/L	1
		0.3 mg/L	2
		0.4 mg/L	3
		0.5 mg/L	4
	DIP concentration	0.015 mg/L	1
		0.03 mg/L	2
		0.03 mg/L	3
		0.045 mg/L	4
III	DO	6 mg/L	1
		5 mg/L	2
		4 mg/L	3
		3 mg/L	4
	COD	2 mg/L	1
		3 mg/L	2
		4 mg/L	3
		5 mg/L	4

2.-4-2 Standards in Japan

There are two types of water quality standards that can be applied for the eutrophication assessment in Japan, namely ‘Environmental water quality standard (Ministry of the Environment of Japan, 1971)’ and ‘Fisheries water quality standard (Japan Fisheries Resource Conservation Association, 2005)’ listed in Table 2-4.

Table 2-4 Environmental water quality standards and fisheries water quality standards in Japan.

Category	Assessment parameter	Environmental water quality	Water use	Fisheries water quality standard	Water use
I	TN concentration	0.2 mg/l	Type I[2]		
		0.3 mg/l	Type II	0.3 mg/l	Fishery Type 1[4]
		0.6 mg/l	Type III	0.6 mg/l	Fishery Type 2
		1.0 mg/l	Type IV	1.0 mg/l	Fishery Type 3
	TP concentration	0.02 mg/l	Type I		
		0.03 mg/l	Type II	0.03 mg/l	Fishery Type 1
		0.05 mg/l	Type III	0.05 mg/l	Fishery Type 2
		0.09 mg/l	Type IV	0.09 mg/l	Fishery Type 3
	Winter DIN concentration	None		0.07-0.1 mg/l	Min. concentration required for laver farming (not limited to winter)
	Winter DIP concentration	None		0.007-0.014 mg/l	Min. concentration required for laver farming (not limited to winter)
	Winter DIN/DIP ratio	None		None	
II	Chlorophyll-*a* concentration	None		None	
III	DO	7.5 mg/l	Type A[3]	6 mg/l	General
		5 mg/l	Type B		
		2 mg/l	Type C		
	COD[1]	2 mg/l	Type A	1 mg/l	General
		3 mg/l	Type B	2 mg/l	Laver farm or enclosed
		8 mg/l	Type C		

1) COD standards of ‘Environmental water quality standard’ and ‘Fisheries water quality standard’ are in COD_{Mn} and COD_{OH} respectively (COD_{OH} ≒ 0.6 x COD_{MN})

2) Type I: Conservation of natural environment
Type II: Fishery class 1, bathing
Type III: Fishery class 2
Type IV: Fishery class 3, industrial water, conservation of habitable environment for marine biota

3) Type A: Fishery class 1, bathing, conservation of natural environment
Type B: Fishery class 2, industrial water
Type C: Conservation of environment

4) Fishery Type 1: Stable and well-balanced catch of various fishery species including benthic fish/shellfish
Fishery Type 2: Large catch of fishery species, except certain benthic fish/shellfish
Fishery Type 3: Catch of fishery species tolerant to pollution

2.-4-3 Standards in Korea

Marine environmental monitoring in Korea started in 1972. The monitoring system begun as a simple system with limited parameters measured, but has expanded over time to cover newly emerging pollution issues. Currently, monitoring of marine environment in Korea is largely composed of three monitoring systems: national marine environment system, oceanographic observation system, and red tide monitoring system with other occasional monitoring programs including Tele-Monitoring System (TMS). The coastal monitoring system is the most comprehensive system and it addresses coastal environment quality at a total of 296 stations in the coastal area of Korean peninsula.

Table 2-5 Environmental water quality standards in Korea.

Category	Assessment parameter	Environmental water quality	Grade
I	TN concentration	≤ 0.3 mg/L	I
		≤ 0.6 mg/L	II
		< 1.0 mg/L	III
	TP concentration	≤ 0.03 mg/L	I
		≤ 0.05 mg/L	II
		< 0.09 mg/L	III
III	DO	≥ 7.5 mg/L	I
		≥ 5 mg/L	II
		> 2 mg/L	III
	COD	≤ 1 mg/L	I
		≤ 2 mg/L	II
		4 mg/L	III

2.-4-4 Standards in Russia

The Federal Service on Hydrometeorology and Environmental Monitoring (ROSHYDROMET) is responsible for routine monitoring in Russia. In Primorskii Krai, monitoring of contamination of river and coastal waters is implemented by the Primorskii Krai Office on Hydrometeorology and Environmental Monitoring according to State Monitoring Programs. Water quality assessment in Russia is conducted in compliance with maximum permissible concentrations (MPC). There are three sets of MPC in ambient water: (1) for the drinking water; (2) for the water of domestic, drinking and cultural uses –“public waters”; and (3) for the water used for the fishery purposes.

Table 2-6 Maximum permissible concentrations of chemical substances in Russia

Category	Assessment parameter	Environmental water quality standard	Type of water use
I	TN [*1]	9.5 mg/L	Fishery purpose
	TP [*1]	0.05 mg/L	Fishery purpose
	NO_3^+	9.1 mg/L	Fishery purpose
	NO_2^+	0.02 mg/L	Fishery purpose
	NH_4^+	0.4 mg/L	Fishery purpose
	PO_4^{3+}	0.05 mg/L	Fishery purpose
	SO_4^{2-}	100 mg/L	Fishery purpose
III	DO	3 mg/L	Fishery purpose
	COD_{Mn}	5 mg/L	Fishery purpose
	COD_{Cr}	15 mg/L	Fishery purpose

[*1]: for dissolved forms (PO_4 and NO_3^-+NO_2^-+NH_4^+)

2.-5 Reference values used in selected sea areas

2.-5-1 Changjiang/Yangtze River Estuary and adjacent area, China

In the case study in Changjiang/Yangtze River Estuary and adjacent area in China, reference values of DIN, DIP, COD and DO were set to be equivalent to Class III in the 'National Sea Water Quality Standard of China,' and maximum and mean values of chlorophyll-*a* were set to be equivalent to Bricker *et al.* (2003), i.e., 20 and 5 ug/L respectively. Reference values for riverine input of DIN and DIP were not set. Redfield ratio of 16 was used as the reference ratio of DIN to DIP. In China, classification to either High or Low class was decided by comparing the most recent available latest one-year values to reference values for each parameter.

Table 2-7 Reference values used in Changjiang/Yangtze River Estuary and adjacent area, China

Categories	Assessment parameters	Reference value	Reference
I	①Riverine input of DIN	None	None
	②Riverine input of DIP	None	None
	③DIN concentration	0.4 mg/L (28.6 μM)	NSQS (1997) class III
	④DIP concentration	0.03 mg/L (0.97 μM)	NSQS (1997) class III
	⑤DIN/DIP ratio	16	Redfield ratio
Ⅱ	⑥Maximum of chlorophyll-*a*	20 μg/L	Bricker et al. (2003)
	⑦Mean of chlorophyll-*a*	5 μg/L	Bricker et al. (2003)
	⑧Red tide events	?	
Ⅲ	⑨DO	2 mg/L	NSQS (1997) class III
	⑩COD	4 mg/L	NSQS (1997) class III

2.-5-2 Northwest Kyushu sea area and Toyama Bay, Japan

For the case studies in Japan (Northwest Kyushu sea area and Toyama Bay), reference values of TN, TP and COD were set by using the 'Environmental quality standards for water pollution' by the Ministry of the Environment, Japan. It is noted that three different environment water quality standards (Type II-IV) are applied depending on the type of water use in the Northwest Kyushu sea area, while only Type II was applied for the case study in Toyama Bay. Since there are no water quality standards for winter DIN and DIP concentrations in Japan, their reference values were set through a regression analysis of winter DIN and TN concentration (winter DIP and TP concentration). Redfield ratio of 16 was used as the ratio of winter DIN to DIP. Chlorophyll-a concentration was set based on Bricker *et al.* (2003). For setting DO value, the 'Fisheries water quality standard' was applied. Red tide (diatom sp. and dinoflagellate sp.) was rated as 'High' when one or more incidents occurred in the recent three years; and 'low' if no incidents occurred. Different from these two, red tide of *Noctiluca* species was rated as 'High' when three or more incidents occurred in the past three years, an 'Low' if less than three incidents occurred. This criterion was applied because red tide of *Noctiluca* sp. is known to occur not only due to eutrophication but also when this species is physically aggregated due to conversion of oceanographic currents. In other words, there will be a lower risk of misinterpreting *Noctiluca* sp. occurrences as a sign of eutrophication if the criterion of ‘maximum of three events in three years is applied. When one or more incidents of abnormal fish kill and shell fish poisoning occurred in the recent three years, their status was rated as ‘High.’ They were evaluated by comparing either the mean of the recent three years or the number of incidents to the reference value respectively.

Table 2-8 Reference values used in the northwest Kyushu sea area, Japan

Categories	Assessment parameters	Reference value	Reference
Ⅰ	①Riverine input of TN	None	None
	②Riverine input of TP	None	None
	③Sewage plant input of TN	None	None
	④Sewage plant input of TP	None	None
	⑤TN concentration	0.3 mg/L	Environmental quality standards for water pollution, Type II
		0.6 mg/L	Environmental quality standards for water pollution, Type III
		1.0 mg/L	Environmental quality standards for water pollution, Type IV
	⑥TP concentration	0.03 mg/L	Environmental quality standards for water pollution, Type II
		0.05 mg/L	Environmental quality standards for water pollution, Type III
		0.09 mg/L	Environmental quality standards for water pollution, Type IV
	⑦Winter DIN concentration	0.169 mg/L	Correspond to 'Environmental quality standards for water pollution, Type II’
		0.338 mg/L	Correspond to 'Environmental quality standards for water pollution, Type III’
		0.562 mg/L	Correspond to 'Environmental quality standards for water pollution, Type IV’
	⑧Winter DIP concentration	0.011 mg/L	Correspond to 'Environmental quality standards for water pollution, Type II’
		0.017 mg/L	Correspond to 'Environmental quality standards for water pollution, Type III’
		0.029 mg/L	Correspond to 'Environmental quality standards for water pollution, Type IV’
	⑨Winter DIN/DIP ratio	16	Redfield ratio
Ⅱ	⑩Annual maximum of chlorophyll-*a*	20 μg/L	Bricker et al. (2003)
	⑪Annual mean of chlorophyll-*a*	5 μg/L	Bricker et al. (2003)
	⑫Red tide events (diatom sp.)	1 event/year	None
	⑬Red tide events (dinoflagellate sp.)	1 event/year	None
Ⅲ	⑭Dissolved oxygen (DO)	6.0 mg/L	Fisheries water quality standard
	⑮Fish kill incidents	1 event/year	None
	⑯Chemical oxygen demand (COD)	3.0 mg/L	Environmental quality standards for water pollution, Type B
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	3 event/3 years	None
	⑱Shell fish poisoning incidents	1 event/year	None

Table 2-9 Reference values used in Toyama Bay, Japan

Categories	Assessment parameters	Reference value	Reference
Ⅰ	①Riverine input of TN	None	None
	②Riverine input of TP	None	None
	③Sewage plant input of TN	None	None
	④Sewage plant input of TP	None	None
	⑤TN concentration	0.3 mg/L	Environmental quality standards for water pollution, Type II
	⑥TP concentration	0.03 mg/L	Environmental quality standards for water pollution, Type II
	⑦Winter DIN concentration	0.144 mg/L	Correspond to 'Environmental quality standards for water pollution, Type II’
	⑧Winter DIP concentration	0.017 mg/L	Correspond to 'Environmental quality standards for water pollution, Type II’
	⑨Winter DIN/DIP ratio	16	Redfield ratio
Ⅱ	⑩Annual maximum of chlorophyll-*a*	20 μg/L	Bricker et al. (2003)
	⑪Annual mean of chlorophyll-*a*	5 μg/L	Bricker et al. (2003)
	⑫Red tide events (diatom sp.)	1 event/year	None
	⑬Red tide events (dinoflagellate sp.)	1 event/year	None
Ⅲ	⑭Dissolved oxygen (DO)	6.0 mg/L	Fisheries water quality standard
	⑮Fish kill incidents	1 event/year	None
	⑯Chemical oxygen demand (COD)	3.0 mg/L	Environmental water quality standard Type B
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	3 event/3 years	None
	⑱Shell fish poisoning incidents	1 event/year	None

2.-5-3 Jinhae Bay, Korea

In Korea, values of TN, TP, winter DIN and winter DIP in Gijang area was used as reference values since this area was considered not to be affected by eutrophication. Redfield ratio was applied for DIN/DIP ratio. The reference value of the ratio of area with high chlorophyll-*a* concentration (> 2.4 μ /L) to the total area was set as 5%. Reference value of DO was set to 6mg/L based on OSPAR (2005). For COD, the values from Gijang area were set as the reference values. They were , which are 1.0 mg/L in the surface layer and 0.9 mg/L in the bottom layer.

Table 2-10 Reference values used in Jinhae Bay, Korea

Categories	Assessment parameters	Reference value	Reference
Ⅰ	①Riverine input of TN	None	None
	②Riverine input of TP	None	None
	③TN concentration	0.28 mg/L	Background value in Gijang area
	④TP concentration	0.027 mg/L	Background value in Gijang area
	⑤Winter DIN concentration	0.09 mg/L	Background value in Gijang area
	⑥Winter DIP concentration	0.016 mg/L	Background value in Gijang area
	⑦Winter DIN/DIP ratio	16	Redfield ratio
Ⅱ	⑧Annual mean of chlorophyll-*a*	2.4 μg/L	Background value in Gijang area
	⑨Ratio of area with high chlorophyll-a concentration to the total area	Less than 5%	None
	⑩Red tide events (diatom sp.)	None	None
Ⅲ	⑪Dissolved oxygen (DO)	6 mg/L	OSPAR (2005)
	⑫Fish kill incidents	None	None
	⑬Chemical oxygen demand (COD)	1.0 mg/L in surface 0.9 mg/L in bottom	Background value in Gijang area
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	None	None
	⑱Shell fish poisoning incidents	None	None

2.-5-4 Peter the Great Bay, Russia

In Russia, reference values of riverine input DIN and DIP were set in each sub-area. Reference values of DIN, DIP and DSi were calculated on the basis of stoichiometrical relations based on Redfield ratio. Concisely, reference values of DIN, DIP and DSi concentration were set based on the minimum necessary DO in sea water. A reference value for DIN/DIP was not set. For chlorophyll-*a* concentration, the reference value was set as 8 µg/L. The reference value of DO was set as 76 µM, which is the mean of 2 mg/L (63 µM) (Diaz, 2001) and 2 mL/L (89 µM)(Diaz and Rosenberg, 2008) defined as limit values for hypoxia.

Table 2-11 Reference values used in Peter the Great Bay, Russia

Categories	Assessment parameters	Reference values	Reference
I	①Riverine input of DIN	?	
	②Riverine input of DIP	?	
	③DIN concentration	33.4 μM 24.3 μM 18.3 μM	Winter Spring, Autumn Summer
	④DIP concentration	2.1 μM 1.5 μM 1.1 μM	Winter Spring, Autumn Summer
	⑤DSi concentration	35.5 μM 25.8 μM 19.4 μM	Winter Spring, Autumn Summer
	⑥DIN/DIP ratio	-	
Ⅱ	⑦Annual mean of chlorophyll-*a*	8 μg/L	
	⑧Annual maximum of chlorophyll-*a*	8 μg/L	
Ⅲ	⑨Annual mean of DO		
	⑩Annual minimum of DO	76 μM	
Ⅳ	⑪Zoo-phytobenthos	-	
	⑫Kill fishes	-	

3. Eutrophication status and trends in selected sea areas of NOWPAP region

3.-1 Changjiang/Yangtze River Estuary and adjacent area, China

The Changjiang/Yangtze River is the largest river in China. The Changjiang/Yangtze River's basin is characterized by many industrial and urban centers, especially along its lower reaches and the estuary. With the influence of the dense population, the extensive use of chemical fertilizers and domestic waste, the Changjiang/Yangtze River Estuary is facing the challenge of environmental deterioration. In recent decades, the Changjiang/Yangtze River Estuary has received a high loading of anthropogenic nutrients from more and more activities in agriculture, and sewage due to massive economic growth and urban development.

All assessment parameters related to eutrophication that are monitored within the assessment area were categorized into the three categories. Since some data were extracted from literatures, sub-areas were not set in this study.

Category I (degree of nutrient enrichment) parameters: Riverine input of DIN and DIP from Changjian River showed increasing trends in 1963-1997. DIN concentrations were higher than reference concentration (28.6 µM) except in 1963. On the contrary, the DIP concentration was generally lower than reference concentration (0.97 µM). DIN pollution was serious in this estuary, which resulted in the high DIN/DIP ratio. Therefore, the Category I was classified as HI (See Fig. 2-1 for abbreviations).

Category II (direct effects of nutrient enrichment) parameters: Maximum of Chl-*a* was higher than reference concentration (20 µg/L) in 2009, and no trend was detected. Mean of Chl-*a* was lower than reference (5 µg/L) in recent years, but an increasing trend was detected. High occurrence of red tide events and their increasing trend were observed. Category II was classified as HI.

Category III (indirect effects of nutrient enrichment) parameters: DO concentration was generally not lower than 2 mg/L and had no trend. COD concentration was lower than 2 mg/L and decreasing trend was detected. Category II was classified as LN.

In Categories I and II, the Changjiang/Yangtze River estuary has a current High eutrophication status and increasing trend (Classification as HI). Category III, the Changjiang/Yangtze River estuary has a Low current eutrophication status and there is no trend (Classification as HI).

Table 3-1 Assessment results of each assessment category in Changjiang/Yangtze River Estuary and adjacent area, China

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of DIN	×	×	I	I	HI
	②Riverine input of DIP	×	×	I	I	
	③DIN concentration	H	×	I	HI	
	④DIP concentration	L	×	I	LI	
	⑤DIN/DIP ratio	H	×	N	HN	
Ⅱ	⑥Maximum of chlorophyll-*a*	H	×	N	HN	HI
	⑦Mean of chlorophyll-*a*	L	×	I	LI	
	⑧Red tide events	×	H	I	HI	
Ⅲ	⑨DO	L	×	N	LN	LN
	⑩COD	L	×	D	LD	

3.-2 Northwest Kyushu sea area, Japan

3.-2-1 Sub-area A (Hakata Bay)

Subarea A is a semi-enclosed bay facing Fukuoka City. The city has a population of 1.45 million.

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

Category II parameters: Annual max/mean of chlorophyll-*a* concentration showed a decreasing trend, despite exceedance of reference values in some years. Events of diatom and dinoflagellate red tides were also observed.

Category III parameters: DO was below the reference value. COD was also below the reference value, but many stations showed an increasing trend in COD levels.

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

Table 3-2 Assessment results of each assessment category in sub-area A (Hakata Bay)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	D	D	LI
	②Riverine input of TP	×	×	D	D	
	③Sewage plant input of TN	×	×	I	I	
	④Sewage plant input of TP	×	×	N	N	
	⑤TN concentration	L	×	I	LI	
	⑥TP concentration	L	×	N	LN	
	⑦Winter DIN concentration	H	×	I	HI	
	⑧Winter DIP concentration	L	×	N	LN	
	⑨Winter DIN/DIP ratio	H	×	I	HI	
Ⅱ	⑩Annual maximum of chlorophyll-*a*	H	×	D	HD	HD-HN
	⑪Annual mean of chlorophyll-*a*	H	×	D	HD	
	⑫Red tide events (diatom sp.)	×	H	N	HN	
	⑬Red tide events (dinoflagellate sp.)	×	H	N	HN	
Ⅲ	⑭Dissolved oxygen (DO)	L	×	N	LN	LN
	⑮Fish kill incidents	×	L	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	I	LI	
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

3.-2-2 Sub-area B (Dokai Bay and Kanmon strait)

An industrial zone with large-scale factories is located along the coastal area of sub-area B (Dokai Bay sea area). Sub-area B is also connected to Kanmon Strait.

