A Case Study Report on

Assessment of Eutrophication Status

in Toyama Bay, Japan

Northwest Pacific Region

Environmental Cooperation Center

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1. Scope of the assessment

1.1 Objective of the assessment

i) Toyama Bay is fed by several Class-A rivers and other small river, and river-based nutrients are supplied into the surface water of the bay. Nutrients included in the river water are not only natural ones, but also ones originated from anthropogenic sources such as industrial activities, domestic life and livestock. Therefore, in terms of nutrient loads, the coastal environment of the closed-off section of Toyama Bay has been influenced strongly by the Oyabe River and the Jinzu River. In this area, phytoplankton blooms increase in summer, and they lead increase of chemical oxygen demand (COD). In order to improve the coastal environment of Toyama Bay, it is essential to understand nutrient loads from rivers, nutrient concentration in the sea area, and biochemical reaction caused by nutrient concentration. For that purpose, a new eutrophication assessment following the Procedures for assessment of eutrophication including evaluation of land based sources of nutrients for the NOWPAP region (so-called 'the NOWPAP Common Procedures') was implemented in selected sea areas of the NOWPAP member states to identify the problems and effective countermeasures in 2011. In 2012-2013, NOWPAP member states decided to refine the NOWPAP Common Procedures to improve the suitability and set and re-apply in selected sea areas in each member state. The refined NOWPAP Common Procedures consist of two steps: screening procedure to detect symptoms of eutrophication with the minimum required parameters, and comprehensive procedure to assess the eutrophication status and possible causes in details.

1.2 Selection of assessment area by application of the screening procedure.

The same geographical location as the previous case study in 2011 was chosen for Toyama Bay: to the south from the line drawn between the border Toyama-Niigata and Cape Rokkozaki in Ishikawa Prefecture.

In line with the screening procecedure, eutrophication status in Toyama Bay was preliminarily assessed by detecting symptoms of eutrophication with the minimum required parameters; nutrients data and their residencfe time, frequencies of red tide (diatom sp. and flagellate sp.) events, and high chlorophyll-a detected by satellite. Nutrients data showed higher concentration in the Oyabe River and the Jinzu River basins (Kawasaki, 1985). No red tide events of diatom sp. and flegellate sp. was recorded in Toyama Bay in recent three years (2007 to 2009). High chlorophyll-a (> 5ug/L) was detected in the Toyama Bay coastal area in the recent 3 years (2007 to 2009) means of satellite derived chlorophyll-a data (Fig. 1.1). Since high chlorphyll-a area detected by satellite includes high concentration of nutrients data, this area was choosen as assessment area for comprehensive procedure.

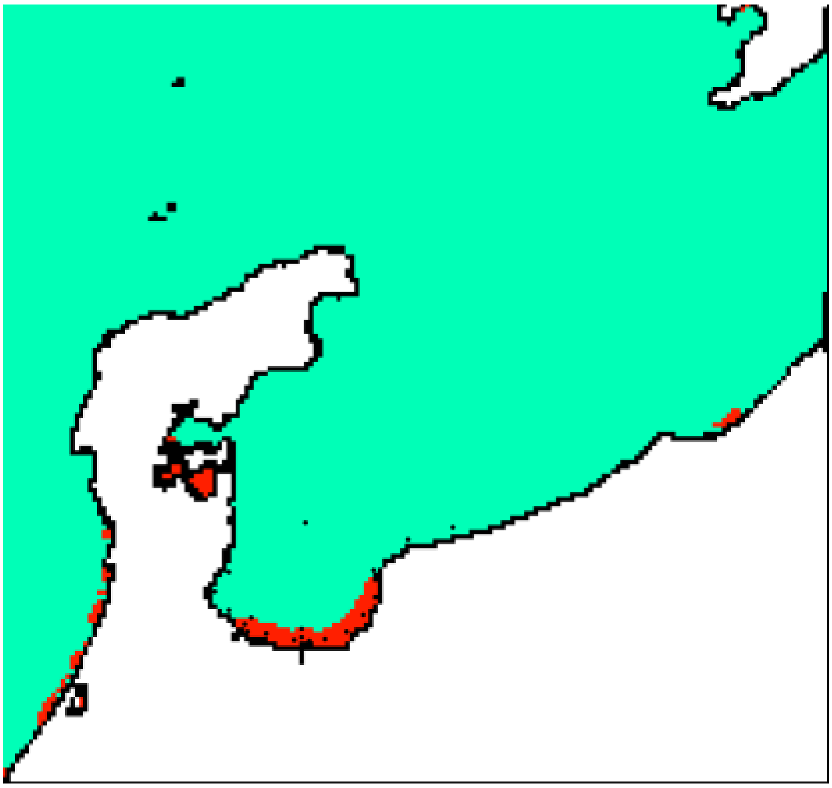

Fig. 1.1 High chlorphyll-a area detected by satellite.
Black dots indicate water sampling stations by the Toyama Prefectural Government.

1.3 Collection of relevant information

Table 1.1 shows the information/data collected for the eutrophication assessment by the comprehensive procedure.

Table 1.1 Information/data collected for the eutrophication assessment by the comprehensive procedure in Toyama Bay coastal area

Survey type	Responsible organization	Survey name	Objective	Survey period	Main survey parameters	Survey frequency	No. of station
Water quality monitoring by environ-mental authorities	Toyama Pref. (Environmental Conservation Division)	Water quality survey of public waters (Water quality survey of sea water)	Monitoring of water quality status	1976 - present (TN, TP: 1997-)	DO, COD, TN, TP	1/month	23 (Coastal: 10 the Jinzu: 7 the Oyabe: 6)
	Toyama Pref. (Environmental Conservation Division)	Survey of water quality conservation measures of Toyama Bay (Comple-mentary survey)	Understanding of eutrophication status in Toyama Bay sea area	1997-	DIN,DIP, chrolophyll-*a*, TN, TP	1/month	9
	Toyama Pref. (Environmental Conservation Division)	Accident report on water quality	Understanding of water quality accidents	1975-	accident site, extent of pollution, cause of emission, influence to fish	When an accident occurs	
Environ-mental survey/ research	Toyama Pref. (Environmental Conservation Division)	Basic research on a prediction model	Accuracy improvement of a prediction model by organizing data of nutrients from rivers	2005-	estimate of input loads (TN, TP) (1985-2004)	2005 ONLY	
Water pollution monitoring by fisheries authorities	Toyama Prefectural Agricultural, Forestry and Fisheries Research Center, Fisheries Research Institute	Red tide survey	Survey of red-tide events and report of related information	1966-	extent of occurrence, types of phytoplankton , density	When red tide occurs	
others	Toyama Pref. （Public Health Division）	Report on food poisoning incidents	Prevention of outspread of food poisoning	1994-	date, place, food of cause	When food poisoning occurs	

1.4 Selection of assessment parameters

1.4.1 Assessment categories of Toyama Bay case study

Based on the comprehensive procedure, the parameters for the eutrophication assessment were categorized into the four assessment categories shown in Table 1.2.

Table 1.2 Assessment categories of Toyama Bay case study

Category I	Degree of nutrient enrichment (nutrient input, nutrient concentration etc.)
Category II	Direct effects of nutrient enrichment (increase of phytoplankton, chlorophyll-*a* etc.)
Category III	Indirect effects of nutrient enrichment (increase of organic material, decrease of DO etc.)
Category IV	Other possible effects of nutrient enrichment (shellfish poisoning etc.)

1.4.2 Assessment parameters of Toyama Bay case study

Table 1.3 shows the assessment parameters that were used for Categories I-IV.

