A Case Study Report on

Assessment of Eutrophication Status

in Toyama Bay, Japan

Northwest Pacific Region

Environmental Cooperation Center

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Contents

1. Scope of the assessment

1.1   Objective of the assessment

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 to identify the problems and effective countermeasures.

1.2   Selection of assessment area

In Toyama Bay Case Study, this bay was selected for implementing eutrophication assessment, as this place has been a target of several existing assessments, and plenty of data from them are available (Fig.1.1). In this case study, the sea area of Toyama Bay was defined in consideration of geographical conditions of the water body and municipal borderlines between neighboring prefectures: to the south from the line drawn between the border Toyama-Niigata and Cape Rokkozaki. However, it is necessary to collect as much data as possible to implement this case study as well as to coordinate with relevant organizations for releasing the study results. Thus, in order to examine collected data free from restrictions as much as possible, it was decided to focus on only the water area where Toyama prefecture has implemented the environmental assessments, and the coastal area along Noto Peninsula and Nanao Bay was excluded.

Toyama Bay is located to the east of Noto Peninsula, at the center of the eastern part of NOWPAP sea area. For descriptive purposes, the area is defined inside the line drawn between Cape Rokkozaki and the border of Toyama-Niigata. This is a semi-enclosed bay with the surface area of approximately 2,120 km^2 and 1,250 m as the deepest spot, The entire volume is approximately 1,280 km^3. The depth of 3,000 m is a border of two different waters: mainly the Tsushima Warm Current flows on top while Japan Sea Proper Water flows below the borderline. Five Class-A rivers (the Oyabe River, the Sho River, the Jinzu River, the Joganji River and the Kurobe River) and twenty-nine Class-B rivers flow into the coastal area of Toyama Bay, so it is said that the coastal area is strongly influenced by river water.
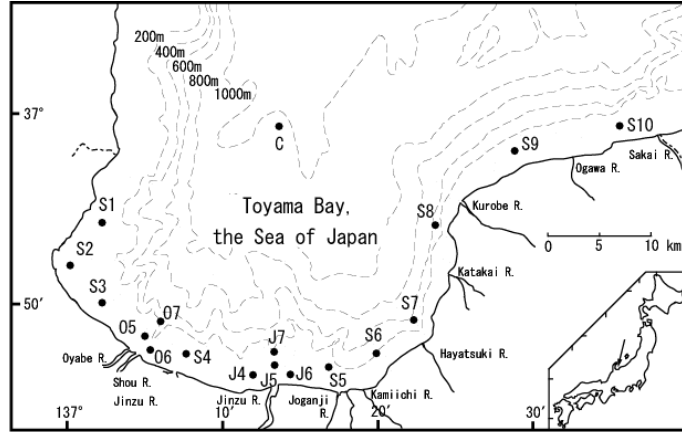
Fig. 1.1   Schematic view of Toyama Bay

1.3　Collection of relevant information

Table 1.1 shows the information/data collected for the eutrophication assessment in Toyama Bay Case Study.

Table 1.1　Information/data collected for the eutrophication assessment of
Toyama Bay Case Study

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 Common Procedures, 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
	(15) Abnormal fish kill
	(16) COD
IV. Other possible effects of nutrient enrichment	(17) Red tide (*Noctiluca* sp.)
	(18) Shellfish poisoning

1.5   Setting of sub-areas

The result of the preliminary eutrophication assessment of Toyama Bay using satellite data (Fig. 1.2) was used as reference for dividing sub-areas. Chlorophyll-*a* concentration in the closed-off section of bay is high, and the left and east sides of the Jinzu River mouth showed increasing tendency. On the other hand, in the coastal area along Himi city to the Oyabe River mouth, chlorophyll-*a* concentration is low but showing increasing trend.

In this case study, Toyama Bay was divided into three sub-areas: (A)-Coastal Area, the area with high chlorophyll-*a* concentration (>5 μg/L) and increasing trend in some spots; (B)-Inner Area, the area with low chlorophyll-*a* (≤5μg/L)

and increasing trend; and (C)-Offshore Area, the area with low chlorophyll-*a* concentration and no trend (Fig. 1.3).