Category I parameters: TN and TP inputs from the rivers showed a decreasing trend. TN input from the two sewage treatment plants showed no increasing or decreasing trend. TP input from sewage treatment plants showed decreasing trends. TN and TP concentration showed a decreasing trend, and most stations were below the reference value. However, note that the reference value for TN and TP was set as Type IV water use, which is the most allowing level in the ‘Environmental water quality standard'. Winter DIN/DIP concentration was not assessed due to the lack of recent data.

Category II parameters: Annual maximum/mean of chlorophyll-*a* concentration exceeded the reference value in some years. The number of diatom and dinoflagellate red tide events was low.

Category III parameters: DO was below the reference value at one station hence it was classified as 'Low'. COD exceeded the reference value at three stations, most stations were below the reference value and thus also classified as 'Low'. Furthermore, COD levels have decreased at stations that had high levels in the past; and improvement in water quality was confirmed.

Category IV parameters: *Noctiluca* red tide occurred once in both 1982 and 1989. No shellfish poisoning incidents were confirmed.

Table 3-3 Assessment results of each assessment category in sub-area B (Dokai Bay and Kanmon strait)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	D	D	LD
	②Riverine input of TP	×	×	D	D	
	③Sewage plant input of TN	×	×	N	N	
	④Sewage plant input of TP	×	×	D	D	
	⑤TN concentration	L	×	D	LD	
	⑥TP concentration	L	×	N	LN	
	⑦Winter DIN concentration	×	×	×	-	
	⑧Winter DIP concentration	×	×	×	-	
	⑨Winter DIN/DIP ratio	×	×	×	-	
Ⅱ	⑩Annual maximum of chlorophyll-*a*	H	×	N	HN	LN-HN
	⑪Annual mean of chlorophyll-*a*	H	×	N	HN	
	⑫Red tide events (diatom sp.)	×	L	N	LN	
	⑬Red tide events (dinoflagellate sp.)	×	L	N	LN	
Ⅲ	⑭Dissolved oxygen (DO)	L	×	N	LN	LN
	⑮Fish kill incidents	L	×	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	N	LN	
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

3.-2-3 Sub-area C (Kyushu intermediate area)

Sub-area C is the intermediate area that lies between the coastal and offshore areas, and also includes Kanmon Strait.

Category I parameters: TN and TP inputs from the rivers showed no increasing or decreasing trends. TN input from the two sewage treatment plants showed decreasing trend. TP input from the sewage treatment plants showed an increasing trend. TN and TP inputs from Hiagari treatment center, which discharges into the Kanmon Strait, were predominant. TN and TP concentration in the Kanmon Strait was below the reference value, and there was no trend detected.

Category II parameters: Annual max/mean of chlorophyll-*a* concentrations were below the reference values. However, dinoflagellate red tides did occur.

Category III parameters: DO was below the reference value at one station. While COD exceeded the reference value at three stations, most stations were below the reference value. Furthermore, COD levels have decreased at stations that had high levels in the past; and improvement in water quality was confirmed.

Category IV parameters: *Noctiluca* red tide occurred seven times during the recent three years. No shellfish poisoning incidents were confirmed.

In sub-area C, concentration of TN, TP, winter DIN and winter DIP was low. However, the area may be influenced by the other sea areas as there were dinoflagellate and *Noctiluca* red tides.

Table 3-4 Assessment results of each assessment category in sub-area C (Kyushu intermediate area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
Ⅰ	①Riverine input of TN	×	×	N	N	LN
	②Riverine input of TP	×	×	N	N	
	③Sewage plant input of TN	×	×	D	D	
	④Sewage plant input of TP	×	×	I	I	
	⑤TN concentration	L	×	N	LN	
	⑥TP concentration	L	×	N	LN	
	⑦Winter DIN concentration	L	×	N	LN	
	⑧Winter DIP concentration	L	×	D	LD	
	⑨Winter DIN/DIP ratio	H	×	N	HN*	
Ⅱ	⑩Annual maximum of chlorophyll-*a*	L	×	N	LN	LN
	⑪Annual mean of chlorophyll-*a*	L	×	N	LN	
	⑫Red tide events (diatom sp.)	×	L	N	LN	
	⑬Red tide events (dinoflagellate sp.)	×	H	N	HN	
Ⅲ	⑭Dissolved oxygen (DO)	L	×	N	LN	LN
	⑮Fish kill incidents	L	×	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	N	LN	
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	×	H	N	HN	HN
	⑱Shell fish poisoning incidents	×	L	N	LN	

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

3.-2-4 Sub-area D (Kyushu offshore area)

Sub-area D is the sea area offshore of Fukuoka Prefecture.

Category I parameters: There are no rivers or sewage treatment plants that discharge directly into sub-area D. Trend analysis was not possible as TN and TP data were limited for the period from 1997 to 1998.

Category II parameters: Annual max/mean of chlorophyll-*a* concentration were below the reference value. However, dinoflagellate red tide did occur.

Category III parameters: DO was above the reference value at some stations. However, no fish kill was confirmed. COD was below the reference value, and no was detected.

Category IV parameters: *Noctiluca* red tide occurred only once within the recent three years. No shellfish poisoning incidents were confirmed.

Except for DO, all parameters were classified as either ‘LN’ or ‘N’. Hence, eutrophication has not appeared to have been a major issue in sub-area B. However, it will be necessary to investigate the causes of the low DO concentration in 2005.

Table 3-5 Assessment results of each assessment category in sub-area D (Kyushu offshore area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	×	-	-
	②Riverine input of TP	×	×	×	-	
	③Sewage plant input of TN	×	×	×	-	
	④Sewage plant input of TP	×	×	×	-	
	⑤TN concentration	×	×	×	-	
	⑥TP concentration	×	×	×	-	
	⑦Winter DIN concentration	×	×	×	-	
	⑧Winter DIP concentration	×	×	×	-	
	⑨Winter DIN/DIP ratio	×	×	×	-	
II	⑩Annual maximum of chlorophyll-*a*	×	×	N	N	LN
	⑪Annual mean of chlorophyll-*a*	×	×	N	N	
	⑫Red tide events (diatom sp.)	×	L	N	LN	
	⑬Red tide events (dinoflagellate sp.)	×	L	N	LN	
III	⑭Dissolved oxygen (DO)	H	×	N	HN	LN
	⑮Fish kill incidents	L	×	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	N	LN	
IV	⑰Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

3.-3 Toyama Bay, Japan

3.-3-1 Sub-area A (Toyama Bay coastal area)

Toyama Bay is a semi-enclosed bay, located in the center of the eastern part of NOWPAP area, and 5 Class-A rivers flow into the bay. The biggest is the Jinzu River, originated in Gifu Prefecture and runs through Toyama City with the population of 4.2 million.

Category I parameters: TN input from all of the Class-A rivers didn't show any trends. However, TN input from the Jinzu River and the Kurobe River showed increasing trend. Because of its size and location, it is the biggest rivers and flows into the closed-off section of the bay), the Jinzu River has significant influence over Toyama Bay. Thus, it is necessary to address TN input from this river in order to prevent the bay from becoming eutrophic. On the other hand, TP input from all of the Class-A rivers showed a decreasing trend. The mean concentrations of TN input, TP input, winter DIN and winter DIP of the recent three years were each below each the reference values, and there were no trends detected.

Category II parameters: The annual maximum and mean of chlorophyll-*a* concentrations of the recent three years were below the reference values respectively, and there was no increasing or decreasing trend. The number of diatom red tides showed a decreasing trend, and there were no events in recent years. Also, there were no dinoflagellate red tides in the recent three years.

Category III parameters: DO in most stations was below the reference value; however, some stations also showed a decreasing trend. COD in all stations was below the reference value; however, some stations showed an increasing trend.

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

In Sub-area A, all categories were classified as 'LN' (low eutrophication status and no increasing/decreasing trends). However, among Category I parameters, it is necessary to reduce TN input from the Jinzu River. Among Category III parameters, some stations showed a decreasing trend of DO and an increasing trend of COD. Therefore, it is required to improve the status by reducing nutrient enrichment.

Table 3-6　Assessment results of each assessment category in sub-area A (Toyama Bay coastal area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	N	N	LN
	②Riverine input of TP	×	×	D	D	
	③Sewage plant input of TN	×	×	×	－	
	④Sewage plant input of TP	×	×	×	－	
	⑤TN concentration	L	×	N	LN	
	⑥TP concentration	L	×	N	LN	
	⑦Winter DIN concentration	L	×	N	LN	
	⑧Winter DIP concentration	L	×	N	LN	
	⑨Winter DIN/DIP ratio	H	×	N	HN*	
Ⅱ	⑩Annual maximum of chlorophyll-*a*	L	×	N	LN	LN
	⑪Annual mean of chlorophyll-*a*	L	×	N	LN	
	⑫Red tide events (diatom sp.)	×	L	D	LD	
	⑬Red tide events (dinoflagellate sp.)	×	L	N	LN	
Ⅲ	⑭Dissolved oxygen (DO)	L	×	N	LN	LN
	⑮Fish kill incidents	×	L	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	N	LN	
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

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

3.-3-2 Sub-area B (Toyama Bay intermediate area)

Sub-area B (Toyama Bay intermediate area) is to the offshore side of Sub-area A (the coastal area of the bay), and it is considered that eutrophication occurring in the coastal area influences this area spreading to this direction.

Category I parameters: No direct nutrient input from rivers or sewage treatment plants. Both TN and TP concentrations in this area were below the reference values. However, they showed decreasing trends at stations in the western part of the bay. The winter DIN and DIP concentrations were below the reference values, and no trend were detected.

Category II parameters: Both annual maximum and annual mean chlorophyll-*a* were below the reference values, and no trend was detected. The number of diatom red tides decreased from the 1970s, and there were no events in the recent three years. There were also no events of dinoflagellate red tides during the recent three years.

Category III parameters: DO concentrations in all stations exceeded the reference value; however, it showed decreasing trend at some stations. COD concentration satisfied the reference value; however, 6 stations out of 7 showed decreasing trend.

Category IV (other possible effects of nutrient enrichment) parameters: The number of *Noctiluca* red tide was 0-3 per year, and hence it was below reference level. No shellfish poisoning incidents were confirmed.

In Sub-area A, all categories were classified as ‘LN’ (low concentration status and no increasing/decreasing trend). However, at two stations (S1 and S3) located in the western part of the bay, there was an increasing trend in TN and TP concentrations. So, it is possible that eutrophication in Sub-area A had reached to Sub-area B. Also, some stations showed decreasing trends of DO and an increasing trend of COD. This tendency was also shown in Sub-area A. Therefore, it is expected that implementation of countermeasures in Sub-area A can lead to be improvement of the marine environment of Sub-area B.

Table 3-7 Assessment results of each assessment category in sub-area B (Toyama Bay intermediate area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	×	–	LN
	②Riverine input of TP	×	×	×	–	
	③Sewage plant input of TN	×	×	×	–	
	④Sewage plant input of TP	×	×	×	–	
	⑤TN concentration	L	×	N	LN	
	⑥TP concentration	L	×	N	LN	
	⑦Winter DIN concentration	L	×	N	LN	
	⑧Winter DIP concentration	L	×	N	LN	
	⑨Winter DIN/DIP ratio	H	×	N	HN*	
II	⑩Annual maximum of chlorophyll-*a*	L	×	N	LN	LN
	⑪Annual mean of chlorophyll-*a*	L	×	N	LN	
	⑫Red tide events (diatom sp.)	×	L	D	LD	
	⑬Red tide events (dinoflagellate sp.)	×	L	N	LN	
III	⑭Dissolved oxygen (DO)	L	×	N	LN	LN
	⑮Fish kill incidents	×	L	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	I	LI	
IV	⑰Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

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

3.-3-3 Sub-area C (Toyama Bay offshore area)

Sub-area C is the offshore area of Toyama Bay.

Category I parameters: Concentrations of TN, TP, winter DIN and winter DIP were below the reference values respectively, and no trend was detected for any parameter.

Category II parameters: Both annual maximum and mean of chlorophyll-*a* concentrations were below the reference values; and no trend was detected. There were no events of diatom or dinoflagellates red tides in the recent three years.

Category III parameters: DO concentration exceeded the reference value; however, it showed a decreasing trend. COD concentration was below the reference value; however, it showed an increasing trend.

Category IV parameters: No *Noctiluca* red tide events occurred in the recent three years. No shellfish poisoning was confirmed either.

Based on the results in Categories I, II and IV, it was concluded that the area was not eutrophicated. However, DO concentration showed a decreasing trend. and COD concentration showed an increasing trend in Category III. Since Sub-area A and B had the same pattern, it is necessary to find the causes of these phenomenon.

Table 3-8 Assessment results of each assessment category in sub-area C (Toyama Bay offshore area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	×	−	LN
	②Riverine input of TP	×	×	×	−	
	③Sewage plant input of TN	×	×	×	−	
	④Sewage plant input of TP	×	×	×	−	
	⑤TN concentration	L	×	N	LN	
	⑥TP concentration	L	×	N	LN	
	⑦Winter DIN concentration	L	×	N	LN	
	⑧Winter DIP concentration	L	×	N	LN	
	⑨Winter DIN/DIP ratio	H	×	N	HN*	
II	⑩Annual maximum of chlorophyll-*a*	L	×	N	LN	LN
	⑪Annual mean of chlorophyll-*a*	L	×	N	LN	
	⑫Red tide events (diatom sp.)	×	L	N	LN	
	⑬Red tide events (dinoflagellate sp.)	×	L	N	LN	
III	⑭Dissolved oxygen (DO)	L	×	I	LI	LI
	⑮Fish kill incidents	×	L	N	LN	
	⑯Chemical oxygen demand (COD)	L	×	I	LI	
IV	⑰Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

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

3.-4 Jinhae Bay, Korea

3.-4-1 Sub-area A (Jinhae Bay)

Jinhae Bay, located in the south eastern part of Korea, is a semi-closed, coastal embayment surrounded by land and island. It is surrounded by big cities like Masan and Changwon city. Masan-Haengum Bay facing Masan city, and located in the innnermost Jinhae Bay was evaluated as sub-area B. The water quality of Jinhae Bay, excluding Masan-Haengum Bay, has been improved with remarkable decrease of nutrient loading.

For acquiring background values to be used as reference value for Jinhae Bay, water quality data for Gijang coast was used. Gijang coast is located 10 km eastward of Busan City and has little effect from land-based nutrient sources and faces open sea rather than an embayment.

Category I parameters: In 2008, the value of TN and TP showed almost similar or slightly higher levels than reference values from Gijang area with decreasing values up to 50% and 51% for TN and TP, respectively, compared to year 2002. Particularly, the value of winter DIN and DIP in Jinhae Bay has sharply decreased since 2007 showing slightly smaller values than the reference value in 2007 and 2008. Winter N/P ratio in Jinhae Bay has shown a decreasing trend in recent years, likewise for both TN and TP and winter DIN/DIP, by showing similar or lower levels than both Redfield ratio (16:1) and background values after 2006.

Category II parameters: chlorophyll-*a* concentrations were higher than reference values, although they showed a slightly decreasing trend after 2006.

Category III parameters: DO level in the surface layer showed a slightly increasing trend. The fish-killing species, *Cochlodinium polykrikoides* never made any dense blooms in Jinhae Bay. Further, there has not been any fish kill incidents in Jinhae since 1970s. COD levels both in surface and bottom of Jinhae Bay showed slightly decreasing trends during 2002-2008, likewise in TN/TP. COD mean values at the surface ranged from 1.7 to 2.8 mg/L. Overall, COD values at the surface of Jinhae Bay were about two times higher than reference values acquired from Gijang area. The high COD values in Jinhae Bay compared to background values were estimated to be related to the high amount of organic matter substances including phytoplankton biomass.

Category IV parameters: Annual red-tide events by *Noctiluca scintillans* occured three times (2002, 2006, 2008) during 2001-2008 with a decreasing trend. It was not possible to seek any trend of Paralytic shellfish poisoning (PSP) incidents over time based on the data from the shellfish monitoring program. In addition, there has been no reports of patient suffering from PSP intoxication in Jinhae Bay since 1992.

Conclusively, it was summarized that eutrophication status of Jinhae Bay, including several small bays, was ‘Low eutrophication status’ and ‘Decreasing trend’.

Table 3-9 Assessment results of each assessment category in Jinhae Bay, Korea

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
Ⅰ	①Riverine input of TN	×	×	×	–	LD
	②Riverine input of TP	×	×	×	–	
	③TN concentration	H	×	D	HD	
	④TP concentration	H	×	D	HD	
	⑤Winter DIN concentration	L	×	D	LD	
	⑥Winter DIP concentration	L	×	D	LD	
	⑦Winter DIN/DIP ratio	L	×	D	LD	
Ⅱ	⑧Annual mean of chlorophyll-*a*	H	×	D	HD	HN
	⑨Ratio of area with high chlorophyll-a concentration to the total area	×	×	N	N	
	⑩Red tide events (diatom sp.)	×	×	N	N	
Ⅲ	⑪Dissolved oxygen (DO)	L	×	D	LD	LD
	⑫Fish kill incidents	×	L	N	LN	
	⑬Chemical oxygen demand (COD)	H	×	D	HD	
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	×	×	D	D	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

3.-4-2 Sub-area B (Masan-Haengam Bay)

Masan-Haegum Bay is located in the innnermost part of Jinhae Bay. Masan City facing Masan-Haengam Bay is one of the heavily industrialized cities in Korea. After Masan industrial complex was constructed in the 1960s, the marine ecosystem of the surrounding areas was deteriorated drastically (Oh et al., 2006). The water quality of Masan-Haengam Bay has been seriously eutrophicated by the discharge of domestic and industrial sewage, resulting in massive algal blooms from the early 1980s. However, the water quality of Masan-Haengam Bay has improved, showing remarkable decrease of nutrient loading since the Korean government designated Masan Bay as a special marine management area in 1982 under the revision of Korea Marine Pollution Prevention Law (Nam et al., 2005).

Reference values were set based on the values of Gijang area, and they were used in sub-area B (Masan-Haengam Bay) as well as sub-area A (Jinhae Bay).

Category I parameters: TN and TP showed higher level than the reference value with a decreasing trend between 2002 and 2008. Winter DIN and DIP in Masan-Haengam Bay showed a decreasing trend with slightly lower values than the reference value. Winter N/P ratio in Masan-Haengam Bay has shown decreasing trend.

Category II parameters: chlorophyll-*a* concentration was at a higher level than the background value although it showed a decreasing trend between 2002 and 2006. Ratio of area with high chlorophyll-a concentration to the total area and red-tide events of diatoms were not assessed in Masan-Haengam Bay.

Category III parameters: DO level in the surface layer showed an increasing trend. Annual mean of DO was higher than 6 mg/L ranging between 8 and 11 mg/L from 2002 to 2008. Abnormal fish kill incidents have not been observed since 1970. COD showed high status and no trend between 2002 and 2008.

Category IV parameters: Red-tide events of *Noctiluca scintillans* took place 0-4 times per year from 1981 to 2008 with decrease trend. In addition, there has been no patient reported suffering from paralytic shellfish poisoning (PSP) since 1992.

The water quality of Masan-Haengam Bay is still in a relatively higher eutrophication status than any other bay of Jinhae Bay. However, it will be improved year by year due to implementation of the the ongoing national water quality management activities. Therefore, eutrophication of Masan-Haengam Bay was assessed as ‘High eutrophicaion status’ and ‘Decreasing trend’ considering the eutrophication assessment parameters.

Table 3-10　Assessment results of each assessment category in Masan-Haengam Bay, Korea

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of TN	×	×	×	–	LD
	②Riverine input of TP	×	×	×	–	
	③TN concentration	H	×	D	HD	
	④TP concentration	H	×	D	HD	
	⑤Winter DIN concentration	L	×	D	LD	
	⑥Winter DIP concentration	L	×	D	LD	
	⑦Winter DIN/DIP ratio	L	×	D	LD	
Ⅱ	⑧Annual mean of chlorophyll-*a*	H	×	D	HD	HD
	⑨Ratio of area with high chlorophyll-a concentration to the total area	×	×	×	–	
	⑩Red tide events (diatom sp.)	×	×	×	–	
Ⅲ	⑪Dissolved oxygen (DO)	L	×	D	LD	LN
	⑫Fish kill incidents	×	L	N	LN	
	⑬Chemical oxygen demand (COD)	H	×	N	HN	
Ⅳ	⑰Red tide events (*Noctiluca* sp.)	×	×	×	D	LN
	⑱Shell fish poisoning incidents	×	L	N	LN	

3.-5 Peter the Great Bay, Russia

3.-5-1 Sub-area A (Amursky Bay)

Peter the Great Bay is situated in a northwestern part of NOWPAP region. Amursky Bay is situated to west from the Vladivostock. The Razdolnaya River flows into the northern part of the bay.