Table 1.3 Assessment parameters used for Toyama Bay Case Study

Category	Assessment parameter
I. Degree of nutrient enrichment	(1) TN input from river
	(2) TP input from river
	(3) TN input from sewage treatment plant
	(4) TP input from sewage treatment plant
	(5) TN concentration
	(6) TP concentration
	(7) Winter DIN concentration
	(8) Winter DIP concentration
	(9) Winter DIN/DIP ratio
II. Direct effects of nutrient enrichment	(10) Annual maximum chlorophyll-*a* concentration
	(11) Annual mean chlorophyll-*a* concentration
	(12) Red tide (diatom sp.)
	(13) Red tide (dinoflagellate sp.)
III. Indirect effects of nutrient enrichment	(14) DO (surface)
	(15) Abnormal fish kill
	(16) COD
IV. Other possible effects of nutrient enrichment	(17) Red tide (*Noctiluca* sp.)
	(18) Shellfish poisoning

Table 1.4 shows the list of water sampling station locations in asessement areas used in Toyama Bay case study.

Table 1.4 List of water sampling satation locations in assesement area

Station	Latitude	Longitude	Survey name
J4	36.7767°	137.2039°	Water quality survey of public waters
J5	36.7828°	137.2222°	
J6	36.7764°	137.2406°	

Station	Latitude	Longitude	Survey name
J7	36.7981°	137.2222°	Survey of water quality conservation measures of Toyama Bay
O5	36.8072°	137.0847°	
O6	36.7939°	137.0914°	
S4	36.7894°	137.1356°	
S5	36.7789°	137.2786°	
S6	36.7931°	137.3311°	
S7	36.8256°	137.3703°	

2. Data processing

Eutrophication related information/data (1-3 Collection of relevant information) were collected from Division of Civic Affairs, Environment and Cultural Department, Toyama Prefecture and the Fisheries Research Institute of Toyama Prefectural Agricultural, Forestry and Fisheries Research Center. They are part of official government data, and it means that any unreliable information is removed from them before the data is released in public. Therefore, screening of the collected data was not applied in this case study.

The collected data was processed as shown in Table 2.1-2.3 explains data processing methodologies.

Table 2.1 Data processing methodologies applied for Toyama Bay Case Study (Category I)

	Assessment parameter	Data processing methodology
I	(1) TN input from river	For volume of flow into Toyama Bay from Class-A rivers, the mean volume of flow per day in Water Information System of Ministry of Land, Infrastructure, and Transport, Japan was used. TN concentration from Class-A rivers was collected from monthly data at the lowest point of a river in 'water quality survey of public waters.' Monthly TN input was calculated by multiplying the mean volume of river flow per day by TN concentration, then, the annual mean TN was calculated by averaging the monthly data (Apr.-Mar.). The trend of the annual mean value from 1985-2009 was also analyzed.
	(2) TP input from river	For volume of flow into Toyama Bay from Class-A rivers, the mean volume of flow per day in Water Information System of Ministry of Land, Infrastructure, and Transport, Japan was used. TP concentration from Class-A rivers was collected from monthly data at the lowest point of a river in Water quality survey of public waters. Monthly TP input was calculated by multiplying the mean volume of river flow per day by TP concentration, then, annual mean TP was calculated by averaging the monthly data (Apr.-Mar.). The trend of the annual mean value from 1985-2009 was also analyzed.
	(3) TN input from sewage treatment plant	
	(4) TP input from sewage treatment plant	
	(5) TN concentration	Annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters.' The mean value of the recent three years (2007-2009) was compared with the reference standard.

	Assessment parameter	Data processing methodology
		The trend of the annual mean value from 1997-2009 was also analyzed.
	(6) TP concentration	The annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters.' The mean value of the recent three years (2007-2009) was compared with the reference value. The trend of the annual mean value from 1997-2009 was also analyzed.
	(7) Winter DIN concentration	The winter mean value was calculated by averaging the monthly data of 3 winter months (Jan.-Mar.). Data was acquired from the 'survey of water quality conservation measures of Toyama Bay.' The mean value of the recent three years (2007-2009) was compared with the reference value. The trend of the winter mean value from 2000-2009 was also analyzed.
	(8) Winter DIP concentration	The winter mean value was calculated by averaging the monthly data of three winter months (Jan.-Mar.). Data was acquired from the 'survey of water quality conservation measures of Toyama Bay.' The mean value of the recent three years (2007-2009) was compared with the reference standard. The trend of the winter mean value from 2000-2009 was also analyzed.
	(9) Winter DIN/DIP ratio	Calculated by converting the winter DIN and DIP concentrations into Molar concentration. The mean value of the recent three years (2007-2009) was compared with the reference value. Trend of the winter mean value from 2000-2009 was also analyzed. Winter DIN/DIP ratio was not used in the classification of assessment category if both winter DIN and DIP concentrations were below the reference values respectively.

Table 2.2 Data processing methodologies applied for Toyama Bay Case Study (Category II~IV)

	Assessment parameter	Data processing methodology
II	(10) Annual maximum chlorophyll -*a* concentration	The annual maximum value was determined by the selecting maximum value of the monthly data of the 'survey of water quality conservation measures of Toyama Bay.' The mean of the annual maximum value of the recent three years (2007-2009) was compared with the reference value. The trend of the annual maximum value from 1997-2009 was also analyzed.
	(11) Annual mean chlorophyll-*a* concentration	The annual mean value was calculated by averaging the twelve monthly data acquired through the 'survey of water quality conservation measures of Toyama Bay.' The mean of the annual mean value of the recent three years (2007-2009) was compared with the reference value. The trend of the annual mean value from 1997-2009 was also analyzed.
	(12) Red tide (diatom sp.)	The number of diatom red tide was counted by referring to the red tide survey of the Fisheries Research Institute of Toyama prefectural Agricultural, Forestry and Fisheries Research Center. The total number of diatom red tide in the recent three years (2007-2009) was compared with the reference value. The trend of diatom red tide was analyzed from 1966-2009.
	(13) Red tide (dinoflagellate sp.)	The number of dinoflagellate red tide was counted by referring to the red tide survey of the Fisheries Research Institute of Toyama prefectural Agricultural, Forestry and Fisheries Research Center. The total number of dinoflagellate red tide in the recent three years (2007-2009) was compared with the reference value. The trend of dinoflagellate red tide was analyzed from 1966-2009. *Noctiluca* sp. was not included.
III	(14) Annual minimum DO concentration	The annual minimum value was determined by selecting the minimum value of the monthly data of the 'water quality survey of public waters.' The mean of the annual minimum value of the recent three years (2007-2009) was compared with the reference value. The trend of the annual minimum value from 1976-2009 was also analyzed. DO at bottom layer was not used because of insuficient length of observation record.
	(15) Abnormal fish kill	The number of abnormal fish kill was counted by referring to the data collected by Toyama Prefecture. The total number of abnormal fish kill in the recent three years (2007-2009) was compared with the reference value. The trend of abnormal fish kill was analyzed from 1985-2009.
	(16) COD	The annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters.' The mean value of the recent three years (2007-2009) was compared with the reference value. The trend of the annual mean value from 1985-2009 was also analyzed.
IV	(17) Red tide (*Noctiluca* sp.)	The number of *Noctiluca* red tide was counted by referring to the red tide survey of the Fisheries Research Institute of Toyama prefectural Agricultural, Forestry and Fisheries Research Center. The total number of *Noctiluca* red tide in the recent three years (2007-2009) was compared with the reference value. The trend of *Noctiluca* red tide was analyzed from 1966-2009.
	(18) Shellfish poisoning	The number of shellfish poisoning was counted by referring to the data collected by Toyama Prefecture. The total number of shellfish poisoning in the recent three years (2007-2009) was compared with the reference value. The trend of shellfish poisoning was analyzed from 1994-2009.