As mentioned above, Nanao Bay at Noto Peninsula and Uchinada Coastal area were excluded from this assessment.
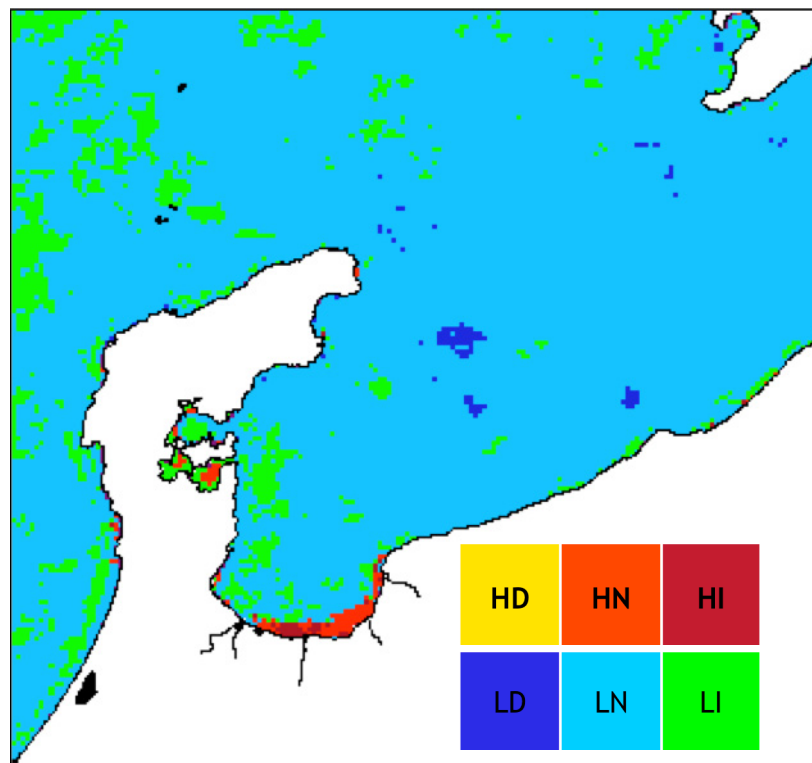

Fig. 1.2   Results of the preliminary eutrophication assessment of Toyama Bay
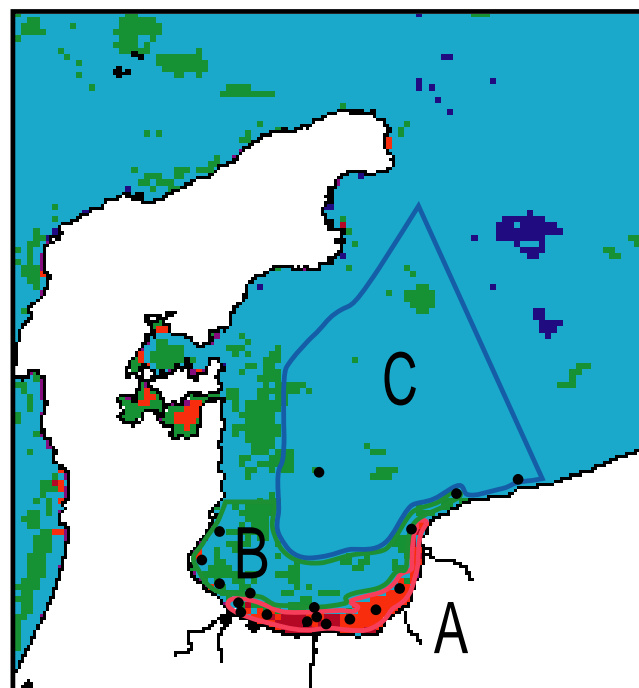based on remotely observed satellite

Fig. 1.3   Sub-areas in Toyama Bay
(A) Coastal Area, (B) Intermediate Area, (C) Offshore Area