Table 3-11 Assessment results of each assessment category in sub-area A (Amursky Bay)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of DIN	H	×	I	HI	HI
	②Riverine input of DIP	H	×	I	HI	
	③DIN concentration	H	×	I	HI	
	④DIP concentration	H	×	I	HI	
	⑤DSi concentration	H	×	I	HI	
	⑥DIN/DIP ratio		×			
Ⅱ	⑦Annual mean of chlorophyll-*a*	L	×	I	LI	HN
	⑧Annual maxmum of chlorophyll-*a*					
Ⅲ	⑨Annual mean of DO	H	×	I	HI	HI
	⑩Annual minimum of DO					
Ⅳ	⑪Zoo-phytobenthos					LN
	⑫Kill fishes	×	L	N	LN	

3.-5-2 Sub-area B (Ussuriisky Bay)

Ussuriysky Bay is an open basin. It is located in the northeastern part of the Peter the Great Bay. During winter season ice formation occurrs in sub-area II. However, consolidated ice is not formed because the basin is open and strong winds, intensive water exchange between the bay and the unfavorable conditions for the formation of consolidated ice.

Table 3-12 Assessment results of each assessment category in sub-area B (Ussuriisky Bay)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	①Riverine input of DIN	L	×	N	LN	LN
	②Riverine input of DIP	L	×	N	LN	
	③DIN concentration	L	×	N	LN	
	④DIP concentration	L	×	N	LN	
	⑤DSi concentration	L	×	N	LN	
	⑥DIN/DIP ratio		×			
Ⅱ	⑦Annual mean of chlorophyll-*a*	L	×	N	LN	LN
	⑧Annual maxmum of chlorophyll-*a*					
Ⅲ	⑨Annual mean of DO	L	×	D	LD	LD
	⑩Annual minimum of DO					
Ⅳ	⑪Zoo-phytobenthos					LN
	⑫Kill fishes	×	L	N	LN	

3.-5-3 Sub-area C (South part of the Peter the Great Bay)

Sub-area C is the southern part of the Peter the Great Bay. Its area is about 6400 km^2. Depth varies from 0 up to 150 m and the average depth is about 70 m. In this sub-area, the biggest town is Nakhodka with a population of about 180,000. Total population in this sub-area is about 200,000. There are small rivers which flow into this sub-area. The most distinct feature of this sub-area is the intensive exchange between shelf waters of the bay and deep waters of the sea by downwelling and upwelling processes along the steep slope.

Table 3-13 Assessment results of each assessment category in sub-area C (South part of the Peter the Great Bay)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
Ⅰ	①Riverine input of DIN	L	×	N	LN	LN
	②Riverine input of DIP	L	×	N	LN	
	③DIN concentration	L	×	N	LN	
	④DIP concentration	L	×	N	LN	
	⑤DSi concentration	L	×	N	LN	
	⑥DIN/DIP ratio		×			
Ⅱ	⑦Annual mean of chlorophyll-*a*	L	×		L	L
	⑧Annual maxmum of chlorophyll-*a*					
Ⅲ	⑨Annual mean of DO	L	×	N	LN	LN
	⑩Annual minimum of DO					
Ⅳ	⑪Zoo-phytobenthos					
	⑪Kill fishes	×				

3.-6 Comparison of eutrophication assessment results in the selected sea areas of the NOWPAP member states

3.-6-1 Comparison of DIN concentrations

DIN concentrations were compared among the selected sea areas as an assessment parameter in Category I (Direct nutrient enrichment). China and Russia used data of annual mean DIN concentration while Japan and Korea used that of winter DIN concentration as a parameter. Data in Changjiang River Estuary and adjacent area, Sub-area A (Hakata Bay) in Northwest Kyushu area and Sub-area A (Amursky Bay) in Peter the Great Bay showed increasing trend. However, data in Jinhae Bay and Masan-Haengam Bay in Korea showed decreasing trend.

In comparison with the respective reference values, the values of Changjiang River Estuary and adjacent area and Sub-area A of Northwest Kyushu sea area exceeded their respective reference values and were classified as ‘High status.’ On the other hand, the values of Sub-area C (Intermediate area) in Northwest Kyushu area, all of the sub-areas of Toyama Bay, Jinhae Bay and Masan-Haengum Bay were under their respective references and classified as ‘Low status.’ Sub-area B (Dokai Bay) and Sub-area D (Offshore area) in Northwest Kyushu area did not have relevant data of the recent 3 years, so no classification was made. Assessment parameters in Sub-area A of Peter the Great Bay exceeded the reference and Sub-area A was classified as ‘High status.’

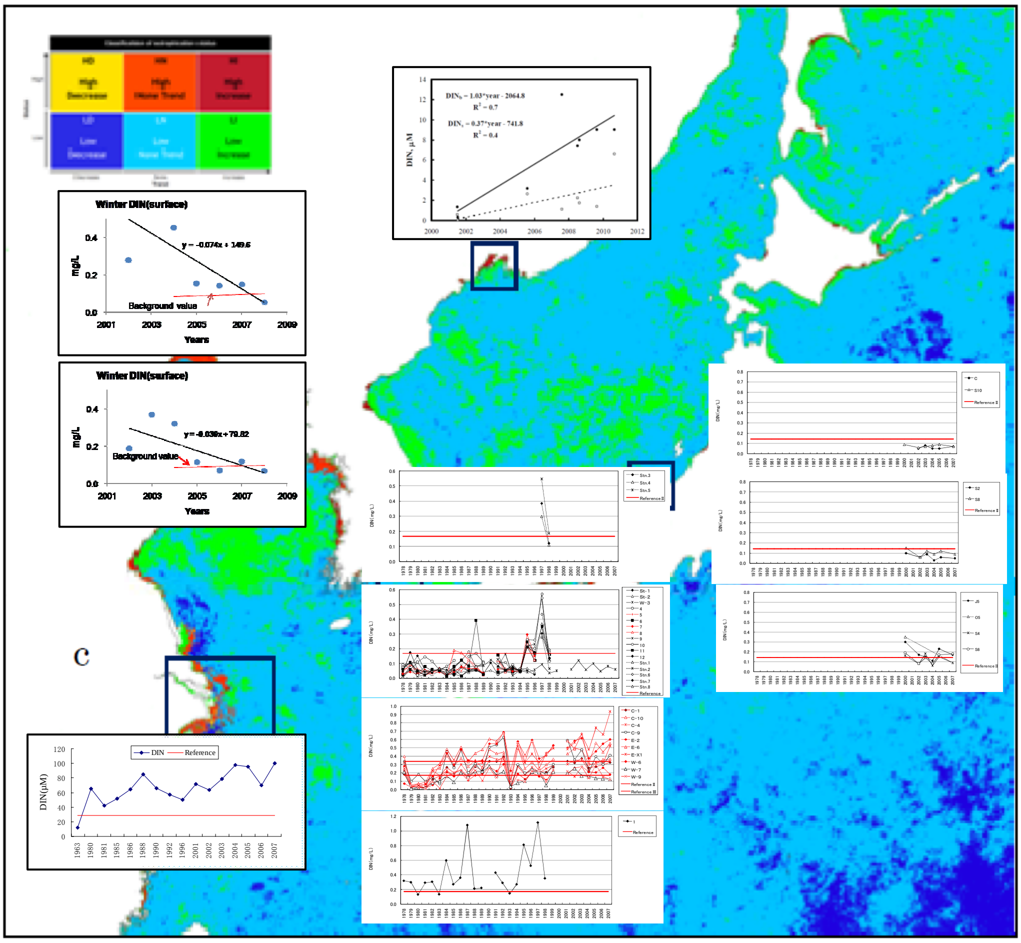

Fig. 3-1　　DIN concentrations in selected sea areas in NOWPAP region

DIN concentrations in each selected sea area is shown in Fig. 3-1. Annual mean DIN concentration with µM was used in Changjiang/Yangtze River Estuary and adjacent area. The reference value was 28.6 µM. Line graphs in Northwest Kyushu sea area are Sub-area D (Offshore area), Sub-area C (Intermediate area), Sub-area A (Hakata Bay) and Sub-area B (Dokai Bay) from the top. In Northwest Kyushu sea area, winter mean DIN concentration of each station was with mg/L was used. The reference values were: 0.338 mg/L (innermost of bay) and 0.169 mg/L (mouth of bay) in Sub-area A; and 0.169 mg/L in Sub-area B, C and D. Line graphs in Toyama Bay are Sub-area C (Offshore area), Sub-area B (Intermediate area), and Sub-area A (Coastal area) from the top. Same as Northwest Kyushu, data of winter mean DIN concentration with mg/L in each station was used. The reference value was 0.169 mg/L in all of the sub-areas. In Jinhae Bay, Korea, the top graph is Masan-Haengam Bay and the bottom one is Jinhae Bay. Also, data of winter mean DIN concentration with mg/L was used. The reference value was 0.09 mg/L in both sub-areas. In case of Peter the Great Bay, the data of Sub-area A (Amursky) is shown. DIN concentrations of the surface layer and the bottom layer are shown in lines with white circles and black circles respectively. Data of annual mean DIN concentration with µM. Russian reference value was set at unknown (need confirmation).

3.-6-2 Comparison of DIP concentrations

DIP concentrations were compared among the selected sea areas as an assessment parameter in Category I (Direct nutrient enrichment). China and Russia used data of annual mean DIP concentration while Japan and Korea used that of winter DIP concentration. Data in Changjiang River Estuary and adjacent area and the bottom layer of Sub-area A (Amursky) in Peter the Great Bay showed increasing trend. However, data of Jinhae Bay and Masan-Haengam Bay in Korea and Sub-area B (Dokai Bay) and C (Intermediate Bay) in Northwest Kyushu area showed decreasing trend. There was no trend identified in Sub-area A (Hakata Bay) and Sub-area D (Offshore area) in Northwest Kyushu sea area and all of the sub-areas in Toyama Bay.

In comparison with the reference values, values of Changjiang River Estuary and adjacent area exceeded the reference value and was classified as ‘High status.’ On the other hand, values in Sub-area A (hakata Bay) and C (Intermediate area) of Northwest Kyushu sea area, all of the sub-areas of Toyama Bay, Jinhae Bay and Masan-Haengum Bay were under their respective references and were classified as ‘Low status.’ Sub-area B (Dokai Bay) and D (Offshore area) of Northwest Kyushu area did not have relevant data of the recent 3 years, so no classification was made. Values of Sub-area A (Amursky Bay) in Peter the Great Bay exceeded its reference and was classified as ‘High status.’

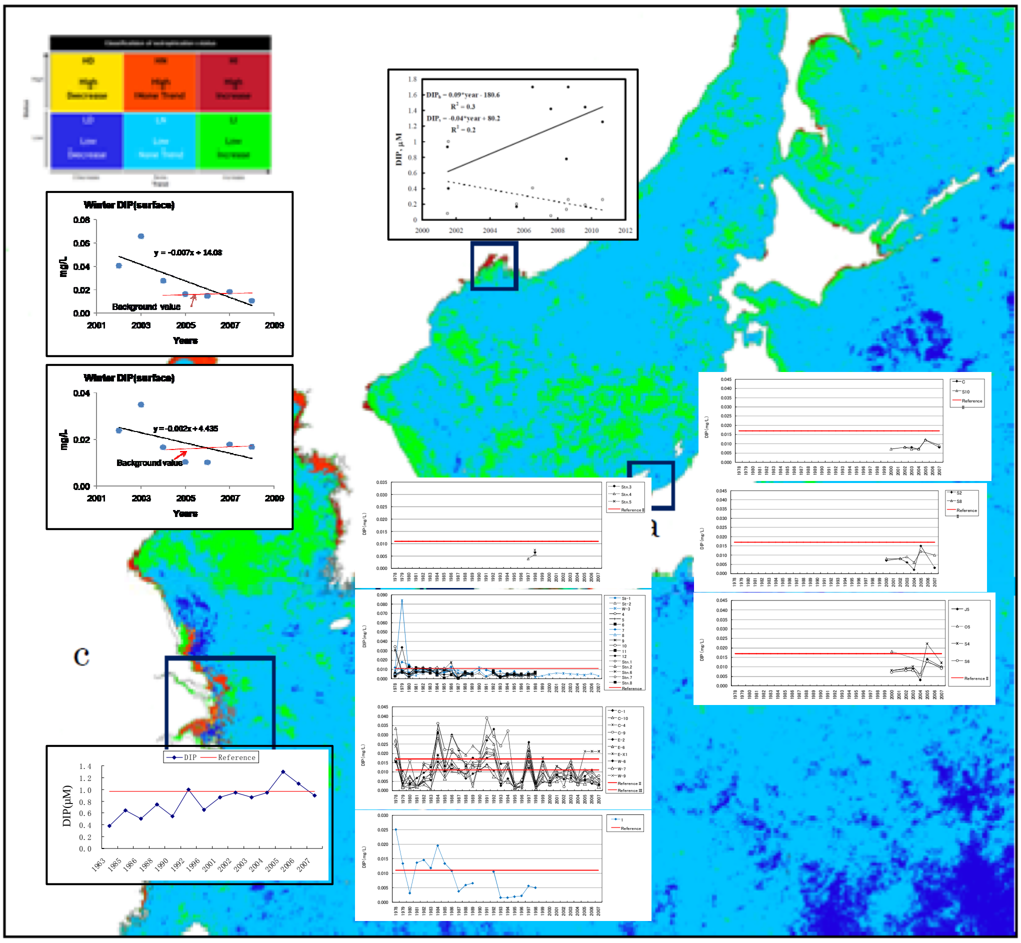

Fig. 3-2 DIP concentration in selected sea areas in NOWPAP

Fig. 3-2 shows DIP concentrations in each selected sea area. In Changjiang/Yangtze River Estuary and adjacent area, data of annual mean DIP as DIP concentration with µM was used. The reference value was 0.97 µM. Line graphs in Northwest Kyushu sea area are Sub-area D (Offshore area), Sub-area C (Intermediate area), Sub-area A (Hakata Bay) and Sub-area B (Dokai Bay) from the top. Data of winter mean DIP of each station with mg/L was used. The reference values were: 0.017 mg/L (innermost of bay) and 0.011 mg/L (mouth of bay) in Sub-area A; and 0.011 mg/L in Sub-area B, C and D. Line graphs in Toyama Bay are Sub-area C (Offshore area), Sub-area B (Intermediate Bay) and Sub-area A (Coastal area) from the top. Same as Northwest Kyushu, winter mean concentration of each station with mg/L was used.The reference value was 0.017 mg/L in all of the sub-areas. In case of Jinhae Bay, the top graph is Masan-Haengam Bay and the bottom one is Jinhae Bay. Winter mean DIP was used, with mg/L, and the reference value was set as 0.016 mg/L in all of the sub-areas. In case of Peter the Great Bay, the data of Sub-area A (Amursky Bay) is shown. DIP concentrations of the surface layer and the bottom layer are shown with lines with white circles and black circles respectively. Annual mean DIP concentration with µM was used.

3.-6-3 Comparison of DIN/DIP ratio

DIN/DIP ratios were compared among the selected sea areas as an assessment parameter in Category I (Degree of nutrient enrichment). China and Russia used data of annual mean DIN and DIP concentrations while Japan and Korea used data of winter DIN and DIP concentrations for calculation. Data in Changjiang River Estuary and adjacent area and Sub-area A (Hakata Bay), B (Dokai Bay) and C (Intermediate area) of Northwest Kyushu sea area showed increasing trend. However, data in Jinhae Bay and Masan-Haengam Bay showed decreasing trend. There was no increasing or decreasing trend identified in all of the sub-areas in Toyama Bay in Japan.

In comparison with the reference values, values in Changjiang River Estuary and adjacent area, sub-area A (Hakata Bay) and C (Intermediate area) of Northwest Kyushu sea area, and all of the sub-areas in Toyama Bay exceeded their respective references and were classified as ‘High status.’ On the other hand, values of Jinhae Bay and Masan-Haengum Bay were under the references and classified as ‘Low status.’ Sub-area B and D of Northwest Kyushu sea area did not have relevant data of the recent 3 years, so no classification was made. Reference value of DIN/DIP ratio was not set at Sub-area A (Amursky Bay) of Peter the Great Bay.

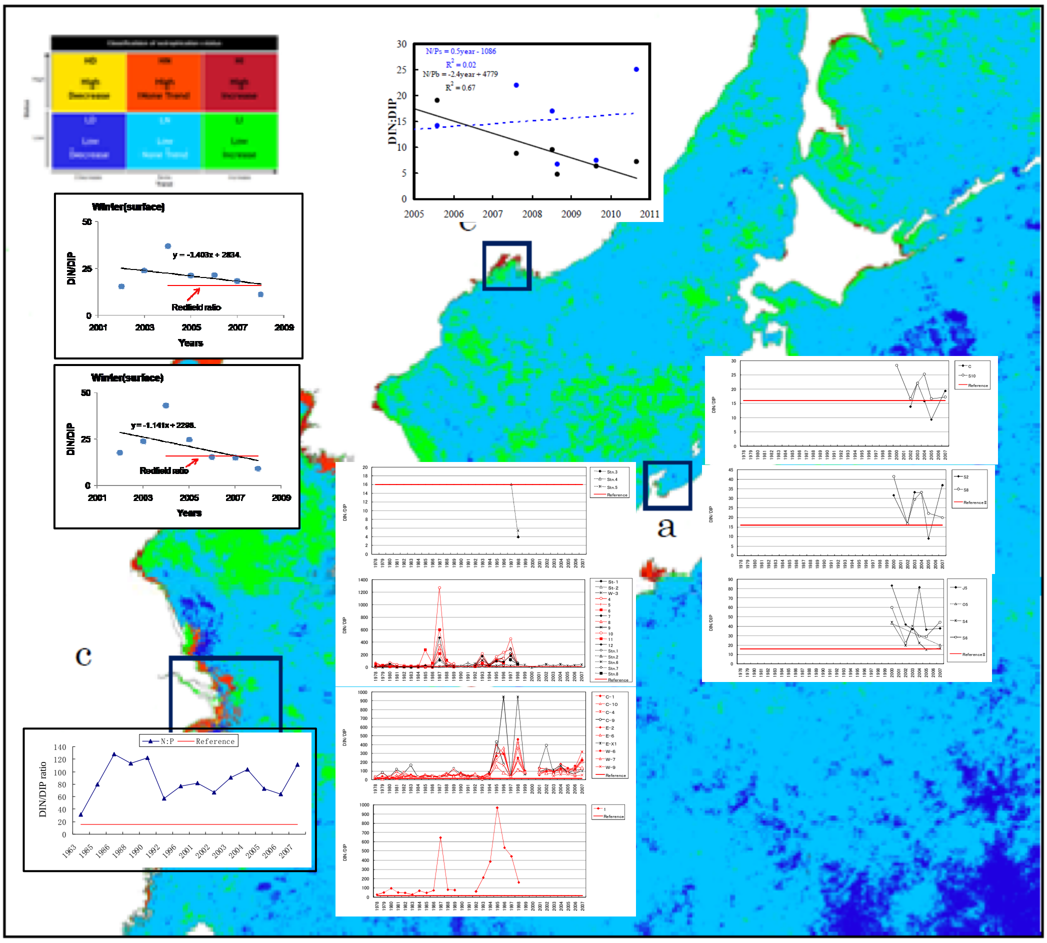

Fig. 3-3　DIN/DIP ratio in selected sea areas in NOWPAP

Fig. 3-3 shows data of DIN/DIP ratio in the selected sea areas. DIN/DIP ratio in Changjiang/Yangtze River Estuary and adjacent area was calculated by annual mean DIN and DIP concentrations. Redfield ratio of 16 was used as the reference value. Line graphs of DIN/DIP ratio in Northwest Kyushu sea area are Sub-area D (Offshore area), Sub-area C (Intermediate area), Sub-area A (Hakata Bay) and Sub-area B (Dokai Bay) from the top. DIN/DIP ratio was calculated by winter DIN and DIP concentrations of each station. Same as China, Redfield ratio of 16 was used as the reference value.