Table 2.3 Analytical method of chemical assessment parameters

Category	Assessment parameter		Analysis method used in the 'Water quality survey of public waters'	Analysis method used in the 'Survey of water quality conservation measures of Toyama Bay'
I	TN concentration		Copper-cadmium column reduction method (Methods stipulated in 45.4 of JIS (Japanese Industrial Standard) K0102.)	Copper-cadmium column reduction method (Methods stipulated in 45.4 of JIS (Japanese Industrial Standard) K0102.)
	TP concentration		Molybdenum-blue spectrophotometric method (Methods stipulated in 46.3 of JIS K0102) (unconcentrated, analysis with the AutoAnalyzerTM)	Molybdenum-blue spectrophotometric method (Methods stipulated in 46.3 of JIS K0102) (unconcentrated, analysis with the Auto Analyzer)
	DIN	Ammonium	-	Methods stipulated in 5.5.3 of Manual on Oceanographic Observation (Japan Meteorological Agency) Indophenol blue method, non-concentrated, analysis using AutoAnalyzer
		Nitrate	-	Methods stipulated in 5.5.3 of Manual on Oceanographic Observation (Japan Meteorological Agency) Naphthylethylenediamine absorptiometry after copper cadmium column reducing, non-concentrated, analysis using AutoAnalyzer
		Nitrite	-	Methods stipulated in 5.5.3 of Manual on Oceanographic Observation (Japan Meteorological Agency) Naphthylethylenediamine absorptiometry, non-concentrated, analysis using AutoAnalyzer
	DIP		-	Methods stipulated in 5.5.3 of Manual on Oceanographic Observation (Japan Meteorological Agency) Ascorbic acid reduction absorptiometry, non-concentrated, analysis using AutoAnalyzer
II	Chlorophyll-*a* concentration		-	Fluorometry stipulated in 9.2.4 of Research Methods of Studying Ocean Environment
III	DO		Winkler sodium azide modification method	Winkler sodium azide modification method
	COD		Methods stipulated in 17 of JIS K0102 (potassium permanganate method)	Methods stipulated in 17 of JIS K0102 (potassium permanganate method)

3. Setting of assessment criteria

3.1 Setting of standard

In Japan, there are two types of quality standards that can be applied for the eutrophication assessment: 'Environmental water quality standard' and 'Fisheries water quality standard' (Table 3.1). For the case study of Toyama Bay, reference values were set for each assessment parameter by referring to the above water quality standards (see Table 3.2). Values of total nitrogen (TN) and total phosphorus (TP) concentrations were set to be equivalent to the 'Environmental water quality standard Type II.' In addition, values of dissolved oxygen (DO) and chemical oxygen demand (COD) were set to be equivalent to the 'Fisheries water quality standard' and the 'Environmental water quality standard Type B' respectively. Since there are no water quality standards for winter DIN and DIP concentrations, their reference values were set through a regression analysis of winter DIN and TN concentration (winter DIP and TP concentration) in Toyama Bay. Based on the identified relationship, the reference value of DIN (DIP) was calculated with TN: 0.3 mg/L (TP: 0.03 mg/L) (see Fig.3.1 and 3.2). The reference values of annual maximum/mean chlorophyll-*a* concentrations were set based on Bricker *et al.* (2003), which are 20 µg/L (upper threshold of medium eutrophication level) and 5 µg/L (lower threshold of medium eutrophication level) respectively (see Table 3.2).

Table 3.1 Standards of the 'Environmental water quality standard' and 'Fisheries water quality standard'

Cate-gory	Assessment parameter	Environmental water quality standard	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		
	COD1)	2 mg/l	Type A	1 mg/l	General
		3 mg/l	Type B	2 mg/l	Laver farm or enclosed bay
		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 ($COD_{OH} = 0.6 \times COD_{MN}$)

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

Table 3.2 Reference values applied for the eutrophication assessment of Toyama Bay Case Study

	Assessment parameter	Reference value	Remarks
I	(1) TN input from river	-	
	(2) TP input from river	-	
	(3) TN input from sewage treatment plant	-	
	(4) TP input from sewage treatment plant	-	
	(5) TN concentration	0.3 mg/L	Environmental water quality standard Type II
	(6) TP concentration	0.03 mg/L	Environmental water quality standard Type II
	(7) Winter DIN concentration	0.144 mg/L	1)
	(8) Winter DIP concentration	0.017 mg/L	2)
	(9) Winter DIN/DIP ratio	16	Redfield ratio
II	(10) Annual maximum chlorophyll-*a* concentration	20 μg/L	3)
	(11) Annual mean chlorophyll-*a* concentration	5μg/L	4)
	(12) Red tide (diatom sp.)	1 event/ year	
	(13) Red tide (dinoflagellate sp.)	1 event/ year	
III	(14) Annual minimum DO	6.0 mg/L	Fisheries water quality standard
	(15) Abnormal fish-kill	1 event/ year	
	(16) COD	3.0 mg/L	Environmental water quality standard Type B
IV	(17) Red tide (*Noctiluca* sp.)	3 events/3 year	
	(18) Shellfish poisoning	1 event/ year	

1) Set based on the relationship between winter TN and DIN
2) Set based on the relationship between winter TP and DIP
3) Upper threshold of medium eutrophication based on Bricker *et al.* (2003)
4) Lower threshold of medium eutrophication based on Bricker *et al.* (2003)

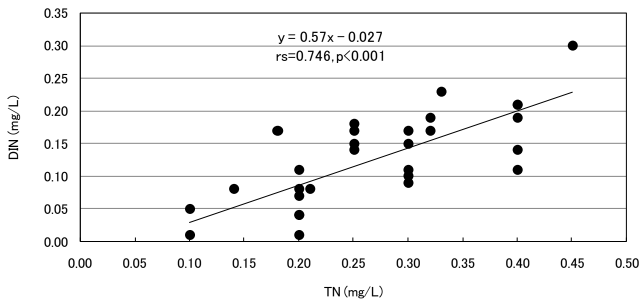

Fig. 3.1 Relationship between winter TN and DIN in Toyama Bay

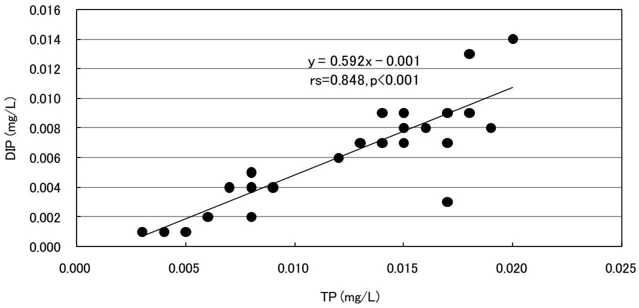

Fig. 3.2 Relationship between winter TP and DIP in Toyama Bay

Table 3.3 Classification of eutrophication levels by chlorophyll-*a* concentration

Hypereutrophic	> 60 μg/L
High	> 20, ≤ 60 μg/L
Medium	> 5, ≤ 20 μg/L
Low	> 0, ≤ 5 μg/L

Bricker *et al*. (2003)

3.2 Setting of classification criteria

The eutrophication status was classified according to the 'status' and 'trend' of the assessment values. Three types of 'identification tools' (comparison, occurrence and trend) were used and combined to determine the 'status' and 'trend' of the assessment values.

With the 'comparison' tool, the mean value of the recent three years (2007-2009) in each survey station was compared with the reference values listed in Table 3.2. However, assessment was not conducted when data availability was limited to less than three years within the five-year period from 2005-2009. A survey station in a sub-area was classified as 'high' when the three-year mean value there was above the reference value; and 'low' when it was below the reference value. The status of the assessment parameter was classified as 'High' when greter than or equal to 50% of the survey stations in a sub-area were classified as 'high'; and 'Low' if less than 50% of the survey stations in a sub-area were classified as 'Low'. Since a healthy marine environment is usually associated with high DO concentration, the status of DO was rated as 'low' when the mean value was above the reference value; and 'high' when the mean value was below the reference value.