Table 1.4　　　List of data collection stations

Sub-area	Station	Latitude	Longitude	Survey name
(A) Coastal Area	J4	36.7767°	137.2039°	Water quality survey of public waters
	J5	36.7828°	137.2222°	
	J6	36.7764°	137.2406°	
	O5	36.8072°	137.0847°	Survey of water quality conservation measures of Toyama Bay
	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°	
(B) Intermediate Area	J7	36.7981°	137.2222°	
	O7	36.8197°	137.0997°	
	S1	36.9081°	137.0461°	
	S2	36.8714°	137.0119°	
	S3	36.8353°	137.0444°	
	S8	36.9131°	137.3953°	
	S9	36.9700°	137.4803°	
(C) Offshore Area	S10	36.9925°	137.5886°	
	C	37.0033°	137.2300°	

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 1978-2007 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 1978-2007 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 (2005-2007) was compared with the reference standard. The trend of the annual mean value from 1985-2007 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 (2005-2007) was compared with the reference value. The trend of the annual mean value from 1985-2007 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 (2005-2007) was compared with the reference value.

Assessment parameter	Data processing methodology
	The trend of the winter mean value from 1997-2007 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 (2005-2007) was compared with the reference standard. The trend of the winter mean value from 1997-2007 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 (2005-2007) was compared with the reference value. Trend of the winter mean value from 1997-2007 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 (2005-2007) was compared with the reference value. The trend of the annual maximum value from 1985-2007 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 (2005-2007) was compared with the reference value. The trend of the annual mean value from 1985-2007 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 (2005-2007) was compared with the reference value. The trend of diatom red tide was analyzed from 1966-2007.
	(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 (2005-2007) was compared with the reference value. The trend of dinoflagellate red tide was analyzed from 1966-2007. *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 (2005-2007) was compared with the reference value. The trend of the annual minimum value from 1985-2007 was also analyzed.
	(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 (2005-2007) was compared with the reference value. The trend of abnormal fish kill was analyzed from 1985-2007.
	(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 (2005-2007) was compared with the reference value. The trend of the annual mean value from 1985-2007 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 (2005-2007) was compared with the reference value. The trend of *Noctiluca* red tide was analyzed from 1966-2007.
	(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 (2005-2007) was compared with the reference value. The trend of shellfish poisoning was analyzed from 1994-2007.

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		
	COD[1]	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 ($COD_{OH} = 0.6$ 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

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)
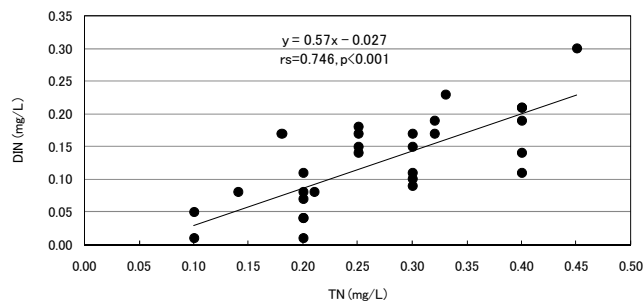

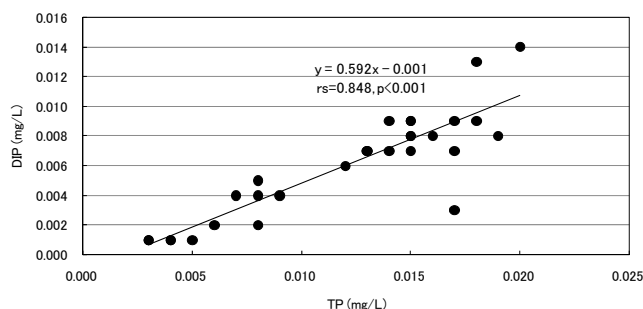Fig. 3.1 Relationship between winter TN and DIN in Toyama Bay

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 (2005-2007) 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 2003-2007. 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 more than 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.