Line graphs in Toyama Bay are Sub-area C (Offshore area), Sub-area B (Intermediate area), and Sub-area A (Coastal area) from the top. DIN/DIP ratio was calculated by winter DIN and DIP concentrations of each station. Redfield ratio of 16 was used as the reference value. In Jinhae Bay, Korea, the top graph is Masan-Haengam Bay and the bottom one is Jinhae Bay. DIN/DIP ratio was calculated by winter DIN and DIP concentrations. Redfield ratio of 16 was used as the reference value.

In the assessment result of Peter the Great Bay, annual mean DIN/DIP in sub-area A (Amursky Bay) was shown. The reference value of DIN/DIP was not set in Peter the Great Bay.

3.-6-4　Comparison of annual maximum chlorophyll-*a*

Data of annual maximum chlorophyll-*a* were compared among the selected sea areas as an assessment parameter in Category II (Direct effects of nutrient enrichment). Data in Changjiang River Estuary and adjacent area showed increasing trend. However, data in Sub-area A (Hakata Bay) of Northwest Kyushu sea area showed decreasing trend. There was no trend identified in Sub-area B (Dokai Bay), C (Intermediate area) and D (Offshore area) of Northwest Kyushu sea area and all of the sub-areas of Toyama Bay.

In comparison with the reference value, values in Changjiang River Estuary and adjacent area exceeded its reference and were classified as 'High status.' Also, values in Sub-area A (Hakata Bay) and B (Dokai Bay) of Northwest Kyushu sea area exceeded the reference and were classified as 'High status.' On the other hand, values of Sub-area C (Intermediate area) of Northwest Kyushu sea area were under the reference and classified as 'Low status.' Sub-area D (Offshore area) of Northwest Kyushu sea area did not have relevant data of the recent 3 years, so no classification was made.

In Korea and Russia, annual maximum chlorophyll-*a* concentration was not used as assessment parameter.

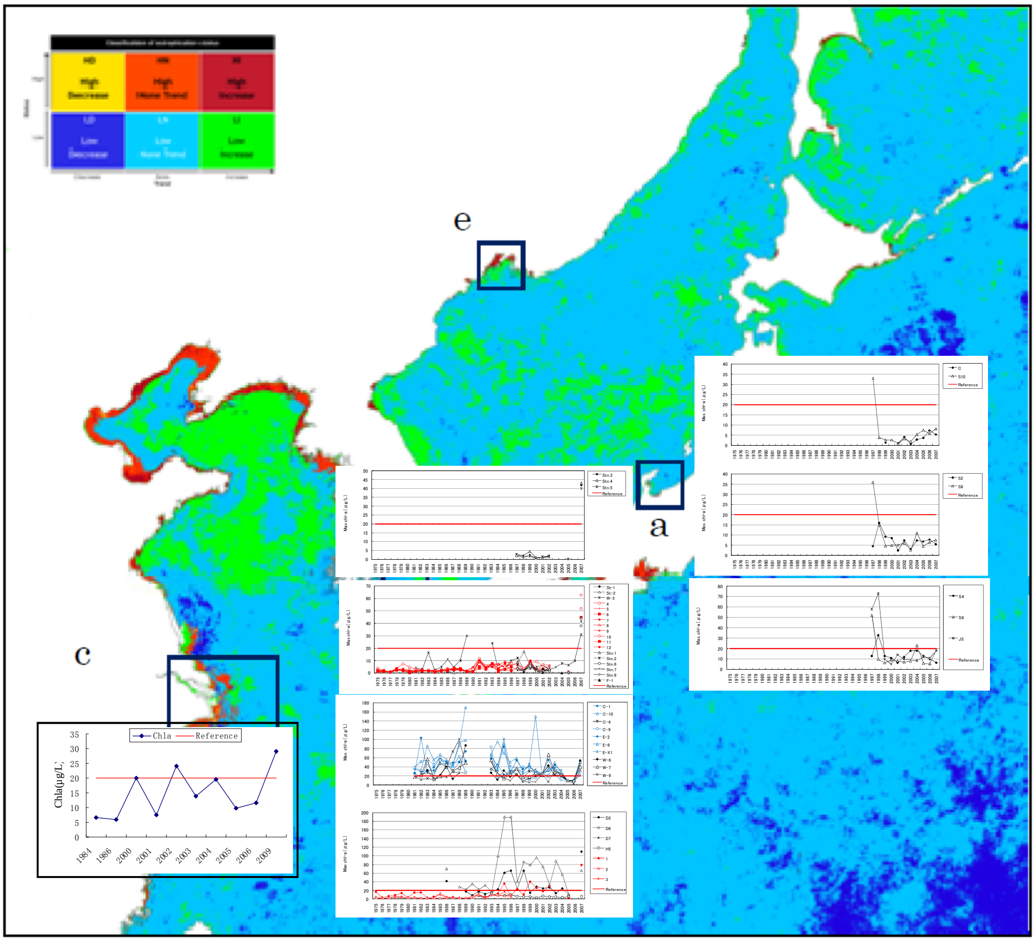

Fig. 3-4　Annual maximum chloropyll-*a* concentration in selected sea areas in NOWPAP

20 µg/L by referring Bricker et al. (2003) was used for the reference value of annual maximum chlorophyll-*a* in the selected sea areas in China, Japan and Korea Line graph of Line graphs of Northwest Kyushu sea area are Sub-area D (Offshore area), Sub-area C (Intermediate area), Sub-area

A (Hakata Bay) and Sub-area B (Dokai bay) from the top. In Toyama Bay, they are Sub-area C (Offshore area), Sub-area B (Intermediate area) and Sub-area A (Coastal area) from the top. In case of Korea, annual maximum chlorophyll-*a* was not selected as an assessment parameter. In the assessment result of Peter the Great Bay, there was no graph shown in the case study report. The reference value is set at 8 µg/L.

3.-6-5 Comparison of annual mean chlorophyll-*a*

Data of annual mean chlorophyll-*a* were compared among the selected sea areas as an assessment parameter in Category II (Direct effects of nutrient enrichment). Data in Changjiang River Estuary and adjacent area, Masan-Haengum Bay, and Amursky Bay showed increasing trend. However, data in Sub-area A (Hakata Bay) of Northwest Kyushu sea area showed decreasing trend. There was no trend identified in the other areas.

In comparison with the reference value, values of Sub-area A (Hakata Bay) and B (Dokai Bay) of Northwest Kyushu sea area, Jinhae Bay, Masan-Haengum Bay, and Amursky Bay exceeded the respective reference values and they were classified as ‘High status.’ On the other hand, values of Changjiang River Estuary and adjacent area, Northwest Kyushu sea area, and Sub-area B (Intermediate area) of Toyama Bay were under the respective references and classified as ‘Low status.’ Sub-area D (Offshore area) of Northwest Kyushu sea area did not have relevant data of the recent 3 years, so no classification was made.

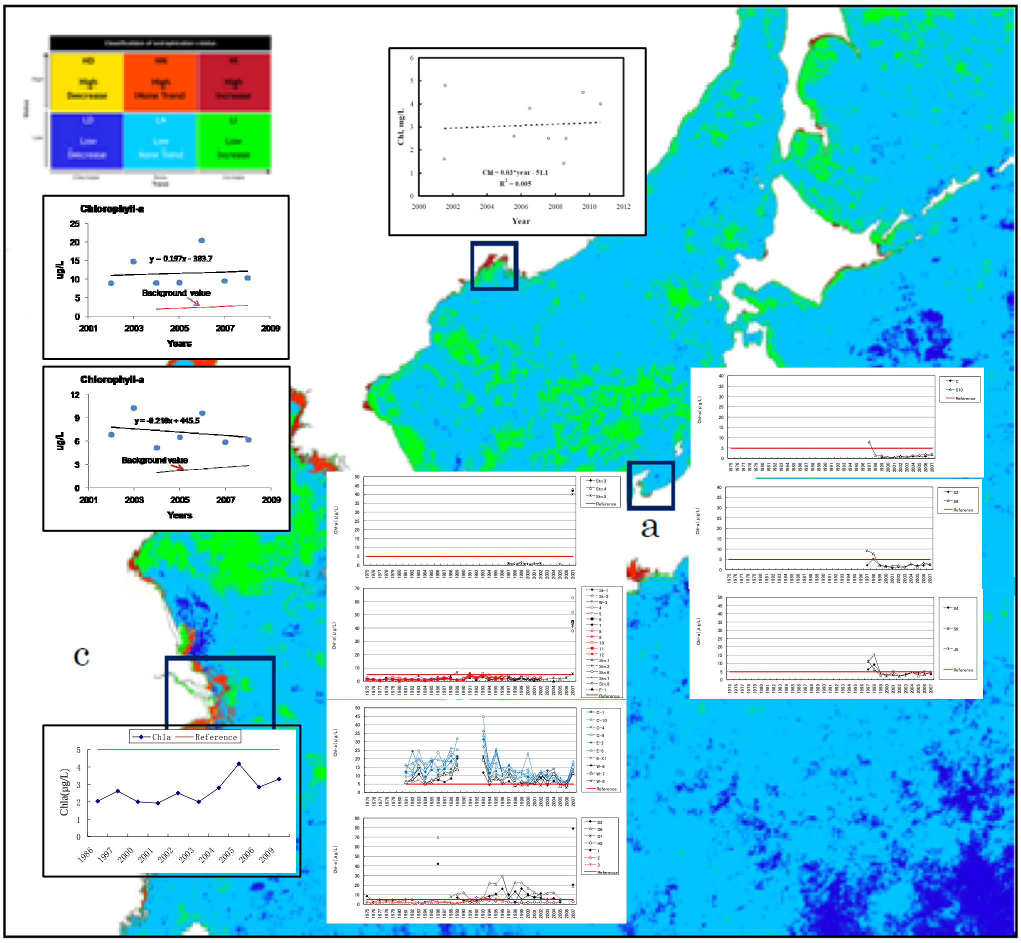

Fig. 3-5 Annual mean chlorophyll-a concentration in selected sea areas in NOWPAP

5 μg/L by referring Bricker et al. (2003) was used for the reference value of annual mean chlorophyll-*a* in the selected sea areas in China, Japan and Korea Line graphs of Northwest Kyushu sea area are Sub-area D (Offshore area), Sub-area C (Intermediate area), Sub-area A (Hakata Bay) and Sub-area B (Dokai Bay) from the top. In Toyama Bay, they are Sub-area C (Offshore area), Sub-area B (Intermediate area), and Sub-area A (Coastal area) from the top. In case of Korea, the top graph is Masan-Haengum Bay and the bottom one is Jinhae Bay. In Peter the Great Bay, the reference value is set at 8 μg/L.

3.-6-6 Comparison of surface DO

Data of surface DO was compared among the selected sea areas as an assessment parameter of Category III (Indirect effects of nutrient enrichment). Data of Changjiang/Yangtze River Estuary and adjacent area show no trend. Data of Sub-area A, B, C and D of Northwest Kyushu sea area and Sub-area A and B in Toyama Bay show no trend. However, data of Masan-Haengum Bay and Jinhae Bay in Korea showed increasing trend, and Sub-area C of Toyama Bay and Sub-area A of Peter the Great Bay showed decreasing trend.

In comparison with the reference value, values of Changjiang River estuary and adjacent area, Sub-area A (Hakata Bay), B (Dokai Bay) and C (Intermediate area) of Northwest Kyushu sea area, all sub-areas in Toyama Bay, Jinhae Bay and Masan-Haengum Bay satisfied the respective reference values and they were classified as ‘Low status.’ On the other hand, values of sub-area D (Offshore area) in Northwest Kyushu sea area, and Sub-area A (Amursky Bay) in Peter the Great Bay were under the respective references and classified as ‘High status.’

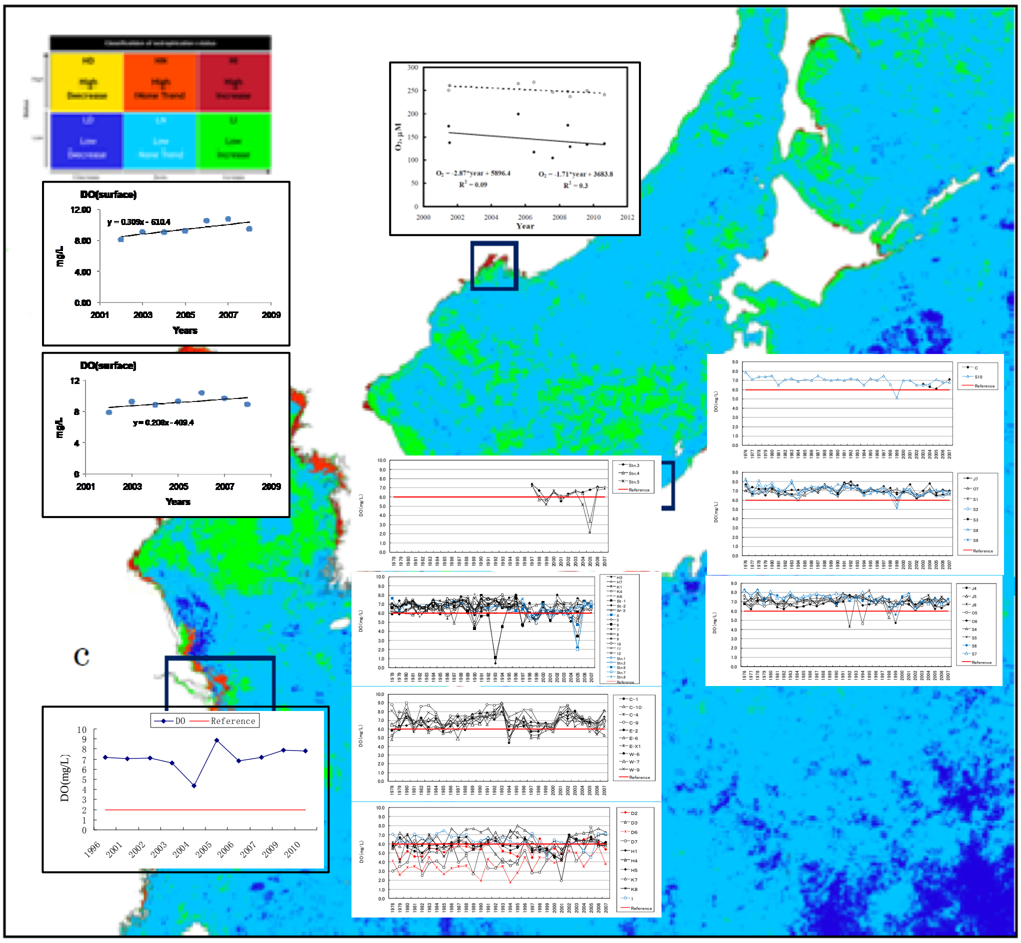

Fig. 3-6 Surface DO in selected sea areas in NOWPAP

In Changjiang/Yangtze River Estuary and adjacent area, annual mean DO was set as surface DO with the reference value: 2.0 mg/L. Line graphs of Northwest Kyushu sea area are Sub-area D, C, A and B from the top. Annual minimum DO was set as surface DO in each station, with the reference value: 6.0 mg/L. Line graphs in Toyama Bay are Sub-area C, B and A from the top. Same as Northwest Kyushu, annual minimum DO was set as surface DO in each station, with the reference value: 6.0 mg/L. In case of Jinhae Bay, the top graph is Masan-Haengam Bay and the bottom one is Jinhae Bay. Annual mean DO was set as surface DO, with 6.0 mg/L as the reference value. In Peter the Great Bay, the result of Sub-area A is shown. Annual minimum DO of the surface layer and the bottom one are shown with the lines of white circles and the black circles respectively. The reference value was set as 76 µM (2.4 mg/L).

3.-7 Nutrients loadings in each selected sea area

3.-7-1 Changjiang/Yantze River Estuary and adjacent area, China

Changjing/Yantze River is the 5th largest in the world, and the largest in the NOWPAP region. The average discharge is reported 9.24 x 10^{11} m^3/year (Tian et al. 1993). TN and TP inputs from Changjiang/Yantze River between 2006 and 2010 were 160-210 x 10^4 t/year and 15-19 x 10^4 t/year, respectively. These values did not show any increasing or decreasing trend. The data of DIN concentration from the river is for 35 years (1963-1997). It shows that DIN concentration increased from 0.2 x 10^6 t/year in 1963 to 1.6 x 10^6 t/year in 1997. In case of DIP concentration, the data is between 1964 and 1996, and the input increased from 14 x 10^4 t/year in 1964 to 63 x 10^4 t/year in 1996.

3.-7-2 Northwest Kyushu sea area, Japan

There are 13 rivers flowing into the Sub-area A (Hakata Bay) of Northwest Kyushu sea area. TN and TP inputs from these rivers were 2,207 t/year and 129 t/year in 2007, and both showed decreasing trend. In Sub-area B (Dokai Bay), there are 4 rivers flowing. TN and TP inputs from the 4 rivers were 196 t/year and 13 t/year respectively in 2007 and both also showed decreasing trend. In Sub-area C (Intermediate area), there are 13 rivers, and TN and TP inputs from the rivers were 2,808 t/year and 168 t/year respectively. In Sub-area C, both TN and TP inputs did not show any increasing or decreasing trend. The sum of TN inputs in all of the sub-areas was 5,211t/year and the sum of TP inputs was 310 t/year in 2007.

Sub-area A (Hakata Bay) has 5 sewage treatment plants from which water is discharged directly into the sea. TN and TP inputs from the 5 plants were 5,042 t/year and 53 t/year in 2007. Sub-area B (Dokai Bay) has 2 sewage treatment plants, and TN and TP inputs were 651 t/year and 15 t/year accordingly. In case of Sub-area C (Intermediate area), there are 4 sewage treatment plants. TN and TP inputs were 942 t/year and 92 t/year in 2007. The sum of TN and TP inputs from sewage treatment plants in these areas were 6,653 t/year and 160 t/year respectively in 2007.

3.-7-3 Toyama Bay, Japan

There are 5 Class A rivers and 29 Class-B rivers flowing into Toyama Bay. The Class-A rivers occupy 77% of the total discharge to the Bay (Toyama Bay Water Quality Preservation Research Committee, 2001). The daily average discharge of Class-A 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 daily average discharge from these 5 rivers is 263.44 m^3/s. TN inputs from these 5 rivers in 2007 was 28.2 t/day, and there was no trend identified. TP inputs from the 5 rivers was 0.65 t/day and showed decreasing trend.

Toyama Bay has 5 sewage treatment plants from which water is discharged directly to the sea. According to the reports of 2004, TN inputs from sewage treatment plants occupy 8% of total inputs into the bay, including inputs from rivers (Toyama Prefecture, 2008). Total phosphorus from the plants occupies 16 % of total inputs in Toyama Bay.

3.-7-4 Jinhae Bay, Korea

There are 6 big cities around Jinhae Bay, Korea. Thus, the water quality of the bay largely depends on chemical loads form the land. There are 40 rivers flowing into the bay. Between 1995 and 1996, total discharge from the rivers was 1,328.4 x 10^4 t/day. Among them, 750.5 x 10^4 t/day of river water flows into Sub-area B (Masan-Haengum Bay). TN and TP inputs into the entire Jinhae Bay were 29.7 x 10^3 kg/day and 2.23 x 10^3 kg/day respectively. In case of TN input, sub-area B (Masan-Haengum Bay) occupies 69% and the amount was 20.5 x 10^3 kg/day. In case of TP input, sub-area B (Masan-Haengum Bay) occupies 64% and the amount was 1.42 x 10^3 kg/day.