The 'occurrence' tool was applied for the following assessment parameters: '(12) red tide (diatom sp.)', '(13) red tide (dinoflagellate sp.), '(15) abnormal fish-kill' and '(18) shellfish poisoning'. For these parameters, the status was rated as 'high' when one or more incidents occurred in the entire sub-area in the recent three years; and 'Low' if no incidents occurred. Although *Noctiluca* species are dinoflagellates, red tide of *Noctiluca* species was not included under '(13) Red tide (dinoflagellate)', but instead assessed separately under category IV '(17) Red tide (*Noctiluca* sp.)'. Red tide of *Noctiluca* sp. is known to occur not only by eutrophication but also when *Noctiluca* sp. is physically aggregated by conversion of oceanographic currents. In other words, there will be a risk of misinterpreting the eutrophication status of '(17) Red tide (*Noctiluca* sp.)' if the criterion of 'three events in three years" is applied. Thus, a different criterion was applied here: the status of '(17) Red tide (*Noctiluca* sp.)' was rated as 'High' when three or more incidents occurred in the recent three years, and 'Low' if less than three incidents occurred.

The 'trend' tool was used to analyze yearly increasing or decreasing trends of the assessment parameters. The increasing or decreasing trends were analyzed by using the non-parameteric method of Mann-Kendall. Calculation was conducted with MAKESENS (Salmi *et al.*, 2002). With a significance level at 10%, the results of the trend were indicated by three colored lines: significant increasing trend (red), significant decreasing trend (blue) and no significant trend (black). For maintaining the set significance level, trend analysis was not conducted for the survey stations with data of less than five years. In such a case, their values were indicated in the graph with dotted lines. The most dominant trend among the survey stations was considered to represent the trend of the respective assessment parameters.

Table 3.4 shows the combination of identification tools applied for each assessment parameter. For most parameters, assessments were conducted by applying either the 'comparison' or 'occurrence' tool with the 'trend' tool, and were classified into one of the following six categories: HI, HN, HD, LI, LN or LD (see Fig.3.3). Some parameters were assessed only with the 'trend' tool, and were classified into one of the following three categories: I, N or D (see Fig.3.4).

The status of each assessment category was classified by a combination of 'comparison or occurrence' tools (H or L) and 'trend' tool (I, N or D) by selecting major results of the assessment parameters in the category.

Table 3.4 Identification tools applied to the assessment parameters of Toyama Bay Case Study

Cate-gory	Assessment parameter	Assessment value	Identification tool			Remarks
			Comparison	Occurrence	Trend	
I	(1) TN input from river	Annual mean			✓	
	(2) TP input from river	Annual mean			✓	
	(3) TN input from sewage treatment plant	Annual mean				
	(4) TP input from sewage treatment plant	Annual mean				
	(5) TN concentration	Annual mean	✓		✓	
	(6) TP concentration	Annual mean	✓		✓	
	(7) Winter DIN concentration.	Winter mean	✓		✓	
	(8) Winter DIP concentration	Winter mean	✓		✓	
	(9) Winter DIN/DIP ratio	Winter mean	✓		✓	
II	(10) Chlorophyll-*a* concentration	Annual max.	✓		✓	
	(11) Chlorophyll-*a*	Annual mean	✓		✓	

	concentration					
	(12) Red tide (diatom sp.)	Annual no. of events		✓	✓	
	(13) Red tide (dinoflagellate sp.)	Annual no. of events		✓	✓	
III	(14) DO	Annual min.	✓		✓	
	(15) Abnormal fish-kill	Annual no. of incidents		✓	✓	
	(16) COD	Annual mean	✓			
IV	(17) Red tide (*Noctiluca* sp.)	Annual no. of events		✓		
	(18) Shellfish poisoning	Annual no. of incidents		✓		

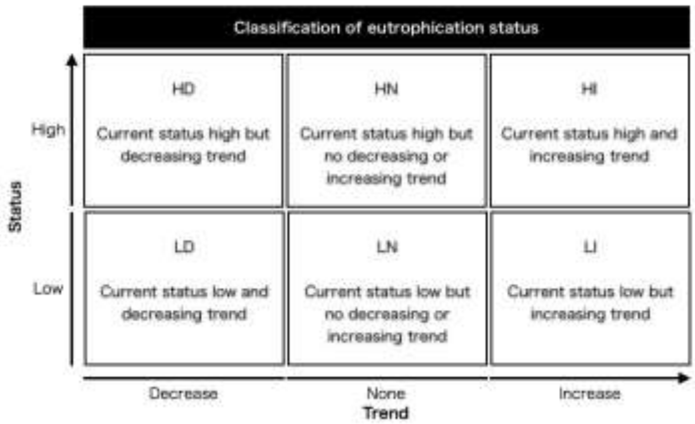

Fig. 3.3 Six classification categories stipulated in the Common Procedures (for 'status' and 'trend')

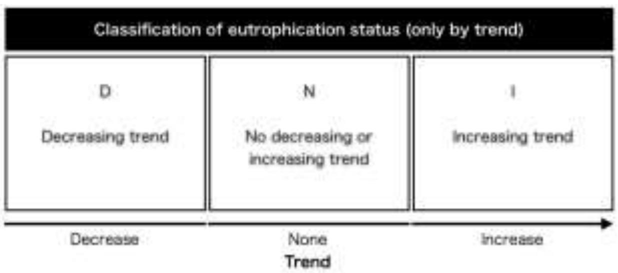

Fig. 3.4 Three classification categories stipulated in the Common Procedures (for 'trend' only)

4. Results

4.1 Assessment results of Category I parameters

(1) TN input from river

There are five Class-A rivers flowing into the assessment area: the Oyabe River, the Shou River, the Jinzu River, the Joganji River and the Kurobe River. TN input of these five rivers per day was between 25.2-39.5 t/day. Input from the Jinzu River dominated among the five, contributing to 54-75% of all. The second biggest source was the Oyabe River: 16-34%. Increasing trends of TN input were identified in the Jinzu River from1985 to 2009, while decresing trend of TN input was identified in Oyabe River during the same period. No trends of TN input were indentified in other river from 1985 to 2009. Since no trend was identified in the total TN input from all rivers, the TN inputs in the assessment area was classified as 'No trend.' In recent 10 years (2000 to 2009), decreasing trend of TN input was identified in Kurobe River while other no trend was identified in TN input in other rivers.

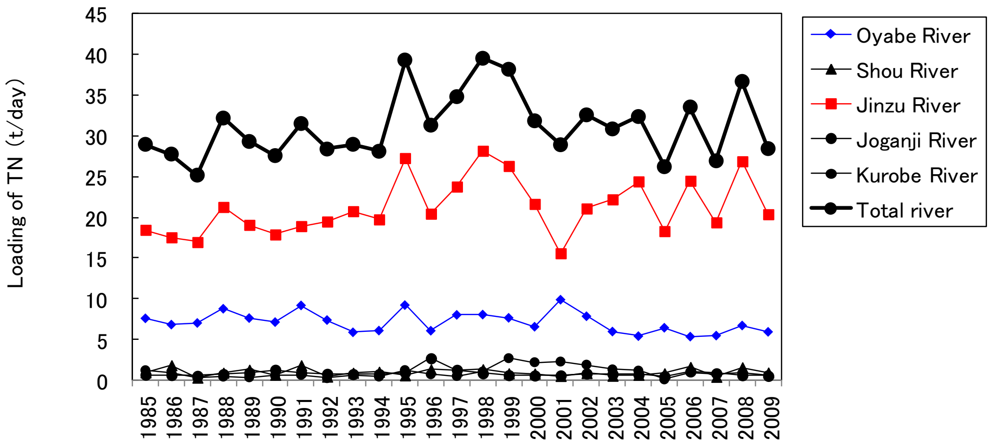

Fig. 4.1 TN input from the rivers in the assessment area

(2) TP input from river

TP input from Class-A rivers into Assessment area was between 0.69-2.75 t/day. The Jinzu River contributed most between 1985 and 1994. The largest input from the Jinzu River was 2.3 ton/day in 1992, however, the amount decreased by 0.3 t/day in 2007. As of 2009, TP input from the Jinzu River and the Oyabe River contributed to 50% and 42% of all respectively. Decreasing trend was identified with the Jinzu River while no trends were identified with other four rivers. Since the total input from all the rivers showed decreasing trend, the TP input from rivers in the assessment area was classified as 'Decreasing trend.' In recent 10 years (2000 to 2009), decreasing trend of TN input was identified in Oyabe and Kurobe Rivers. No trend was identified in TN input in other rivers.