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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 5%, 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* concentration	Annual mean	✓		✓	
	(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		✓		
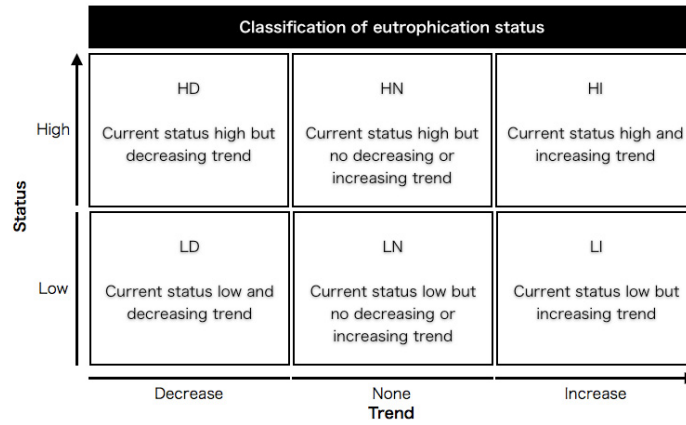
Fig. 3.3　　Six classification categories stipulated in the Common Procedures
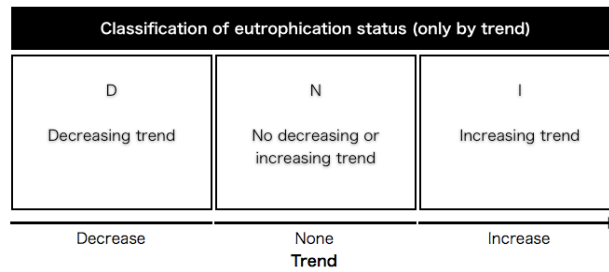(for 'status' and 'trend')

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

4. Results

4.1   Sub-area A (Coastal Area)

Assessment results of Category I parameters

(1) TN input from river

There are five Class-A rivers flowing into Sub-area A: the Oyabe River, the Show 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 54-78% of all. The second biggest source was the Oyabe River: 14-34%. Increasing trends were identified with the Jinzu and Kurobe Rivers while no trends were identified with other three rivers. Since TN inputs from the rivers showed no trends, the trend of TN inputs from rivers in Sub-area A was classified as 'No trend.'
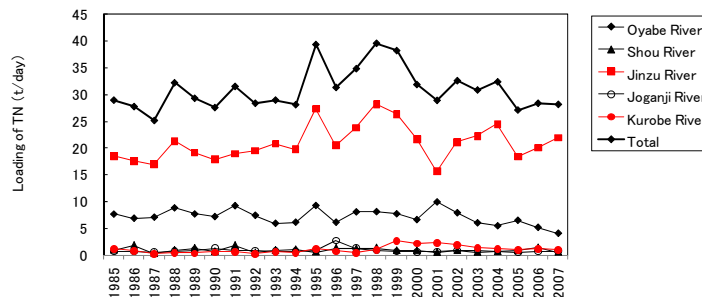

Fig. 4.1   TN input from the rivers in Sub-area A

(2) TP input from river

TP input from Class-A rivers into Sub-area A was between 0.65-2.75t/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 ton/day in 2007. As of 2007, TP input from the Jinzu River and the Oyabe River contributed to 56% and 36% 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 trend of TP input from rivers in Sub-area A was classified as 'Decreasing trend.'
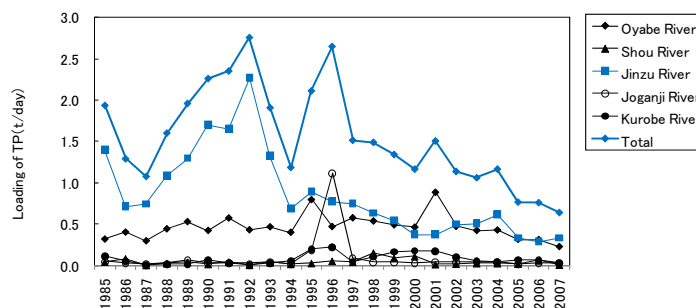