3.-7-5 Peter the Great Bay, Russia

In Peter the Great Bay, sub-area A (Amursky Bay) has big river such as Razdolnaya River and several small rivers including Shmidtovka, Amba, Barabashevka and Narva Rivers. They supply 47-55 x 10^6 t/year of river water discharge to Amursky Bay. TN and TP inputs from rivers were 4,200t/year and 450t/year respectively. DIN and DIP inputs were 1,800 t/year and 120 t/year respectively. Amursky Bay also receives waste water from Vladivostok City and other small towns. TN and TP inputs from waste water were 1,150 t/year and 140 t/year resepctively. Then, DIN and DIP inputs were 700 t/year and 100 t/year respectively.

Sub-area B (Ussuriisky Bay) has several small rivers such as Artemovka, Shkotovka, Sukhodol and petrovka Rivers and the bay receives riverine water of 1.3 km^3/year. TN and TP inputs form the rivers were 669 t/year and 91 t/year respectively. DIN and DIP inputs were 178 t/year and 24.3 t/year respectively. Ussuriisky Bay also receives waste water from Vladivostok City and other small towns same as Amursky Bay. TN and TP inputs from waste water were 1,600 t/year and 185 t/year respectively. DIN and DIP inputs were 950 t/year and 130 t/year respectively.

Sub-area C (Southern part of the Peter the Great Bay) is attached to Nakhodka City and several small rivers including Partizanskaya River flow into the sea. The southern part of the Peter the Great Bay receives riverine water of 1.2 km^3/year. TN and TP inputs from rivers were 500 t/year and 40 t/year respectively. DIN and DIP inputs were 250 t/year and 11 t/year respectively. In case of waste water in the southern part of the Peter the Great Bay, TN and TP inputs were 750 t/year and 160 t/year respectively while DIN and DIP inputs were 450 t/year and 100 t/year.

In entire Peter the Great Bay, TN and TP inputs from rivers were 5,100 t/year and 581 t/year. DIN and DIP inputs from rivers were 2,230 t/year and 156 t/year. TN and TP inputs from waste water were 3,500 t/year and 485 t/year respectively while DIN and DIP inputs were 2,100 t/year and 330 t/year respectively.

3.-7-6 Comparison of nutrient loads in selected sea areas

Figure 3-7 shows TN inputs in the selected sea areas in the NOWPAP member states. Because the discharge from Changjing River is a lot bigger than other rivers, the actual TN inputs from Changjiang River Estuary and adjacent area are a hundrea times the amount shown in the figure. TN input in Changjiang River was estimated at about 1.6 million t/y, based on the data from 2010. In the Northwest Kyushu sea area, TN inputs from rivers and sewage treatment plants to the sea area were calculated separately: they were 5,211 t/y and 6,653 t/y respectively, in 2007. TN inputs in Toyama Bay are indicated as the total inputs from the five Class-A rivers in 2007 and calculated 10,293 t/y. Besides the Class-A rivers, there are also TN inputs from 29 Class-B rivers and several sewage treatment plants. Thus, total TN is estimated at about 13,000 t/y. In the case of Jinhae Bay, Korea, the average TN input between 1995 and 1996 is shown. TN input to Jinhae Bay is a combination of riverine and waste water inputs, and estimated at 10,841 t/y. In Peter the Great Bay, TN input is 8,600 t/y with 5,100 t/y being from riverine and 3,500 from waste water sources..

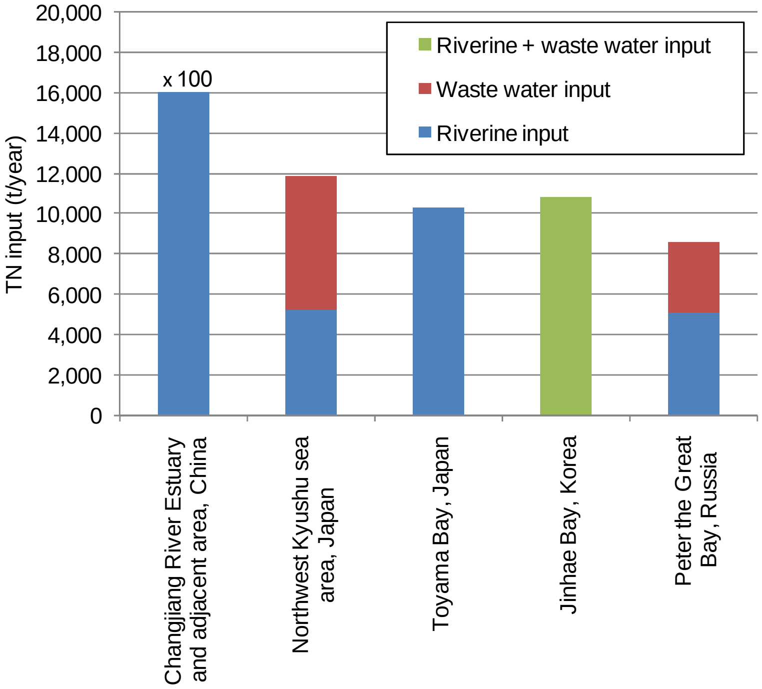

Fig. 3-7 TN inputs in selected sea area in NOWPAP region. Input in Chanjiang River Estuary and adjacent area needs to be multiplied by one hundred. The value of Chanjiang River Estuary and adjacent area, China for 2010. The value of northwest Kyushu sea area and Toyama Bay are from 2007. Value of Jinhae Bay, Korea is the average between 1995 and1996. Value of Peter the Great Bay is xxxx. (unknown)

Figure 3-8 shows TP inputs in the selected sea areas of the NOWPAP member states. Because the discharge from Changjing River is a lot bigger than other rivers, only 1% of actual TP inputs from Changjiang River Estuary and adjacent area is shown in the figure. Then, TP in Changjiang River is estimated about 17 x 10^4 t/y. In the Northwest Kyushu sea area, TP inputs from rivers and sewage treatment plants to the sea are calculated separately: 310 t/y and 160 t/y in 2007. TP inputs in Toyama Bay are indicated as the total inputs from the 5 Class-A rivers in 2007 and calculated 237 t/y. Besides the Class-A rivers, TN inputs from 29 Class-B rivers and several sewage treatment plants. Thus, actual TP is estimated about 360 t/y. In case of Jinhae Bay, Korea, the average input between 1995 and 1996 is shown. TP inputs to Jinhae Bay are combination of riverine and waste water TP inputs, and estimated 814 t/y. In Peter the Great Bay, TP input is 1,066 t/y (riverine TP input is 581 t/y and waste water TP input is 485 t/y).

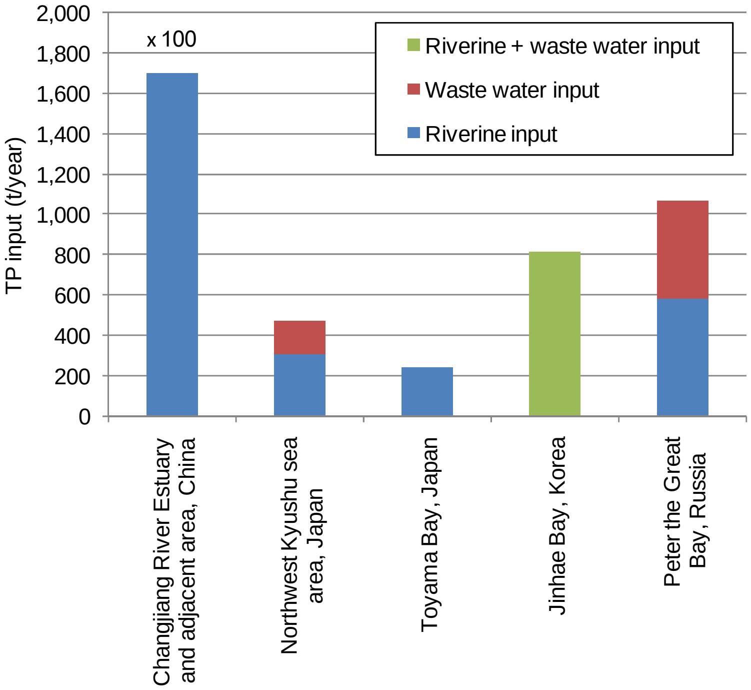

Fig. 3-8 TP inputs in selected sea areas in NOWPAP region. Input in Chanjiang River Estuary and adjacent area needs to be multiplied by one hundred. The value of Chanjiang River Estuary and adjacent area, China for 2010. The values of northwest Kyushu sea area and Toyama Bay are from 2007. The value of Jinhae Bay, Korea is an average for values from 1995 to 1996. The value of Peter the Great Bay is xxxx. (unknown)

3.-7-7 Current state of nutrient load and source information

As mentioned above, case studies from the four NOWPAP member states reported nutrient enrichment from rivers, sewage treatment plants, and waste water in cities. However, results on atmospheric deposition of nitrogen were not included in any of the case study reports. Moreover, there were no reports on detailed analysis of nutrient sources on the land, such as agriculture, industry or urban activities. In addition, besides nutrient enrichment by anthropogenic activities, there may be natural enrichment from the by open sea waters or ground waters. However, these issues were not mentioned in any of the case study reports. Thus, thus reports only provide fragmented information on the eutrophication status in the NOWPAP region.

4. Evaluation of eutrophication status and the NOWPAP Common Procedures

4.-1 Evaluation of eutrophication status in the selected sea areas in the NOWPAP member states

4.-1-1 Changjiang/Yangtze River Estuary and the adjacent area

The Changjiang/Yangtze River Estuary and adjacent area was classified as ‘High eutrophication status, Increased trend (HI).’ The Changjiang/Yangtze River is the largest river in China, and the fifth largest in the world. The population on the river basin is 400 million and nutrient enrichment is caused by industry cities as well as agricultural activities. In Category I (degree of nutrient enrichment), nitrogen and phosphorus loads from the Changjiang/Yangtze River were large, and an increasing trend in inputs of DIN and DIP was recognized between 1963 and 1996. The mean DIN concentration of the recent three years (2005-2007) in the Changjiang/Yangtze River Estuary and adjacent area exceeded the reference value (0.4 mg/L, 28.6μM) and showed an increasing trend between 1963 and 2007. The mean DIP concentration of the recent three years was below the reference value (0.03 mg/L, 0.97μM); however, an increasing trend was observed. On the other hand, DIN/DIP ratio showed no trend between 1963 and 2007. In Category II (direct effects of nutrient enrichment), the annual maximum chlorophyll-*a* concentration was higher than reference value (20 μg/L), and the number of red tide events also showed an increasing trend between 1990 and 2009. In Category III (indirect effects of nutrient enrichment), both DO and COD were under the reference values respectively. Based on this data, it is obvious to conclude that nutrient loads from Changjiang/Yangtze River are significant and nutrient concentrations are also high in the river estuary.

In the Changjiang/Yangtze River Estuary and adjacent area, various phenomena of ecological deterioration caused by eutrophication such as expansion of anoxic/hypoxic water masses (Chen et al., 2007; Wei et al., 2007), red tide and harmful algal bloom (HAB, Zhou, 2010) and green tide events (Leliaert et al., 2009; Liu et al. 2010; Hu et al., 2010), and jellyfish blooms (Dong et al., 2010) have been reported. It has also been pointed out that construction of the Three Gorges Dam has resulted in changes of flow residence and decreased supply of silicate, therefore, it has been considered that its construction would affect species composition and productivity of phytoplankton in the sea area (Chen, 2000; Gong et al., 2006; Harashima, 2007). Thus, reduction of nutrient input to the Changjiang/Yangtze River is expected to lead to an improvement of the environment in its estuary and the adjacent sea area.

4.-1-2 Northwest Kyushu sea area, Japan

The Northwest Kyushu Sea area was divided into the four sub-areas: sub-area A (Hakata Bay), B

(Dokai Bay), C (Intermediate area) and D (Offshore area). The Hakata Bay is located adjacent to Fukuoka City, which has a population of 1.45 million. The Dokai Bay is located adjacent to Kitakyushu City with a 0.98 million population includeing the Kitakyushu industrial zone.

In Category I (degree of nutrient enrichment), TN and TP from rivers showed a decreasing trend in Sub-area A (Hakata Bay). On the other hand, TN from sewage treatment plants showed an increasing trend. In some survey stations, winter DIN was higher than the reference value and showed an increasing trend. Annual mean and maximum chlorophyll-*a* were also higher than the reference values and red tide events were reported between 2005 and 2007. In Category II (direct effects of nutrient enrichment) and III (indirect effects of nutrient enrichment), results of the assessment indicated low eutrophication level status. xxx

In Sub-area A (Hakata Bay), xxx. the concentration of nitrogen and phosphorus should be balanced by adjusting the level of nitrogen and phosphorus inputs. The number of diatom and dinoflagellate red tides should also be reduced. xxx

In Sub-area B (Dokai Bay), survey stations were located in the Dokai Bay and Kanmon Strait. In Dokai Bay, TN and TP concentration decreased significantly between the 1970s and 1990s. COD also decreased from between the 1970s and 1990s and has remained stable during the recent 10 years. There are no significant eutrophication causes in the Kanmon Strait. Thus, it can be concluded that there are no negative effects of eutrophication in this area.

In Sub-area C (Intermediate area), concentrations of TN, TP, winter DIN and winter DIP were low. However, the area may be influenced by the other sea areas as dinoflagellate and *Noctiluca* red tides where found to occur. *Noctiluca* red tides were reported seven times within the assessed three years. Also, *Cochlodinium polykrikoides* was reported to be transferred from Korea through the Tsushima Warm Current (Onitsuka et al., 2010).

In Sub-area D (Offshore area), all parameters except DO were classified as either ‘Low eutrophication status and No trend’ or ‘No trend’. Hence, eutrophication did appear to have been a major issue. However, it will be necessary to investigate the causes of the low DO concentration in 2005.

The Hakata Bay is the most advanced area in the northwest Kyushu sea area in terms of reduction of nutrient enrichment from sewage treatment plants. As a result of decreased nutrient levels, primary production along the coastal area has decreased. This phenomenon may induce decreased reproduction of fish and problems in Nori *Porphyra* spp. (Seaweed) culture and natural growth of seaweeds used as alimental products. This kind of oligotrophication has been reported for the Seto Inland Sea, Japan (Yamamoto, 2003) and adequate nutrient enrichment is required to maintain biological production.

4.-1-3 Toyama Bay, Japan

There are five Class-A rivers flowing into the Toyama Bay. The sum of TN inputs from these five rivers didn’t show any trend between 1985 and 2007; however, the Jinzu River, the largest river, showed an increasing trend of TN input. On the other hand, the sum of TP inputs from these five rivers showed a decreasing trend. Concentration of nutrients in the sea area was under the reference value. The annual maximum of chlorophyll-*a* was lower than the reference value (20 µg/L) and showed no trend. The annual mean chlorophyll-*a* was also lower than the reference value (5 µg/L) and showed no trend. Preliminary assessment of eutrophication using satellite remote sensing indicated a possibility of eutrophication; however, *in situ* data showed only a low level of eutrophication.

In Sub-area A (Coastal area), all categories were classified as ‘Low eutrophication status and no trend’. However, among Category I parameters, as TN increase is identified in the data of the Jinzu River, it is necessary to reduce TN input. Among Category III parameters, some stations showed a decreasing trend of DO and an increasing trend of COD. Thus, there is a need to improve the status by reducing nutrient enrichment.

Similarly to Sub-area A, all categories were classified as ‘Low eutrophication status and No trend’ in Sub-area B (Intermediate area). However, 2 stations located in the western part of the bay showed an increasing trend in TN and TP concentrations. So, it is possible that eutrophication is increasing. In addition, some stations showed a decreasing trend of DO and an increasing trend of COD. This tendency was also shown in the coastal area. Therefore, implementation of countermeasures to nutrient loading in the coastal area could lead to an improvement of the marine environment of the intermediate area.

Based on the results in Categories I, II and IV, it was concluded that Sub-area C (Offshore area) was not eutrophicated eventhough DO concentration showed a decreasing trend, and COD concentration showed an increasing trend. Since the coastal and intermediate areas had the same pattern, there is a need to find the causes for these phenomena.

The level of eutrophication in the three sub-areas of the Toyama Bay (coastal, intermediate and offshore) was found to be low and most parameters showed no trend. The Jinzu River only showed an increasing trend. All sub-areas, however, had stations which showed a decreasing trend of DO and increasing COD. Thus, in order to address negative effects of eutrophication on the Toyama Bay, it is essential to pay close attention to TN input from the Jinzu River and consider measures to reduce the loads. According to Toyama prefectural government (2008), the main sources of TN emissions to this river are factories or plants (68%), domestic life (4%) and diffuse sources (28%). It means that for an effective reduction of TN input, countermeasures against emissions from factories or plants and diffuse sources need to be developed.

In the NOWPAP sea area including the Toyama Bay, giant jellyfish *Nemopilema nomurai* has been an emerging problem. This jellyfish swarms in the bay and causes problems to the local fisheries (Kawahara et al. 2006; Uye, 2008). *N. nomurai* is presumed to breed in the western part of the NOWPAP sea area and to have abnormally increased its numbers as a results of increasing eutrophication, development of the coastal area and global warming.

4.-1-4 Jinhae Bay, Korea

In the Jinhae Bay, the status of eutrophication has improved since 2002. However, eutrophication still exists in the Masan-Haengum Bay and Inner Jinhae Bay. In Category I (degree of nutrient enrichment), the mean of TN and TP concentrations had decreased by half in 2008 compared to 2002 but they still exceeded the reference values. Both winter DIN and DIP were below the reference values and showed a decreasing trend. Winter DIN/DIP ratio also was below the reference value and showed a decreasing trend. In Category II (direct effects of nutrient enrichment), the annual mean chlorophyll-*a* showed a decreasing trend, however, the value exceeded the reference. In case of red tide events, diatom sp. showed a decreasing trend. In Category III (indirect effects of nutrient enrichment) and IV (other possible effects of nutrient enrichment), incidents of paralytic shellfish poisoning by *Alexandrium* were reported.

4.-1-5 Peter the Great Bay, Russia

In the Peter the Great Bay in Russia, Sub-area A (Amursky Bay) was classified as ‘High eutrophication status and increasing trend’ while both Sub-area B (Ussuriisky Bay) and C (Southern part of the Peter the Great Bay) were classified as ‘Low eutrophication status and No-trend.’ In this sea area, addressing eutrophication in the Amursky Bay is required. On the other hand, effects of eutrophication on the Ussuriisky Bay and offshore area were considered rather small. The Razdolnaya River flows into the Amursky Bay, and Vladivostok, the largest city in Primorsky region, is facing the bay. These two are the main sources of nutrient loading to the Amursky Bay. Nutrient concentrations in the surface water of the bay were low but the bottom layer had high concentrations. The reason is assumed to be that the nutrients from the surface are transferred to the deeper layer by vertical transport by the biological pump. During the flooding period, nutrients from the Razdolnaya River are immediately taken up by diatom species and subsequently deposited at the sea bottom. As a result, hypoxic water masses were detected at the sea bottom during the summer. Thus, effects of eutrophication were more obvious in the bottom layer of the sea than the upper layer, and in this area it is a priority to address hypoxia in the sea bottom (Tishchenko et al., 2000).

4.-2 Nutrient sources and loads

4.-2-1 Riverine inputs of nutrients

Case study reports provide information on nutrient inputs of TN and TP from rivers. The inputs from the Changjiang/Yangtze River are 100 times larger than those from rivers in the other selected sea areas. The levels of TN and TP inputs from rivers in the Northwest Kyushu sea area and Toyama Bay in Japan, Jinhae Bay in Korea, and Peter the Great Bay in Russia were almost the same. The Changjiang/Yangtze River has the biggest flow volume in the NOWPAP region, and this also results in the greatest nutrient loads. There have been several studies done on eutrophication-related nutrient loads in the Changjiang/Yangtze River Estuary, and they indicate that nitrogen and phosphorus concentrations have increased compared to the past (Chai et al.,2006; Wang, 2007). The N and P levels were significantly elevated in the Changjiang main stream in a region 2,000-3,000 km inland from the river mouth (Chai et al., 2006). Along with the economic growth nationwide in China, nutrient loads significantly increased from the 1960s to the 2010s, therefore, fertilizers used in agriculture and household effluents are considered one of the major sources (Liu et al., 2003). In addition, due to the construction of the Three Gorges Dam, increases in nitrogen and phosphate with a decrease in silicon have been of concern (Chen, 2000; Gong, 2006). The consequent change of N: P: Si stoichiometric ratio may be advantageous to flagellates but not to diatoms of phytoplankton in the sea area (Harashima, 2007).