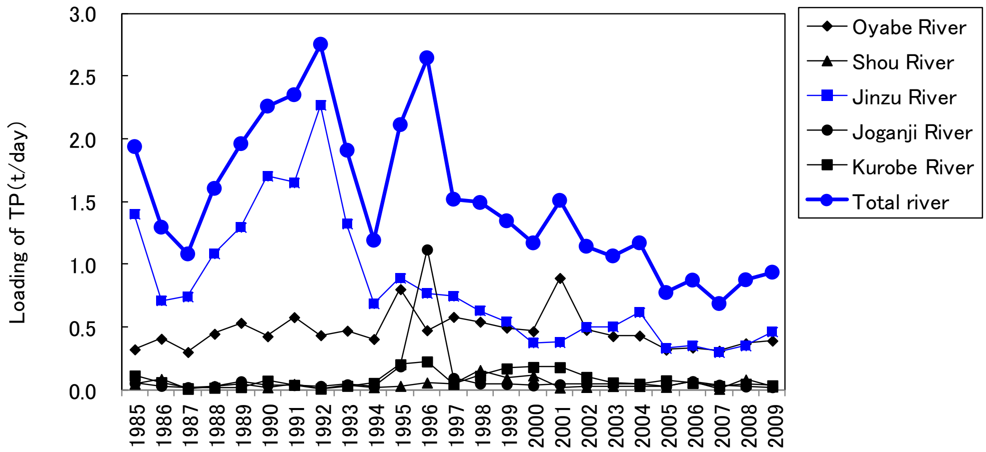

Fig. 4.2 TP input from the rivers in the assessment area

(3) TN input from sewage treatment plant

TN is directly input into Assessment area from five sewage treatment plants: the Jinzu River left-bank Sewage Treatment Plant, Hamakurosaki Sewage Treatment Plant, Fushiki Sewage Treatment Plant, Uozu-city Sewage Treatment Plant, and Namerikawa-city Sewage Treatment Plant. Unfortunately, there was no data until 2009 to identify trend of annual TN input from sewage treatment plants. However, according to compiled statistics in 2004, TN input to Toyama Bay from sewage treatment plants contributed to 8% of total nitrogen input including from rivers (Toyama Prefecture, 2008). Therefore, the amount of TN input from sewage treatment plants was considered smaller than that from rivers.

(4) TP input from sewage treatment plant

Same as TN input, there was no data for annual direct TP input to Assessment area from sewage treatment plants until 2009. According to compiled statistics in 2004, TP input to Toyama Bay from sewage treatment plants occupied 16% of total phosphorus including from rivers (Toyama Prefecture, 2008). Therefore, the amount of TP input from this type of plants was considered small, comparing with that from rivers.

(5) TN concentration

There are nine survey stations in the assessment area, and data were available from 1997 to 2009. The annual mean of TN concentration didn't show any trend at all nine stations. The mean TN concentration of the recent three years ranged between 0.16-0.22 mg/L, and all nine stations were below the reference value (0.3 mg/). Therefore, the TN in the assessment area was classified as 'Low eutrophication status and No trend.' In recent 10 years (2000 to 2009), decreasing trend of TN input was identified at one station (S6), but no trend was identified at other stations in the assessment area.

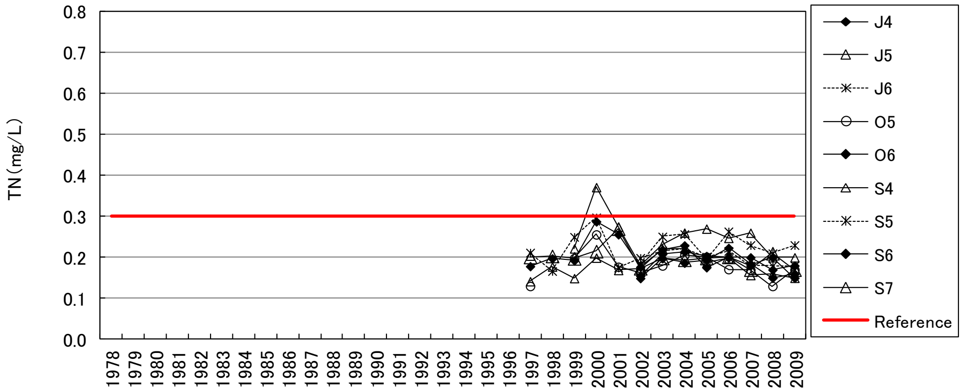

Fig. 4.3 TN concentration in the assessment area

(6) TP concentration

The annual mean of TP concentration showed decreasing trend at five stations (J4, J5, O6, S6 and S7), but no trend at the other four staions.

The mean TP concentration of the recent three years ranged between 0.010-0.014 mg/L, and all nine stations were below the reference value (0.03 mg/L). Therefore, the TP in the assessment area was classified as 'Low eutrophication status and decreasing trend.' In recent 10 years (2000 to 2009), decreasing trend of TP input was also identified at the same five stations (J4, J5, O6, S6 and S7).

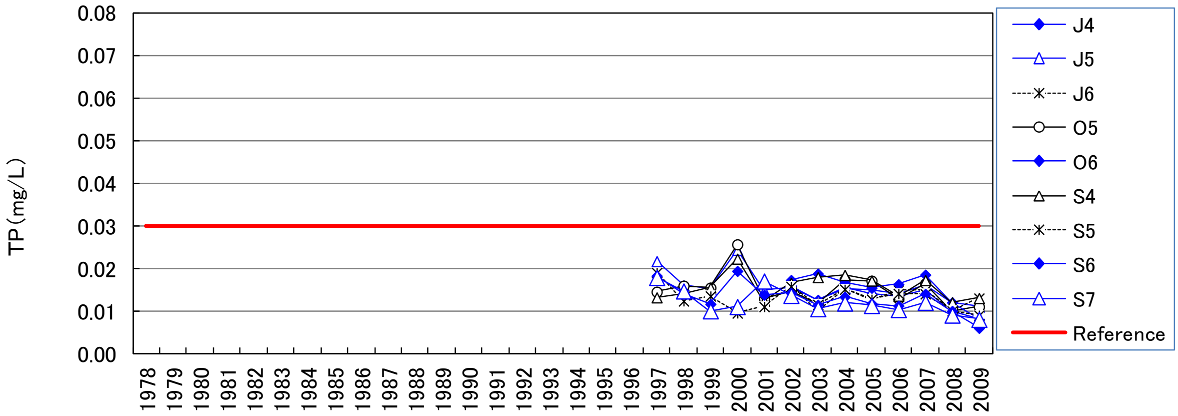

Fig. 4.4 TP concentration in Assessment area

(7) Winter DIN concentration

Winter DIN concentration didn't show any trend at all four stations from 2000 to 2009. The mean winter DIN concentration of the recent three years ranged between 0.08-0.17 mg/L. One station (J5) was above the reference value (0.144 mg/L) while the other three stations were below the reference value. Therefore, the winter DIN concentration in the assessment area was classified as 'Low eutrophication status and No trend.'

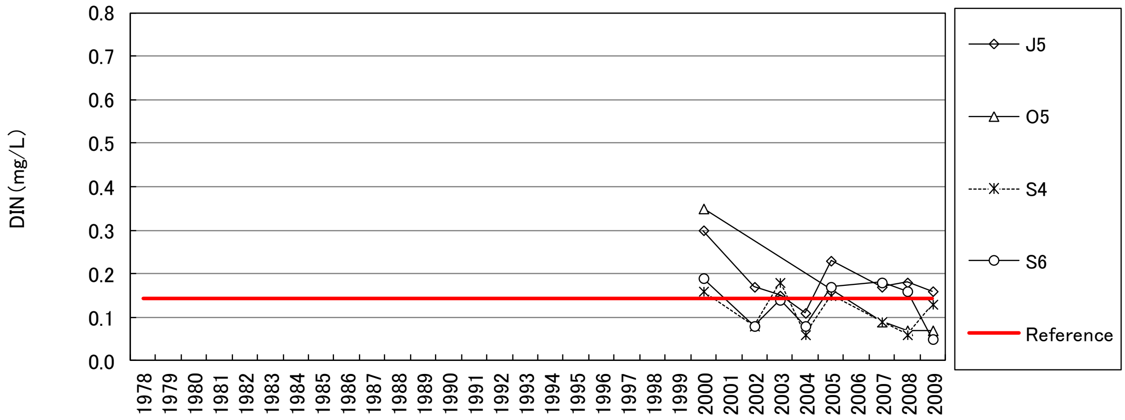

Fig. 4.5 Winter DIN concentration in Assessment area

(8) Winter DIP concentration

Winter DIP concentration didn't show any trend at all four stations from 2000 to 2009. The mean winter DIP concentration of the recent three years ranged between 0.007-0.008 mg/L, and all stations were below the reference value (0.017 mg/L). Therefore, the winter DIN concentration in the ssessment area was classified as 'Low eutrophication status and No trend.'

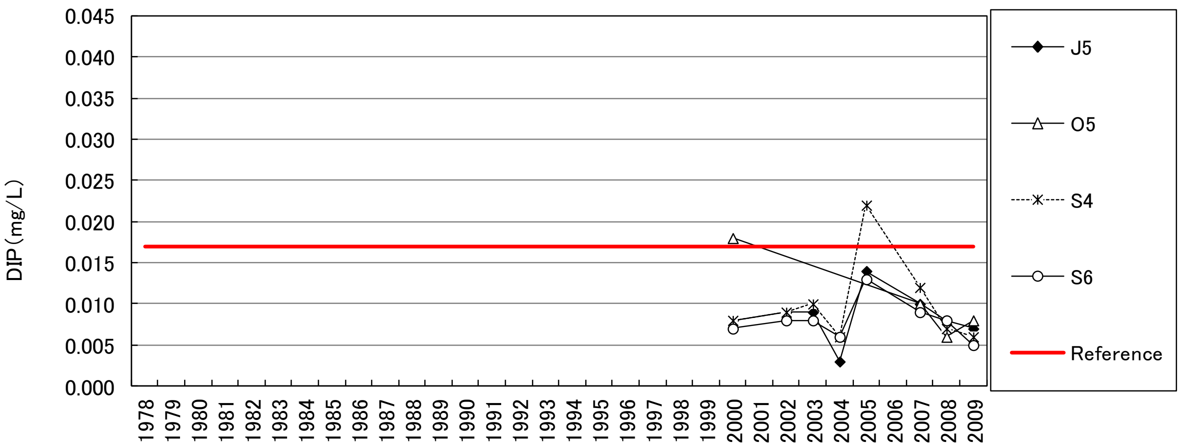

Fig. 4.6 Winter DIP concentration in the assessment area

(9) Winter DIN/DIP ratio

Winter DIN/DIP ratio didn't show any trend at all four stations from 2000 to 2009. The mean winter DIN/DIP ratio of the recent three years ranged between 22 and 46, and all stations were above the reference value of 16. Therefore, the winter DIN/DIP ratio in the assessment area was classified as 'High eutrophication status and No trend.' However, both winter DIN and DIP concentrations were below the reference values respectively, therefore, the classification result of winter DIN/DIP ratio was not reflected in the overall result of Category I.

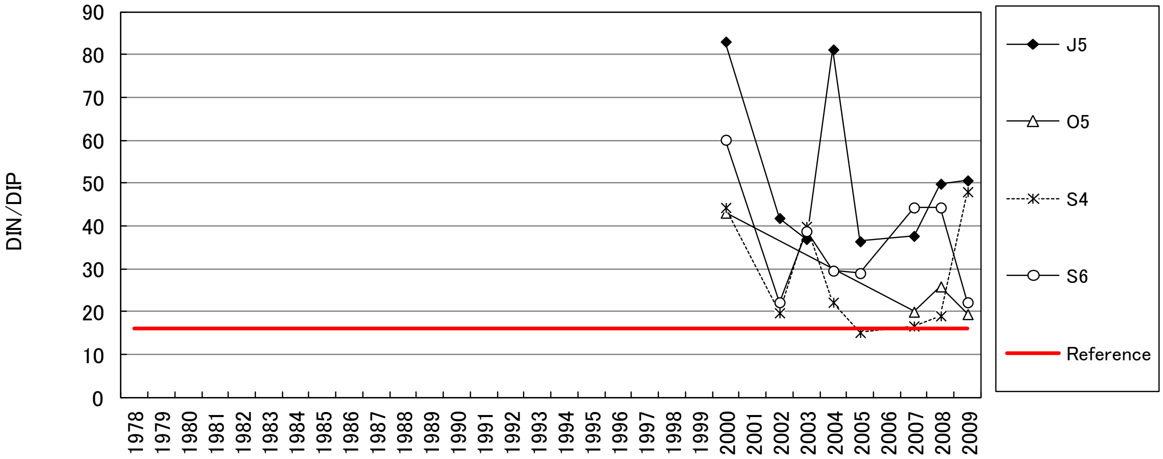

Fig. 4.7 Winter DIN/DIP ratio in the assessment area

4.2 Assessment results of Category II parameters

(1) Annual maximum chlorophyll-*a* concentration

There was no trend in the annual maximum chlorophyll-*a* concentration at all the stations (S4, S6 and J5). The annual maximum chlorophyll-*a* concentration of the recent three years ranged between 15.0-22.3 µg/L, and one station (S6) was above the reference value (20 µg/L) while the other two stations were below the reference value. Therefore, the annual maximum chlorophyll-*a* concentration in the assessment area was classified as 'Low eutrophication status and No trend.' In recent 10 years (2000 to 2009), no trend of annual maxium chlorophyll-*a* concentration was identified in all stations.

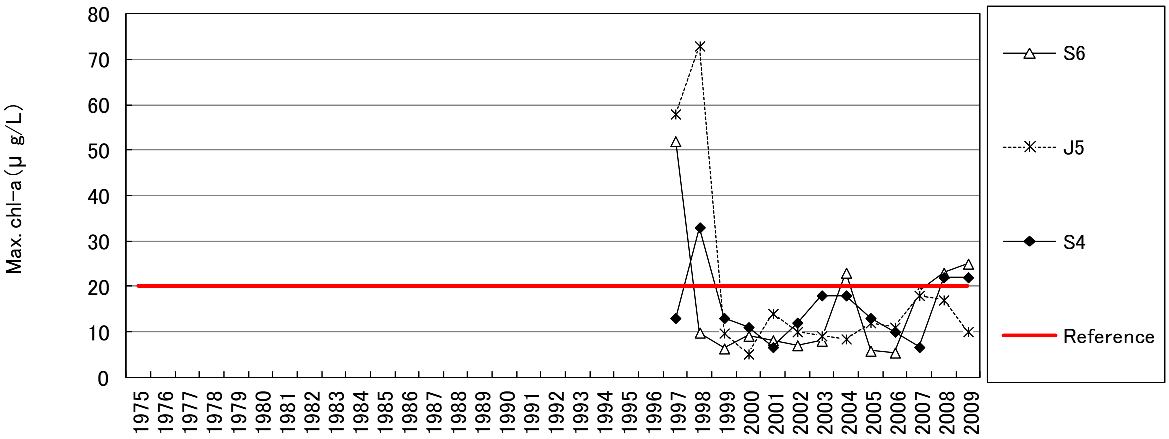

Fig. 4.8 Annual maximum chlorophyll-*a* concentration in Assessment area

(2) Annual mean chlorophyll-*a* concentration

There were no trends in the annual mean chlorophyll-*a* concentration at all stations. The annual mean chlorophyll-*a* concentration of the recent three years ranged between 6.0-8.0 µg/L, and all stations were above the reference value (5 µg/L). Therefore, the annual mean chlorophyll-*a* concentration in the assessment area was classified as 'High eutrophication status and No trend.' In recent 10 years (2000 to 2009), increasing trend of annual mean chlorophyll-*a* concentration was identified in S4 and S6.