The TN and TP inputs from the rivers in Hakata Bay and Dokai Bay in the Northwest Kyushu Sea area and Kanmon Strait showed a decreasing trend. In the Hakata and Dokai Bays, nutrient loads have been on the decrease as a result of the improvement of sewage treatment and enacted regulations on waste water from factories. On the other hand, TN and TP inputs from rivers to the Intermediate area didn’t show any trend. In this area, the major river source of nutrients is the Onga River and the nutrient loads from it didn’t show any trend.

In the case of Toyama Bay, Japan, TN input showed no trend, while TP input showed a decreasing trend. Nitrogen and phosphorus loads from factories have decreased since the Toyama Prefectural Government strengthened the regulations on waste water from, them. However, as diffuse source nitrogen loads from the Jinzu River have increased, TN inputs from all rivers in total has remained unchanged.

There was no long-term data on riverine inputs from the Jinhae Bay, Korea, and thus nutrient loads from rivers were not assessed. However, as TN and TP concentrations and winter DIN and DIP concentrations in the Jinhae Bay have decreased, it can be concluded that land-based nutrient loads have steadily decreased. Winter DIN/DIP ratio has been close to Redfield ratio of 16 since 2006, but exceeded this reference figure before 2005. In other words, the DIN/DIP ratio proves that appropriate management of nutrient emissions has been applied.

Nutrient inputs from the Razdolnaya River account for more than 70% of all inputs to the Amursky Bay in Russia and the load from the river mainly take place between April and September (70-90%). The DIN and DIP inputs from rivers increased between 2001 and 2007. Eutrophication caused by nutrient loads from rivers affect ecological succession in biological communities in the Amursky Bay, by increasing in the number of pollution resistant species.

The report ”Regional overview on river and direct inputs of contaminants into the marine and coastal environment in NOWPAP Region with special focus on the land based sources of pollution” (NOWPAP POMRAC, 2009) further explains nutrient inputs from major rivers into the NOWPAP sea area.

4.-2-2 Atmospheric deposition of nutrients

National reports on atmospheric deposition of contaminants into the marine and coastal environment in NOWPAP region (NOWPAP POMRAC 2006) and the report “Regional overview on atmospheric deposition of contaminants to the marine and coastal environment in NOWPAP Region” (NOWPAP POMRAC, 2007) describe this type of pollution more in detail. The main focus of these reports is on the amount of the atmospheric deposition and the information and knowledge on the influences or damages by them on the marine environment is scarce. Atmospheric deposition is recognized as one of the means of transport of nutrient loads, especially of nitrogen, into the sea. It is reported that in the East China Sea, the volume of deposition of ammonium and nitrate are almost same as the load from the Changjing/Yangtze River (Uematsu et al., 2002; Nakamura et al. 2005). Deposition of terrestrial aerosols is one of the major sources of nutrients to the ocean waters. Atmospheric inputs to the East China Sea are comparable to the riverine inputs of the Changjiang/Yangtze River. The effect of atmospheric nitrogen input on biological production in the Japan Sea have been investigated using a coupled physical-ecosystem model (Onitsuka et al., 2009). The atmospheric nitrogen deposition supports >10% of annual export production in the nearshore region along the Japanese coast. Thus, nitrogen nutrient loads by atmospheric deposition may influence to some degree eutrophication and biological production of the marine ecosystem. It can be expected that further increase of air pollution will lead to an increase of airborne nutrient loads to the sea. Diffusion of atmospherically deposited substances tends to be fast and wide and nitrogen is readily available to phytoplankton. Therefore, it is possible that it results in widespread contamination, further eutrophication, as well as transboundary problems.

4.-2-3 Other possible sources of nutrients

There are other sources of nutrient loads to the sea. The biggest one is the nutrients derived from the pelagic sea. Even though the concentrations of nutrients are low, the total amount of nutrients is so big that they have an influence, depending on the circulation of the seawater masses. Accumulation of nutrients to the sea bottom is also of concern, as they can be released back into the seawater. Especially, as the hypoxia of waters at the sea bottom advances, nutrients are more likely to be released. Thus, even if land-based nutrient loads will be reduced, its effect cannot be seen immediately because of reintroduction of the nutrients in the past.

In addition, the influence of aquaculture on eutrophication has been pointed out. Aquaculture of fishes and invertebrates remains feed and accumulates at the sea bottom, and is a source of eutrophication. In seaweed culture, seaweeds absorb nutrients to grow. In other words, they prevent eutrophication.

Submarine groundwater discharge is also one of the sources of nutrients to the sea. This type of nutrient loading has been reported in Toyama Bay, Japan (Zhang and Satake, 2003). In Masan Bay, Korea, negative effects of groundwater contaminated by industrialization on the sea area have been reported (Lee et al., 2009).

Nutrients loads can be caused by various anthropogenic activities, however, they are also essential for the biological production in the sea. Thus, it is also important to point out that habitat creation for marine organisms and increase in biomass of e.g. plankton, fish, seaweed, benthos, etc can help prevent eutrophication.

As mentioned above, there are various sources of nutrient loads which control eutrophication in the sea. To effectively address eutrophication, there is a need to understand the amounts generated by each source and plan effective reduction. In addition, in order to identify the needed amount of nutrient reduction, it is necessary to understand the quantities of loads to the sea and the amounts already in the sea and to analyse sensitivity of the sea areas to those by using ecological models.

4.-3 Evaluation of the NOWPAP Common Procedures

4.-3-1 Achievements with the use of NOWPAP Common Procedures

Procedures for the assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region (the NOWPAP Common Procedures) were developed by NOWPAP CEARAC in 2009. In this study, they were used to assess eutrophication status in the selected sea areas in the four NOWPAP member states. For these case studies, common parameters were chosen from among the parameters used in regular assessments for eutrophication in the different countries and coordinated for this eutrophication assessment. At the beginning of the assessment, each country set reference values and based on them classified the collected dataeither as 'High Status' when the value exceeded the reference or as 'Low Status' when the value was under the reference.Further, 'Increasing' or 'Decreasing or No Trend' when the values were significant accoding to statistical analysis. As a result, there were six classes identified using the combination of Status and Trend (Fig. 2-1).

In the results of the respective assessments in the selected sea areas, it was possible to compare nutrient loads (TN and TP inputs) and assessment parameters (DIN and DIP concentrations, DIN/DIP ratio, annual maximum chlorophyll-*a*, annual mean chlorophyll-*a* and surface DO) between the countries although there were some differences. It was revealed that there were differences in assessment parameters, assessment periods and reference values among the NOWPAP member states. In addition, remote chlorophyll-*a* concentration was also tested and compared with in situ data and it was considered that after adjustments of algorithms remote sensing has potential to help identifying sea areas at risk of being eutrophicated. However, this assessment of eutrophication status in the selected sea areas is considered to have helped in identification of causes and countermeasures for eutrophication. Furthermore, eutrophication in the NOWPAP region was recognized as a being partly transboundary problem.

4.-3-2 Problems of the NOWPAP Common Procedures

The parameters and reference values used in this eutrophication assessment were different in almost every member state (Table 2-2). The basis used to set reference values in each member state was: 'National Sea Water Quality Standard of China' in China (Table 2-7); 'Environmental Water Quality Standard' (the Ministry of the Environmental of Japan, 1971) and 'Fisheries Water Quality Standard' (Japan Fisheries Resource Conservation Association, 2005) in Japan (Table 2-8, 9). In Korea, ;reference values were set based on the concentrations in Gijang area, which is close to the selected sea area, Jinhae Bay, and has not been affected by eutrophication (Table 2-10). In Russia, the maximum permissible concentration is set by the central government (NOWPAP POMRAC, 2009); however, the values in the regulation are quite high. Thus they were not applied in this case study as reference values. Instead, the reference values for the assessment were calculated by RKR model (Redfield et al. 1963) based on minimum necessary oxygen concentration at the sea bottom (Table 2-11). As mentioned above, reference values in each case study area are different. Accordingly, comparison of the classification results (six classes) in different assessment areas requires scrutiny and interpretation of the raw data.

4.-3-3 Future actions for refinement of the NOWPAP Common Procedures

The assessment of eutrophication status was tested in 2010 in five selected sea areas of the NOWPAP member states using the NOWPAP Common Procedures. In the future, the number of study areas should be increased. In addition, it is crucial to develop a framework for continuous monitoring of eutrophication status in the sea area and of the nutrient loads from various sources. The preliminary eutrophication assessment by remote sensing techniques has potential to help in indentification of the sea areas at eutrophication risk. However, chlorophyll-*a* concentrations estimated by satellites included some errors in high turbid waters,and therefore, improvement of the data quality with the adjusted algorithm (Case II Ocean Color Algorithm) is necessary. In addition, as stated above, further harmonization of reference values is also needed to make the comparison of eutrophication status among the member states more reliable.

5. Exisiting policies related to management of eutrophication in the NOWPAP member states

5.-1 China

China's practices related to the management of its ocean and coastal activities, including eutrophication management, were reviewed by the Task Force set up by the China Council for International Cooperation on the Environment and Development (CCICED). The Task Force conducted an in-depth scientific analysis of a number of urgent ocean and coastal issues including: eutrophication, pollution, climate change, hydraulics (dams), land reclamation, and fisheries management. CCICED published ECOSYSTEM ISSUES AND POLICY OPTIONS ADDRESSING SUSTAINABLE DEVELOPMENT OF CHINA'S OCEAN AND COAST was in 2010 and provided eight policy recommendations, with twelve embedded stand-alone actions. To prevent eutrophication development of a national strategy for the sustainable development of the ocean and coast are recommended.

China has also signed endorsement for of the Regional Strategic Action Programme for the Yellow Sea Large Marine Ecosystem (YSLME) in 2009 and agreed on a 10% reduction of total nutrient loading from point source from 2006 to 2010. The reduction policy is still in effect today and will be continued in the future.

The Ministry of Environmental Protection of China and the Ministry of the Environment of Japan have been working together for reduction of total nutrients loading since 2007. As an outcome of this international collaboration, Guidance for Introducing the Total Pollutant Load Control System (TPLCS) was published by the Ministry of the Environment of Japan in April aiming at contributing to improvement of water quality.

5.-2 Japan

In Japan, various activities have been implemented to prevent eutrophication in the sea areas by reducing land-based COD and TN and TP loads. For example, regulations on total emissions have had some positive effects on eutrophication in Tokyo Bay, Ise Bay and Seto Inland Sea on the coast of the Pacific Ocean side. However, while some anti-eutrophication countermeasures have been successful, there are still hypoxic water masses and occurrences of red tides have still been reported. By now, actions taken have been focused on features such as reduction of nutrient loads from land to sea. For more effectively addressing eutrophication issues, it is necessary to take into consideration physical features (geographical features, ocean currents, and residence time) as well as biological features (material circulation and biological production). Especially, the studies on Seto Inland Sea have reported lowering of purification capacity of the shallow sea area decrease in the amount by reduction of seaweeds and tidal flats by development of the area. Also, simplification of the food web structure by degradation of habitats is of concern. The ideal condition is a steady and smooth circulation of nutrients and carbon by vigorous uptake of materials by various species (Matsuda et al. 2007; Yanagi, 2006; 2011).

5.-3 Korea

The Korean government has been planning to introduce a total pollution load management (TPLM) system into the coastal environment management regime of the Masan Bay. TPLM was initiated in 2005 to assess total pollution load and carrying capacity, and allocated a load reduction requirement to each city (Masan City, Jinhae

City, and Changwon City). Based on the newly formulated mechanisms, central government, local government, the mentioned three cities, the navy, academies, business sectors and NGOs established a Community Advisory Council. Korean government designated Masan Bay and Jinhae Bay as special marine management areas in 1982 under the revision of Korea Marine Pollution Prevention Law to mitigate eutrophication.

Korea also takes part in YSLME, and has agreed on the 10% reduction of total nutrient loading from point sources in the proposal documents to Global Environment Facility for the 2nd phase of the project.

5.-4 Russia

There have been no development of national policy for management of eutrophication besides the Maxim permission concentrations set up by the ROSHYDROMET.

6. Conclusions and recommendations

6.-1 Conclusions

Case studies to evaluate suitability of the NOWPAP Common Procedures in the selected sea areas indicated that comparison of the eutrophicaion status and trend among the four NOWPAP member states was possible through the use of common parameters on eutrophication. However, refinement of the NOWPAP Common procedures is necessary such as revising reference values and classification system.

There were two different cases identified in the NOWPAP sea area: one that requires reduction of nutrient inputs such as Changjiang/Yangtze River Estuary, and another where nutrient loads have been reduced at some degree, and that needs appropriate management of nutrient loads taking into account steady and smooth circulation of nutrients and carbon in the marine ecosystem.

Base on these findings, the following recommendations are proposed for future NOWPAP activities to combat eutrophication in the region.

6.-2 Recommendations to combat eutrophicaion in NOWPAP

6.-2-1 Integrated assessment of eutophication status of the whole NOWPAP region.

Hence case studies included in this report is geographically limited to assess eutrophication status of the whole NOWPAP region, it is expected to carry out an integrated assessment of eutrophication status with refined Common Procedures and use of harmonized reference values, adjusted algorithms of satellite derived chlorophyll and data of atmospheric deposition of nutrients, especially nitrogen, and by adding more case studies and enlarging the assessment area to the open sea.

6.-2-2 Delivering results of eutrophicaion assessment for Integrated Coastal and River Basin Management

It is essential to reduce nutrient loads to the sea to solve eutrophication-related problems in some selected sea area. The sources of nutrients vary, for example, anthropogenic activities such as industry, sewage treatment plants, urban runoff, agriculture, aquaculture, nutrient release by soil erosion and nutrients loss caused by construction of dams. For effective management of nutrients, Integrated Coastal and River Basin Management (ICARM) is one of possible effective measures; therefore, it is recommended developing a concrete management plan in each basin with POMRAC. ICARM in the NOWPAP region is explained in details in NOWPAP POMRAC (2010). It is expected that ICARM will be reflected national/regional/international policies into the countermeasures and enact relevant legislations for management of eutrophicaion.

6.-2-3 Assessment of negative impact of eutrophicaion to marine environment in the NOWPAP region

Although it is known that eutrophication may give negative impacts to marine environment in various ways, quantitative assessment of those negative impact in the NOWPAP region has not been done much in an international framework. CEARAC has been collecting data on red tides and HAB events including composition of plankton species and its economic damage to fishing industry. These information should be further analyzed in comparison with the obtained eutrophication assessment results to quantify negative impacts of eutrophication. It is also necessary to study impacts on benthic comunities, macro algae and sea grasses, which may lead lose of marine biodiversity.

6.-2-4 Introduction of ecological modeling to set appropriate nutrients control (reducation) target

In Tokyo Bay and Ise Bay, and the Seto Inland Sea, which are typical Japanese enclosed sea areas, emissions of land-based TN, TP and organic matter including COD were restricted by ‘Water Quality Total-Volume Restriction.’ This restriction has been effective on eutrophication in part to some extent; however, occurrences of red tides and hypoxic water masses in the bottom layer have still not been completely prevented. Sources of nutrient loads vary, so it is necessary to develop more effective actions to reduce the nutrients loading. One of possible approaches is understanding appropriate level of nutrients to maintain steady and smooth circulation of nutrients and carbon in the marine ecosystem by ecological modeling. This will help the development and implementation of more effective nutritional management. Also, it is necessary to consider integrating physical models and satellite data into the ecological model to predict eutrophication status.

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Glossary

CEARAC: Special Monitoring & Coastal Environmental Assessment Regional Activity Centre

COD: Chemical Oxygen Demand

DIN: Dissolved Inorganic Nitrogen

DIP: Dissolved Inorganic Phosphate
DO: Dissolved Oxygen
DSi: Dissolved Silicic acid
HABs: Harmful Algal Blooms
NOWPAP: Northwest Pacific Action Plan
OSPAR: Convention for the Protection of the Marine Environment of the North-East Atlantic (originally the Oslo and Paris Conventions)
POMRAC: Pollution Monitoring Regional Activity Cntre

Acknowledgements

Annex

- Annex 1. Results of eutrophication assessment in each selected sea area. (To be attached in CD-R)
  - Yangtze River Estuary and adjacent area, China
  - Northwest Kyushu sea area, Japan
  - Toyama Bay, Japan
  - Jinhae Bay, Korea
  - Peter the Great Bay, Russia
- Annex 2. Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region
- Annex 3.Evaluation of preliminary eutrophication assessment by satellite in each selected sea area

Annex 2

Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region

(Developed in June 2009)

－Contents－

1. Introduction

Eutrophication is the phenomenon of aquatic ecosystem enrichment due to increased nutrient loading. Eutrophication is often caused by human activities, such as inputs of fertilizers from agriculture farming, feed for aquaculture, untreated and/or treated sewage as well as industrial wastewater. Eutrophication causes the deterioration of the coastal environment and typically leads to the formation of harmful algal (phytoplankton) blooms which may subsequently induce fish kill, further ecosystem damage and, at times, are directly or indirectly associated with human health problems. Eutrophication degrades the water quality by decreasing oxygen amount and often light penetration through accelerating excessive production of organic matter in the coastal waters.

In the Northwest Pacific region, 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, the availability of continuous and synoptic water quality data, particularly in estuaries and bays is lacking, and it is difficult to characterize the response of water quality to human and natural impacts. Furthermore due to increases in agricultural and industrial activity 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 “Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region (Procedures)”. It is hoped that the obtained assessments will provide arguments to limit or, if possible, to reduce anthropogenic change of the coastal ecosystem.

1.1 Background

1.1. Development of the Procedures was proposed and approved at the 5th CEARAC (Special Monitoring and Coastal Environmental Assessment Regional Activity Center) Focal Point Meeting (FPM) held in Toyama on September 18-19, 2007.

1.2. As part of the development processes of the draft Procedures, NPEC (Northwest Pacific Region Environmental Cooperation Center) 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 First Coastal Environment Assessment Workshop held in Toyama on March 6-8, 2008.

1-2. Objectives of the Procedures

1.3. The objectives of the 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 Procedures will be continuously revised and improved by reflecting the feedbacks from each NOWPAP member state gains through the implementation of the Procedures. Figure 1 schematically shows the concept of the Procedures.

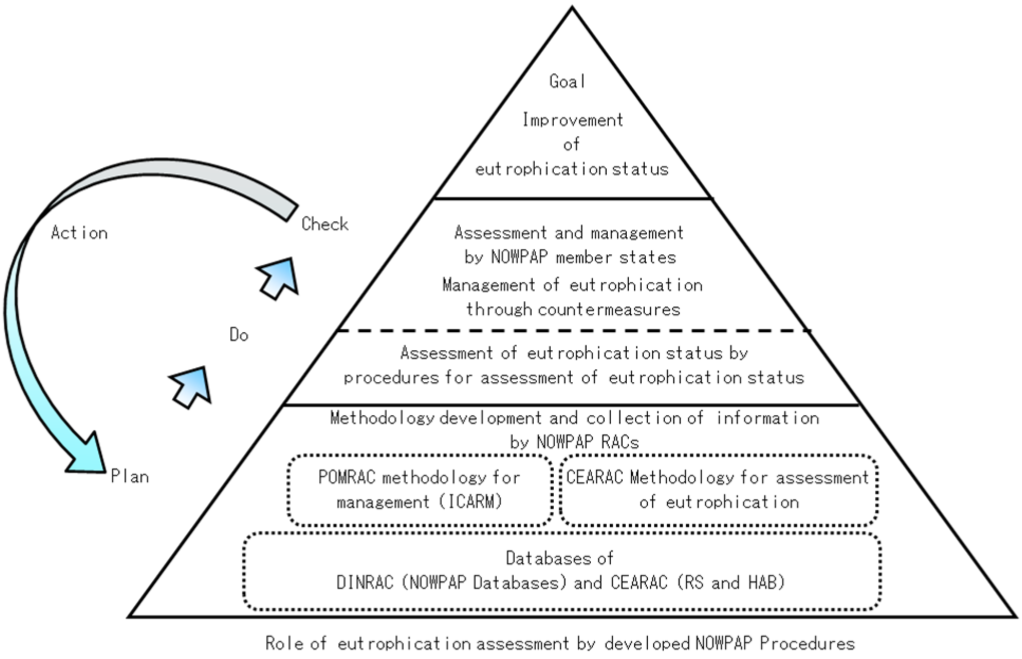


Figure 1 Concept of the Procedures.