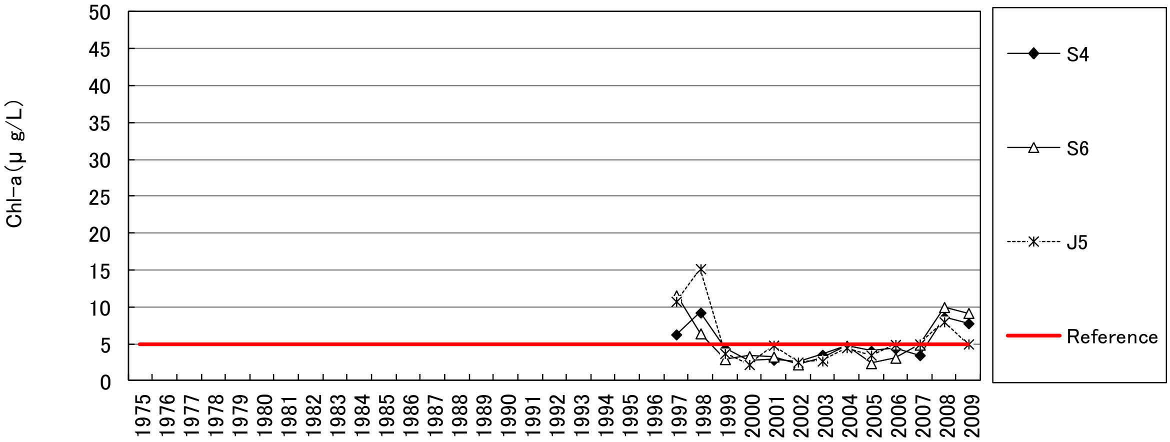

Fig. 4.9 Annual mean chlorophyll-*a* concentration in the assessment area

(3) Red tide (diatom sp.)

The number of diatom red tide in the assessment area ranged between 1-13 events/year from 1967-1999, however, there were no events after 2000, except in 2002 and 2003. The number of diatom red tide events decreased, and there were no events in the recent three years. Therefore, the diatom red tide in the assessment area was classified as 'Low eutrophication status and Decreasing trend.' In recent 10 years (2000 to 2009), no trend of red tide (diatom sp.) was identified in the assessment area.

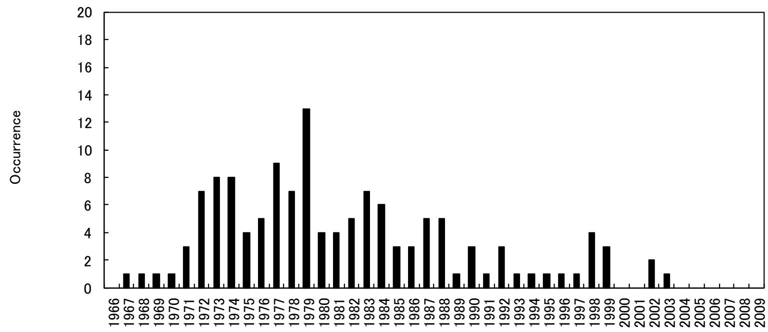

Fig. 4.10 Number of diatom red tide in the assessment area

(4) Red tide (dinoflagellate sp.)

There was only one event of dinoflagellate red tide in 1970 in the assessment area, and no trend was identified. Therefore, the dinoflagellate red tide in the assessment area was classified as 'Low eutrophication status and No trend.' In recent 10 years (2000 to 2009), there was no red tide of dianoflagellate sp. was recorded.

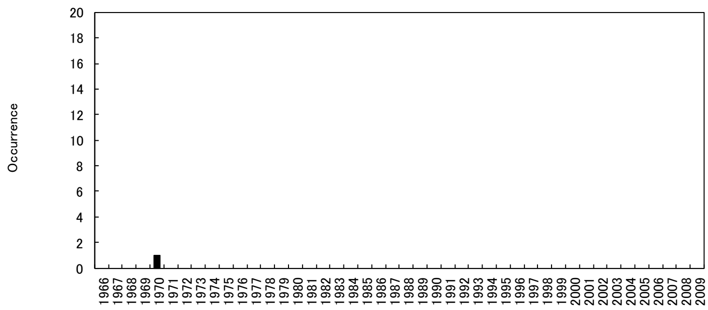

Fig. 4.11 Number of dinoflagellate red tide in the assessment area

4.3 Assessment results of Category III parameters

(1) Dissolved oxygen (DO)

Within nine stations, two stations (S6 and S7) showed decreasing trend in the annual minimum DO concentration. The other seven stations didn't show any trend. The mean DO of the recent three years ranged between 6.8-7.4 mg/L, and all stations were above the reference value (6.0 mg/L). Following the setting of classification criteria (See 3-2), DO was classified in an opposite way of other parameters. Therefore, the DO in the assessment area was classified as 'Low eutrophication status and No trend.' In recent 10 years (2000 to 2009), no trend was identified in all stations.

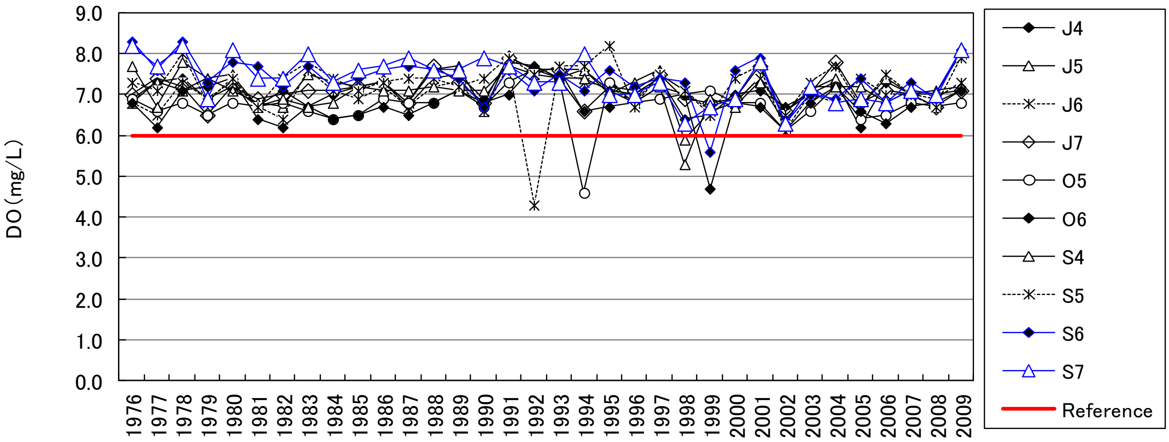

Fig. 4.12 DO concentration in the assessment area

(2) Abnormal fish kill

Incidents of abnormal fish kill were not confirmed. Therefore, the abnormal fish kill in the ssessment area was classified as 'Low eutrophication status and No trend.'

(3) Chemical oxygen demand (COD)

Annual mean COD concentration showed increasing trend at 5 stations at 10 stations. The mean COD of the recent three years ranged between 1.7-1.8 mg/L, and all stations were below the reference value (3.0 mg/L). Therefore, the COD in the assessment area was classified as 'Low eutrophication status and increasing trend.' In recent 10 years (2000 to 2009), decreasing trend was identified only at one station (J4).

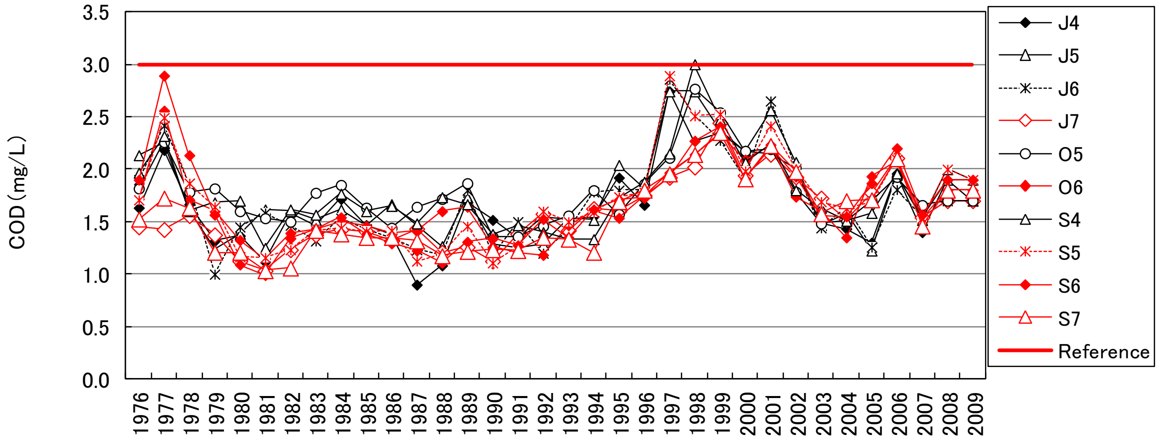

Fig. 4.13 COD concentration in the assessment area

4.4 Assessment results of Category IV parameters

(1) Red tide (*Noctiluca* sp.)

From 1966 to 2009, *Noctiluca* red tide occurred in fourteen years at a frequency of 1-3 times per year. No trend was identified. Within the recent three years, only one *Noctiluca* red tide was confirmed in 2007. Overall, the *Noctiluca* red tide in the assessment area was classified as 'Low eutrophication status and No trend.' In recent 10 years (2000 to 2009), no trended was indentified due to lack of data.

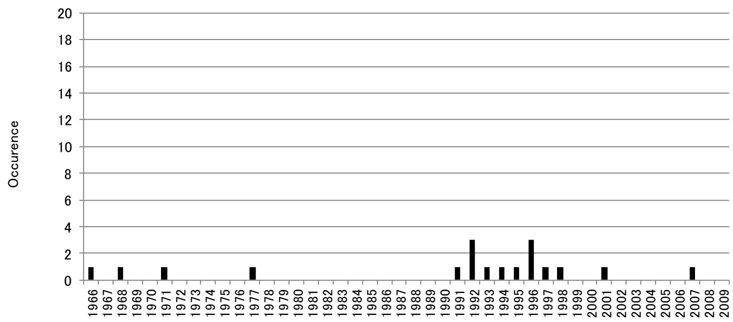

Fig. 4.14 Number of *Noctiluca* red tide in Assessment area

(2) Shellfish poisoning

Incidents of shellfish poisoning were not confirmed. Therefore, its status and trend in Assessment area was classified as 'Low eutrophication status and No trend.'

Assessment results of each assessment category

Table 4.1 Assessment results of each assessment category in Assessment area (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	×	D	LD	
	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	H	×	N	HN	
	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 accidents	×	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.

4.5 Assessment results

Category I (degree of nutrient enrichment) parameters: total TN input from all of the Class-A rivers didn't show any trend. However, total TN input showed increasing trends in the Jinzu River and decresing trend in the Oyabe River. Since its size and location (the biggest and flowing into the closed-off section of the bay) of the Jinzu River, significant influence over the Toyama Bay is considered. On the other hand, total TP input from all of the Class-A Rivers and TP concentration showed decreasing trend. Almost all of the mean concentrations of TN, winter DIN and winter DIP of the recent three years were below each reference value, and there was no trend.

Category II (direct effects of nutrient enrichment) parameters: The annual maximum of Chlorophyll-a concentrations of recent three years in most stations were below the reference value, however, the annual mean of Chlorophyll-a concentrations in all stations were above the reference values, and there was no trend. The number of diatom red tide showed decreasing trend, and there were no events in recent years. Also, there were no dinoflagellate red tides in the recent three years.

Category III (indirect effects of nutrient enrichment) parameters: Decreasing trend of DO was identified at 2 stations, although it satisfied the reference value most stations. Increasing trend of COD was detected at 5 stations, although it satisfied the reference value at all sataions.

Category IV (other possible effects of nutrient enrichment) parameters: There was only one *Nuctiluca* red tide in 2007. No shellfish-poisoning incidents were confirmed.

In the assessment area, all categories were classified as 'Low eutrophication status and No trend'. However, among Category I parameters, it is suggested to reduce TN input since T/P ratio was higher then the reference value. Among Category II parameters, annual mean Chl-a showed high eutrophication status. Therefore, it is required to improve the status by reducing nutrient enrichment. Among Category III parameters, increasing trend of COD and dreasing trend of DO were identified, continous monitoing of these parameters are necessary for management of eutrophication.

Table 4.2 Reasons behind classification of each assessment category in Assessment area (Coastal Area)

	Reason	Classification
I Degree of nutrient enrichment	- TN input from river: No trend, but increasing trend in the Jinzu River - TP inputs from river: Decreasing trend - TN and TP input from sewage treatment plant: Comparing with input from river, both are smaller - TN concentration: Low concentration, and no trend - TP concentration: Low concentration and decreasing trend - Winter DIN and DIP concentration: Low concentration in some stations, but no increasing/decreasing trend - Winter DIN/DIP ratio: High ratio, but no increasing/decreasing trend	LN
II Direct effects of nutrient enrichment	- Annual mean of chlorophyll-*a*: Higher concentrations than the reference values, and no trend - Annual maximum and mean of chlorophyll-*a*: Lower concentrations than the reference values, and no trend - Diatom red tide: Decreasing trend, and no events in the recent three years. - Dinoflagellate red tide: No trend, and no events in the recent three years	LN
III Indirect effects of nutrient enrichment	- DO: Higher concentration than the reference value, but decreasing trends in some stations - COD: Lower concentration than the reference value, but increasing trends in some stations	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: Low frequency throughout the assessment period (1966-2009) - Shellfish poisoning: None	LN

5. Review and Validation of assessment results of Toyama Bay

Based on the overall classification results in Toyama Bay, as TN input from the Jinzu River was increasing trend, it was considered to develop effective countermeasures against reduction of nitrogen. On the other hand, Tsujimoto (2012) reported that it is necessary to reduce both nitrogen and phosphorus, because limiting factor for phytoplankton growth had changed from nitrogen to phosphorus at offshore survey staion off Jinzu River mouth from 2006 to 2007. He also mentioned that nutrients were always rich where saliniy was below 25 and they were not actual limiting factor for phytoplankton growth. Therefore, it was suggested that reduction of phosphorus is still necessary to control water quality of the Toyama Bay coastal area, despite that decreasing trend were observed in TP input and concentation.

Decreasing DO and increasing COD were observed. Possible causes of the DO decrease still remain unknown, but contiouous monitoring are therefore suggested. On the other hand, increasing trend in COD can be explained by the hypothesis that phytoplankton growth in the bay contributes to increase of COD reported by the Toyama Bay Water Quality Preservation Research Committee (2001). Thus, it is necessary to address nutrient loads immediately in Toyama Bay coastal area.

6. Conclusion and recommendation

Through the eutrophication assessment by the refined NOWPAP Common Procedure in Toyama Bay, the coastal area was suspected potentially eutrophic by the application of the screening procedure; high level of satellite derived Chlorphyll-a and dense distribution of nutrients concentration. Further assessment of eutrophication in the Toyama Bay coastal area was conducted by the comprehensive procedure and concluded that reduction of nutrient especially nitrogen and monitoring of chlrophyll-a, DO and COD are necessary.

Review of the obtained assessment results with exsiting paper indicated that reduction of nitrogen is not enough and reduction of phosphorus is also necessary to control water quality of the Toyama Bay coastal area.

Thus, screening procdure of the refined NOWPAP Common Procedure was useful to detect the potential eutrophic zone in Toyama Bay, and causes of eutrophication in the detected potential zone was understood by the application of the comprehensive procedure.

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