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, POMRAC: Pollution Monitoring Regional Activity Centre.

1-3. Characteristics of the Procedures

1.4.The Procedures was developed based on the following principles:

i) It should be adaptable to various environmental conditions in different types of areas in the NOWPAP region.
ii) If applicable, new monitoring techniques such as remote sensing (e.g. physical and biological data) should be used in the assessment procedure.
iii) Eutrophication status is assessed through a holistic approach by integrating the following eutrophication aspects: degree of nutrient enrichment, direct/indirect effects of nutrient enrichment and other possible effects of nutrient enrichment.

1-4. Overall structure

1.5. The assessment procedure is broadly separated into six parts, namely i) scope of assessment, ii) data processing, iii) setting of assessment criteria, iv) assessment process and results, v) review of results and vi) conclusion/recommendations. In the 'scope of assessment' part, assessment area and parameters are selected from predetermined lists and period of observations. In the 'data processing' part, raw data are processed into data sets for the assessment. In the 'setting of assessment criteria' part, assessment criteria are set. In the 'assessment process and results' part, eutrophication status of the assessment area is identified. In the 'review of results' part, the assessment results are reviewed and verified by traditional and new monitoring techniques, such as remote sensing from various satellites/sensors, as well as they are compared with the results of modeling. In the 'conclusion/recommendations' part, future measures and actions are suggested with estimates of costs and benefits and future issues are identified on the basis of the assessment results. Figure 2 shows the implementation flow of the Procedures.

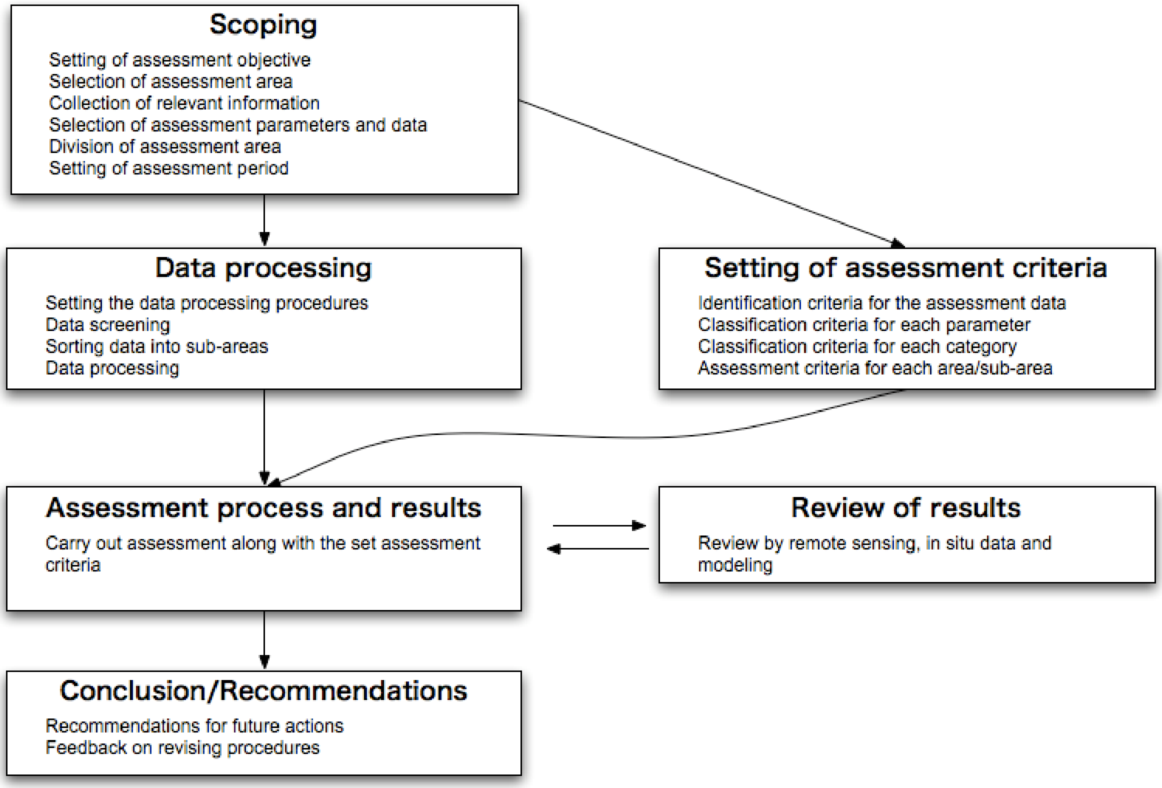


Figure 2 Basic flow of the Procedures.

2. Scope of assessment

2-1. Setting of assessment objective

2.1. State objectives of the assessment.

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

2.3. State any scientific uncertainties that users of the assessment results should take note of, such as:

i) The assessment results may not be applicable for use in environmental impact assessment.

ii) The assessment results may become less reliable/valid when scientific data/information are updated.

iii) The assessment results may have low degree of confidence due to insufficient data.

2-2. Selection of assessment area

2.4. Select an assessment area that can be considered as a single sea area (e.g. geographic unit).

2.5. An assessment area should be an area for which there are ongoing environmental monitoring and assessment programs and where eutrophication was earlier observed or amount of nutrients increases.

2-3. Collection of relevant information

2.6 Collect information on the assessment area that is necessary and relevant to eutrophication assessment such as: i) environmental monitoring/survey data* (e.g. water quality, nutrient load, red tide, marine flora/fauna, shellfish poisoning, ocean remote sensing); ii) pollutant sources (e.g. municipal, industrial, agricultural, 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 implementation of the Procedures.

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

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

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

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

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

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

2.9. Select the most appropriate environmental monitoring/survey program for the assessment process in section 5.

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

i) Monitoring/surveys conducted at very limited frequency
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

2-4 Selection of assessment parameters and data

2-4-1 Categorization of monitored/surveyed parameters

2.11. From the selected environmental monitoring/survey programs, categorize all eutrophication related parameters that are monitored/surveyed within the assessment area into one of the following 4 assessment categories:

i) Category I Parameters that indicate 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

2-4-2. Selection of assessment parameters of each assessment category

2.12. After the categorization process, select the assessment parameters that are applicable for the assessment procedure on the basis of their data reliability and continuity (e.g. data collected at fixed locations and at regular frequencies). The selected assessment parameters should also have established assessment methods.

2.13. In principle, all surveyed/monitored parameters related to eutrophication should be selected for the assessment procedure. If certain parameters are to be excluded from the assessment procedures, the reasons must be stated.

2.14. The final selection of the assessment parameter is subject to the decision of each member state. Table 2 shows the assessment parameters that were used in the Toyama Bay case study. The appropriateness of the selected assessment parameters should be reevaluated as further experiences are gained through the implementation of the Procedures.

Table 2 Assessment parameters used in the Toyama Bay case study

Category		Assessment parameter
I	Degree of nutrient enrichment	Riverine input (T-N, T-P)
		Total nitrogen/Total phosphorus (T-N, T-P)
		Winter DIN/DIP concentration
		Winter N/P ratio (DIN/DIP)
II	Direct effects of nutrient enrichment	Chlorophyll-a concentration (field data)
		Chlorophyll-a concentration (remote sensing data)
		Ratio of area with high chlorophyll-a concentration (remote sensing data) to the total area
		Red-tide events (diatom species)
III	Indirect effects of nutrient enrichment	Dissolved oxygen (DO)
		Abnormal fish kill incidents
		Chemical oxygen demand (COD)
IV	Other possible effects of nutrient enrichment	Red-tide events (*Noctiluca* sp.)
		Shellfish poisoning incidents

2-4-3 Setting of assessment value

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

2.16. Set the assessment values*.

*Assessment value: The type of data (e.g. annual mean, annual max., annual number of events, seasonal mean, seasonal max.) that will be used for the assessment

2-4-4 Selection of monitoring/survey data for the assessment

2.17. Select the monitoring/survey data to be applied for each assessment parameter.

2-5. Division of assessment area into sub-areas

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

2.19. When dividing the assessment area into sub-areas, factors such as location of riverine input, monitoring locations, fishery activities, underwater topography, salinity distribution, ocean currents and red-tide events should be considered.

2-6. Setting of assessment period

2.20. Set the assessment period in accordance with the assessment objectives and availability of reliable data.

3. Data processing

3-1. Data processing method

3.1. For each assessment parameter, determine a methodology to process monitoring/survey data into the selected assessment values (e.g. annual mean).

3-2 Data screening

3.2. Within the selected monitoring/survey data, exclude data that are not suitable for the assessment.

3.3. If certain monitoring/survey data are excluded in the above process, state the reasons for their exclusion. Possible reasons could be related to survey location, data reliability and so on.

3-3. Selection of monitoring/survey data for sub-area assessment

3.4. If the assessment area is divided into sub-areas, the data for the sub-area assessment should be selected based on the location of the survey/monitoring sites.

3-4. Data processing

3.5. Process the selected monitoring/survey data into assessment values in accordance with the methods established in 3.1.

3.6. In principal, process monitoring/survey data of all survey/monitoring site.

3.7. Prior to data processing, it is preferable to arrange the monitoring/survey data into data sets (e.g. data sets for each assessment parameter and survey/monitoring site).

4. Setting of assessment criteria

4.1. Eutrophication status of an assessment area is assessed based on a set of assessment criteria. Detail explanations are provided in the ensuing sections.

4-1. Setting of criteria for selection of eutrophication identification tools

4.2. Eutrophication status based on each assessment parameter is assessed by identifying its current status and/or trend. The current status and trend of an assessment parameter are identified by using a combination of the following 3 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 (identifies current status): The eutrophication status is identified by comparing the obtained assessment value (e.g. annual mean value) with either environmental standards (standards may be set as absolute value or have a range of values such as for DO and chlorophyll-a) or background value (e.g. measurement values obtained at an area that has had negligible influence from anthropogenic activities). This identification tool is used for assessment parameters that can be expressed by concentration or ratio (e.g. N/P ratio).

ii) Identification by occurrence (identifies current status): Eutrophication status is identified by occurrence or non-occurrence of eutrophication-related events. This identification tool is used for assessment parameters that can be expressed by number or frequency of events (e.g. red tide).

iii) Identification by trend (identifies trend): Eutrophication status is identified by identifying the trend. This identification tool can be used for all assessment parameters with reasonably long time series.

4.3. The rationale behind the set identification criteria must be stated clearly and objectively.

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

4.4. After identifying the current status and/or trend with the eutrophication identification tool, the eutrophication status of the assessment parameter should be classified based on set classification criteria*.

*Classification criteria: Criteria for classifying the eutrophication status of assessment parameters.

4.5. Table 3 shows the identification tools applied to each assessment parameter in the Toyama Bay case study.

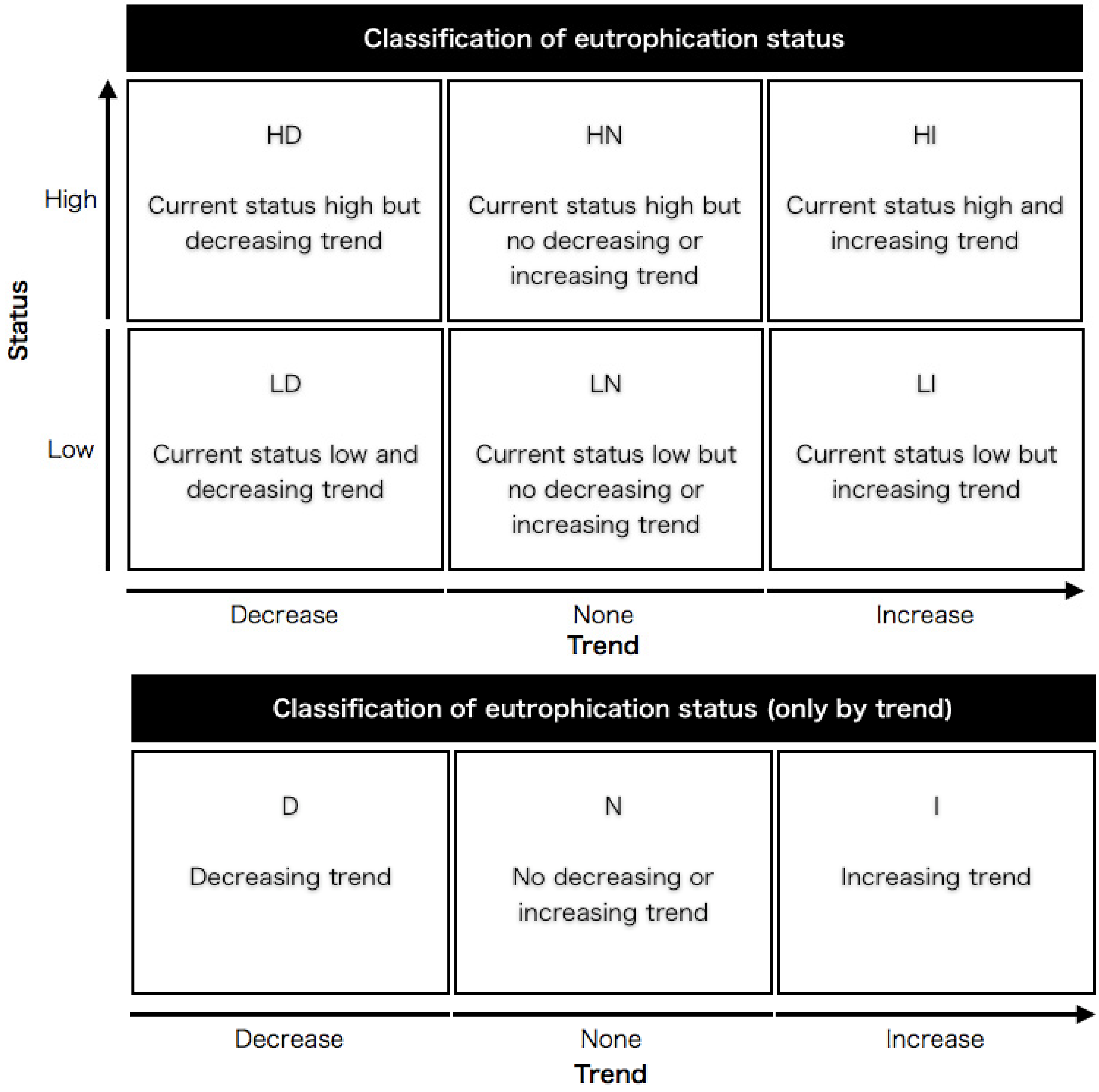
Table 3 Identification tools applied to each assessment parameter in the Toyama Bay case study

Category	Assessment parameter	Assessment value	Identification tools[1)]			Remarks
			Comparison	Occurrence	Trend	
I	Riverine input (T-N, T-P)	Annual mean	▨	▨		
	Total nitrogen/Total phosphorus (T-N, T-P)	Annual mean		▨		
	Winter DIN/DIP concentration	Winter mean		▨		
	Winter N/P ratio (DIN/DIP)	Winter mean		▨		
II	Chlorophyll-a concentration (field data)	Annual max. Annual mean		▨		
	Chlorophyll-a concentration (remote sensing data)	Annual max. Annual mean		▨		
	Ratio of area with high chlorophyll-a concentration (remote sensing data) to the total area	Annual max. Annual mean	▨	▨		
	Red-tide events (diatom species)	Annual occurrences	▨			
III	Dissolved oxygen (DO)	Annual min.		▨		
	Abnormal fish kill incidents	Annual occurrences	▨			
	Chemical oxygen demand (COD)	Annual mean		▨		
IV	Red-tide events (*Noctiluca* sp.)	Annual occurrences	▨			
	Shellfish poisoning incidents	Annual occurrences	▨			

1) Comparison: comparison with environmental standard or background value
Occurrence: occurrence or non-occurrence
Trend: degree of increase/decrease

4.6. Following is an example of classification criteria used to classify the eutrophication status of the assessment parameters. Current status is classified as either ‘high status’ or ‘low status’, and trend is classified as either ‘decrease trend’, ‘no trend’ or ‘increase trend’. The classification results of the current status and trend are then combined together to produce 9 categories of eutrophication status (see Figure 3). If the assessment parameter is assessed only with the trend method, the assessment parameter will be classified as either ‘decrease trend’, ‘no trend’ or ‘increase trend’.

4.7. Figure 3 shows an example of classification criteria set to classify the eutrophication status of assessment parameter.



Classification of eutrophication status

Status	Decrease	None	Increase
High	HD Current status high but decreasing trend	HN Current status high but no decreasing or increasing trend	HI Current status high and increasing trend
Low	LD Current status low and decreasing trend	LN Current status low but no decreasing or increasing trend	LI Current status low but increasing trend

Classification of eutrophication status (only by trend)

Decrease	None	Increase
D Decreasing trend	N No decreasing or increasing trend	I Increasing trend

Figure 3 An example of classification criteria set to classify the eutrophication status of assessment parameter

4-3. Setting of criteria for classifying the assessment category

4.8. Determine the eutrophication status of the assessment category by setting assessment category classification criteria.

4.9. Classify eutrophication status of the assessment category by selecting one classification result of the assessment parameters within the assessment category that most appropriately represents the eutrophication status of the area. However, if the classification results are contradictory among the assessment parameters in the assessment category, and therefore if it is unreasonable to select a representative classification result, this assessment category can be excluded from the classification procedure with its reasons stated.

4-4. Setting of criteria for classifying the assessment area/sub-area

4.10. Set holistic assessment criteria for the assessment area/sub-area so as to diagnostically explain classification results of each assessment parameter and category.

5. Assessment process and results

5.1. The eutrophication status of the assessment area should be assessed on the basis of the identification results of the assessment data and classification results of each parameter and parameter’s categories.

5.2. Identify the eutrophication status of the assessment data 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 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.

6. Review of results

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

6.2. If applicable, new techniques such as remote sensing could also be used for reviewing of the assessment results.

6.3 It is recommended to have interpretation of the results; if there is eutrophicated/oligotrophic status and/or trend, the possible reasons, such as changes of nutrient loads caused by anthropogenic activities and/or climate change would be described.

7. Conclusion and recommendations

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

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

For bibliographical purpose, this document may be cited as:
NOWPAP CEARAC 2009: Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region.

Annex 3

Evaluation of preliminary eutrophication assessment by satellite in each selected sea area

1 Outline

Application of the NOWPAP Common Procedures requires historical records of *in situ* measured data to assess eutrophication. Although this approach surely help understand causes and consequences of eutrophication, it is time consuming and not an easy task especially for coastal managers.

The Common Procedures recommend use of remote sensing techniques to review obtained assessment results. Among the information on sea surface obtained by remote sensing, chlorophyll-*a* concentration (Chl-*a*) can be used as a useful indicator of eutrophication. Chl-*a* is regarded as a proxy for phytoplankton biomass, and it can be categorized as the category II; a parameter that receives direct effects of nutrients enrichment.

This chapter introduce a new methodology to preliminarily assess eutrophication with time series of satellite derived Chl-*a*, and demonstrated the advantage and limitation of the suggested methodology in comparison with the obtained case study result in each selected sea area.

2 Data and method

Since the launch of ADEOS-I satellite with the Japanese Ocean Color and Temperature Sensor (OCTS) in 1996, Chl-*a* of the world ocean has been observed by satellite remote sensing on a regular basis. Subsequently OCTS, NASA launched the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) in 1997, Moderate Resolution Imaging Spectroradiometer (MODIS) in 1999 and 2002, on board Orbview-2, Terra and Aqua satellites, respectively.

We used time series of satellite Chl-*a* from 1997 to 2009 observed by ocean color satellites, Ocean Color and Temperature Scanner (OCTS) of JAXA, Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectroradiometer on board Aqua (MODIS-A) of NASA, obtained from NASA Ocean Color Website (http://oceancolor.gsfc.nasa.gov/). NASA Ocean Biology Processing Group (OBPG) reprocessed data for SeaWiFS and MODIS on Aqua satellite (MODIS-A) from late 2009 to early 2010 to improve agreement of ocean color product between sensors and the updated R2009 dataset are currently available. Therefore current R2009 datasets for SeaWiFS and MODIS-A were used in this study.

Daily, monthly and 13-year overall mean Chl-*a* for each selected case study area was created by Windows Image Manager software (http://www.wimsoft.com/) from the level 2 datasets, which provide best resolution satellite Chl-*a* available (4 km for OCTS, 1.1 km for SeaWiFS and 1 km for MODIS-A). Only “cloud ice” quality flag was used to exclude unreliable data at cloud edge. SeaWiFS and MODIS-A data were both available from July 2002 to December 2004, and they were averaged to make monthly mean Chl-*a*. 13-year overall mean Chl-*a* was used to divide the study area into “High” or “Low” Chl-*a* area, by the Chl-*a* level more than 5 ug l^{-1} referring to the lowest limit of the Medium Chl-*a* condition (5-20 ug l^{-1}) suggested by Bricker et al. (2003). The trend of annual Chl-*a* maximum in monthly mean Chl-*a* and its significance were estimated at pixel wise by the Sen Slope test at 90% confidence level. The study area was then divided into “Increase trend”, “Decrease trend” and “No trend” area. By the combination of Chl-*a* level and its trend, the study area was then classified into the 6 eutrophication status (High-Increase, High-No Trend, High-Decrease, Low-Increase, Low-No trend and Low-Increase) referring to the eutrophication classifications of the NOWPAP Common Procedures for eutrophication assessment (Fig. 2-1).

3 Results

- Yangtze River Estuary and adjacent sea (China)

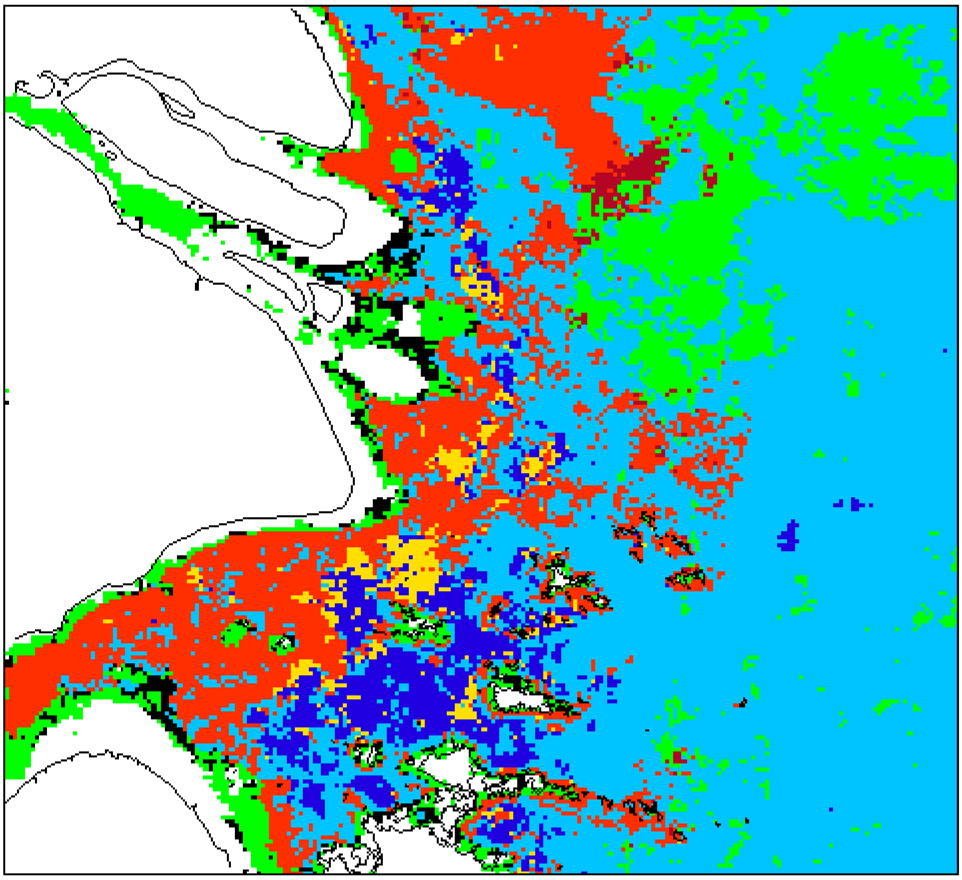


Fig. 1 Preliminary assessment result in Changjiang River Estuary and adjacent area, China

The river mouth of the Yangtze River was mostly classified either as High-No Trend, High Decrease or Low Decrease. There were fewer pixels classified as High Increase at east of the North Branch of Yangtze River. Low increase was found at north eastern part of the assessment area.

The case study with NOWPAP Common Procedures applied the same assessment criteria for *in situ* measured Chl-*a* to determine High or Low Chl-*a* referring to Bricker et al. (2003). Annual maximum of Chl-*a* was classified High- No Trend. Annual mean Chl-*a* data was classified as Low Increase.

Although there were no clear correspondence between satellite and *in situ* Chl-*a* in this area, High-NoTrend area detected by preliminary assessment by satellite Chl-*a* was consistent with increasing nutrients inputs indicated in category I.

- Northwest Kyushu sea area (Japan)

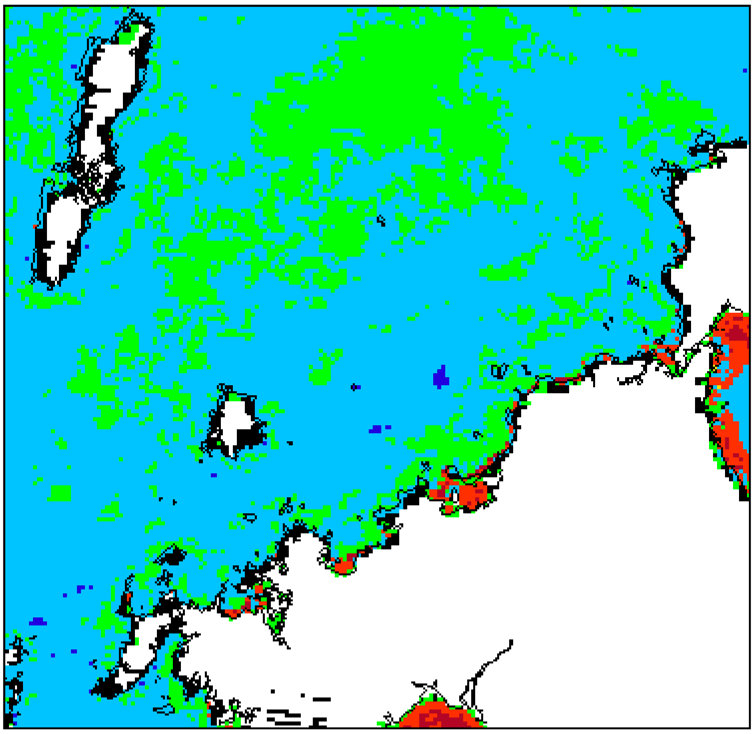


Fig. 2 Preliminary assessment result in northwest Kyushu sea area, Japan

Because *in situ* Chl-*a* to test reliability of satellite Chl-*a* was available in this area, daily mean satellite and *in situ* Chl-*a* on the same day at the same location were compared. 1 x 1 km pixel of daily mean satellite Chl-*a* value was extracted corresponding to the locations of the 7 water sampling stations located 2 km offshore. There were no OCTS and *in situ* Chl-*a matches* during the studies period. 35 and 41 pairs of satellite and *in situ* Chl-*a* matches were obtained respectively for SeaWiFS and MODIS-A during the studied period (Fig. 3). 35 pairs of SeaWiFS and *in situ* Chl-*a* were significantly correlated. 41 pairs of MODIS-A and *in situ* Chl-*a* were also significantly correlated.

Most part Hakata Bay and Kanmon straits was classified as High-No Trend or High-Increase. Low-Increase area was observed along the western coast line of the Fukuoka Prefecture. Tsushima straits was also classified as Low-Increase. Most part of offshore area was classified as Low-No Trend. Because the reliability of the satellite Chl-*a* was confirmed in this study area, we decided to uses the result of preliminary eutrophication assessment by satellite Chl-*a*.

The case study with NOWPAP Common Procedures applied the same assessment criteria for *in situ* measured Chl-*a* to determine High or Low Chl-*a* referring to Bricker et al. (2003). Both annual maximum and mean of *in situ* Chl-*a* in Hakata Bay was classified as High-Decrease, while some pixels of satellite Chl-*a* was classified as High-Increase. Since TN data in category I showed increasing trend, it may be related to the High-Increase classification by satellite Chl-*a*. There were satellite Chl-*a* recorded in Dokai Bay, because it was too narrow to observe Chl-*a* by satellite.

- Toyama Bay (Japan)

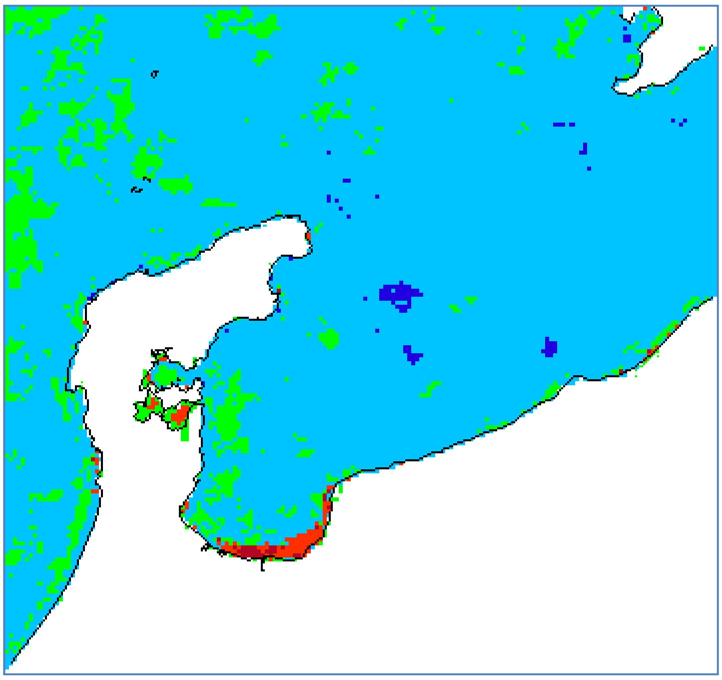


Fig. 3 Preliminary assessment result in Toyama Bay, Japan

Same as Northwest Kyushu area, daily mean satellite and *in situ* Chl-*a* on the same day at the same location were compared to test reliability of satellite Chl-*a* in Toyama Bay. 1 x 1 km pixel of daily mean satellite Chl-*a* value was extracted corresponding to the locations of the 7 water sampling stations located 2 km offshore. There were no OCTS and *in situ* Chl-a *matches* during the studies period. 35 and 41 pairs of satellite and *in situ* Chl-*a* matches were obtained respectively for SeaWiFS and MODIS-A during the studied period. 35 pairs of SeaWiFS and *in situ* Chl-*a* were significantly correlated. 41 pairs of MODIS-A and *in situ* Chl-*a* were also significantly correlated.

The inner part to the eastern coast of Toyama Bay were classified either as High-No Trend or High-Increase. The western coast of Toyama Bay to offshore were mostly classified either as Low-Increase or Low-No Trend. Because the reliability of the satellite Chl-*a* was confirmed in this study area, we decided to uses the result of preliminary eutrophication assessment by satellite Chl-*a*.

The case study with NOWPAP Common Procedures applied the same assessment criteria for *in situ* measured Chl-*a* to determine High or Low Chl-*a* referring to Bricker et al. (2003). Both annual maximum and mean of *in situ* Chl-*a* were classified as Low-No Trend in each sub area, while satellite Chl-*a* was classified as High-Increase or High-No Trend in inner part of Toyama Bay. Although TN input rivers did not show any significant trend, Input from the biggest river, Jinzu River, showed significant increasing trend. This may be related to High-Increase or High-No Trend of satellite Chl-*a* in inner part of Toyama Bay.

- Jinhae Bay (Korea)

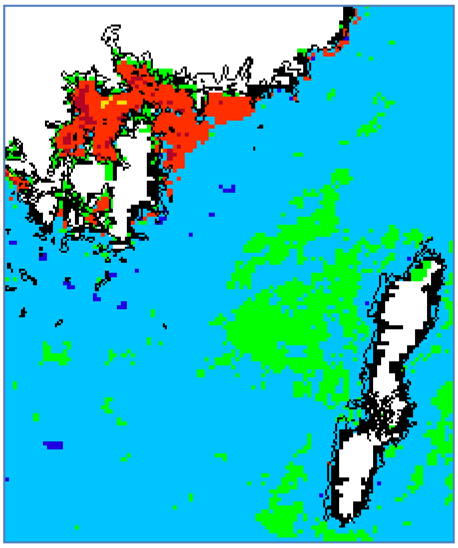


Fig. 4　Preliminary assessment result in Jinhae Bay, Korea

Most of Jinhae Bay was classified as High-No Trend, except its inner most part (Jindong Bay) was classified as High-Increasing Trend.

The case study with NOWPAP Common Procedures used Chl-a value in Gijang area to determine High or Low Chl-*a* area. Nevertheless Chl-*a* mean values ranged from 6.2 to 10.2, and therefore it was consistent with High satellite Chl-*a* area detected by preliminary assessment. Since there were no information about water sampling stations in Jinhae Bay, we could not discuss reliability of High-Increase area detected by the preliminary assessment. Although, TN and TP input data showed decreasing trend in this area, there were not much decreasing trend of annual maxium satellite Chl-*a*.

- Peter the Great Bay (Russia)

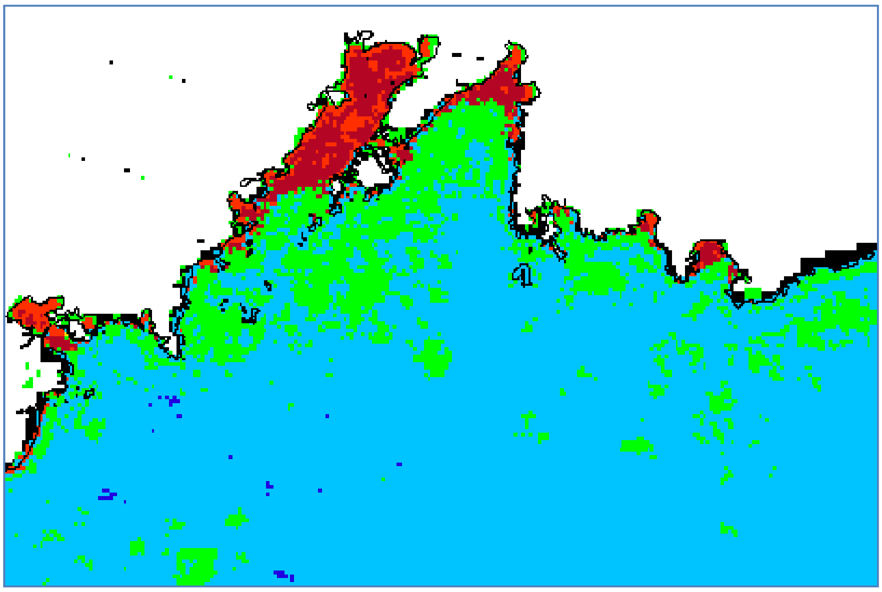


Fig. 5 Preliminary assessment result in the Peter the Great Bay, Russia

Most part of Amursky Bay and inner part of Ussuriiskiy Bay were classified as High-Increase. Next to those High-Increase Chl-a area, Low-Increase area were widely distributed to offshore part of the Peter the Great Bay.

The case study with NOWPAP Common Procedures used Chl-*a* value 8 ug/L as the reference condition to determine High or Low Chl-*a* area. Nevertheless, annual mean of in situ Chl-*a* was 1.9 ug/L, 1.9 ug/L, 0.86 ug/L in Amursky Bay, Ussuriiskiy Bay, South part of the Peter the Great Bay, respectively. However, in situ Chl-*a* in Amurusky Bay showed increasing trend. All nutrients data in category I were classified as High Increase in Amursky Bay, therefore High Increase area detected by satellite Chl-*a* in this area due to increasing nutrient loads and *in situ* Chl-*a*. On the other hand, in situ Chl-*a* in Ussuriiskiy Bay was classified Low Increase and no trend was detected in nutrients data, while Ussuriiskiy Bay was either classified High Increase or Low Increase by satellite Chl-*a*. Thus, there were inconsistencies between in situ and satellite based eutrophication assessment results. South part of the Peter the Great Bay was classified Low Increase by satellite Chl-*a*. Although situ Chl-*a* were also showed low status, trend was not detectable with available data.

4 Conclusion

There were success and failure cases that preliminary eutrophication assessment by satellite Chl-*a* as shown in the following table 4-1.

Taking account of spatio and temporal advantages of satellite observation of sea surface, preliminary eutrophication assessment approach with satellite Chl-*a can* be a useful tool to detect potential eutropic area. However, uncertainty still remains in estimating Chl-*a* in turbid water and improvement of algorithm is necessary. The preliminary eutrophication assessment by improved satellite Chl-*a* for tubid water is expected.

Table 1 Success and failure cases of preliminary eutrophcation assessment by satellite Chl-*a* through comparison of eutrophicaion assessment results by the NOWPAP Common Procedures

Country	**Assessment area**	**Sub area**	**Preliminary eutrophicaion assessment by satellite Chl-a**	**Eutrophication assessmenet by the NOWPAP Common Procedure**	**Success**	**Failure**
China	Yangtze River estuary and adjacent sea	–	HN was distributed along the coast line. HD and LD were also distibuted next to HN area.	Increase of nitrogen input were recorded.	High Chl-a area were detected along the coast line.	Not reliable patchy pattern was observed with preliminary assessment by satellite Chl-a.
Japan	Northwest Kyushu	A: Hakata Bay	Mosly HI	Although category I was classfied as LI, increase trend of of TN input from sewage treatment plan and TN concentration was recorded. In situ Chl-a was high, but showed decresing trend.	High Chl-a area were detected. Reliability of satellite Chl-a was confirmed with in situ Chl-a	
		B: Dokai Bay	No satellite Chl-a available	TN and TP levels have been on a decreasing trend. However, in situ Chl-a is still at high level.		Dokai Bay was too narrow to be observed by satellite Chl-*a*
		C: Intermediate area	LI and LN	TP input from seawage treatment plants have been on an increasing trend. Dinoflagellate and Noctiluca redtides were observed.	Low increasing pattern os satellite Chl-a were detected.	
		D: Offshore area	LN	Although low DO and high COD were recorded, all caterogry were classified as LN.	LN was also detected by satellite Chl-a	
	Toyama Bay	A: Coastal area	HN to HI	Although category I was classfied as LI, significant increasing trend in TN input from Jinzu River was observed.	High Chl-a area were detected. Reliability of satellite Chl-a was confirmed with in situ Chl-a	
		B: Intermediate area	LI and LN	All category were classfied as LN.	Reliability of satellite Chl-a was confirmed with in situ Chl-a	No clear match was obtained
		C: Offshore area	Mostly LN	Except COD that showed increasing trend, other parameters were classified as LN including satellite Chl-a.	Most part of offshore area was classified as LN.	

Country	Assessment area	Sub area	Preliminary eutrophicaion assessment by satellite Chl-a	Eutrophication assessmenet by the NOWPAP Common Procedure	Success	Failure
Korea	Jinhae Bay	–	Mostly HN and some HI	In situ Chl-a was classfied as High status	HI area which was not sampled by in situ Chl-a was detected by	
Russia	Peter the Great Bay	A: Amursky Bay	Mostly HI	Except in situ Chl-a, most parameters were classified as HI.	HI was detected by satellite Chl-a	
		B: Ussuriiskiy Bay	Mostly LI except innner part is HI.	All parameters were claffied as LN.	HI was detected by satellite Chl-a	HI was detected by satellite Chl-a
		C: South part of the Peter the Great Bay	LI and LN	Most parameters were claffied as LN.	LI was partly detected	HI was detected by satellite Chl-a