Fig. 4.2   TP input from the rivers in Sub-area A

(3) TN input from sewage treatment plant

TN is directly input into Sub-area A 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 2007 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 Sub-area A from sewage treatment plants until 2007. 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 Sub-area A, and data were available from 1997 to 2007. 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 0.18-0.26 mg/L, and all nine stations were below the reference value (0.3 mg/). Therefore, the status and trend of TN in Sub-area A was classified as 'Low eutrophication status and No trend.'
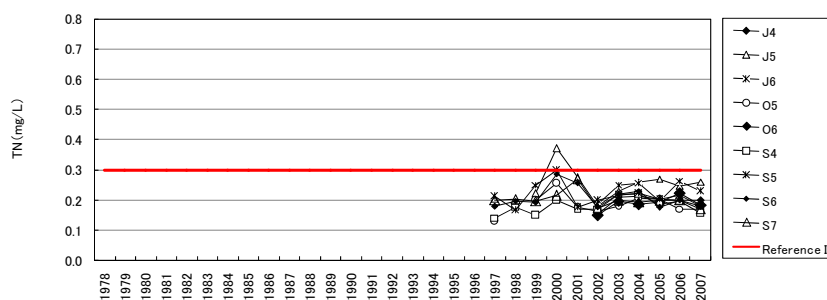

Fig. 4.3   TN concentration in Sub-area A

(6) TP concentration

The annual mean of TP concentration didn't show any trend at all nine stations. The mean TP concentration of the recent three years ranged between 0.011-0.017 mg/L, and all nine stations were below the reference value (0.03 mg/L). Therefore, the status and trend of TP in Sub-area A was classified as 'Low eutrophication status and No trend.'
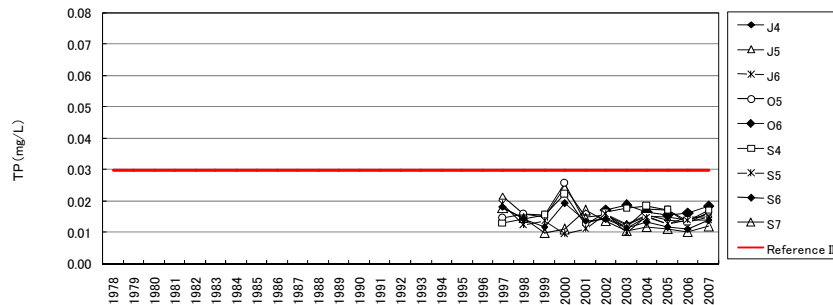

Fig. 4.4   TP concentration in Sub-area A

(7) Winter DIN concentration

Within four stations, three stations (J5, S4 and S6) didn't show any trend in winter DIN concentration. Another station (O5) had data only for two years, so trend couldn't be calculated. The mean winter DIN concentration of the recent three years ranged between 0.10-0.17 mg/L. One station (J5) was above the reference value (0.144 mg/L) while the other two stations were below the reference value. Therefore, the status and trend of winter DIN concentration in Sub-area A was classified as 'Low eutrophication status and No trend.'
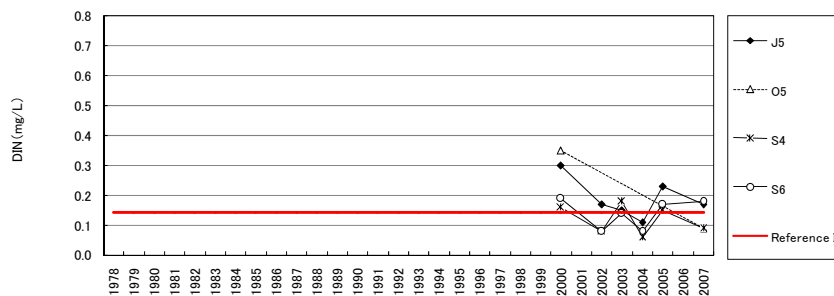

Fig. 4.5   Winter DIN concentration in Sub-area A

(8) Winter DIP concentration

Within the four stations, three stations (J5, S4 and S6) didn't show any trend in winter DIP concentration. Another station (O5) had data only for two years, so trend couldn't be calculated. The mean winter DIP concentration of the recent three years ranged between 0.009-0.013 mg/L, and all stations were below the reference value (0.017 mg/L). Therefore, the status and trend of winter DIN concentration in Sub-area A was classified as 'Low eutrophication status and No trend.'
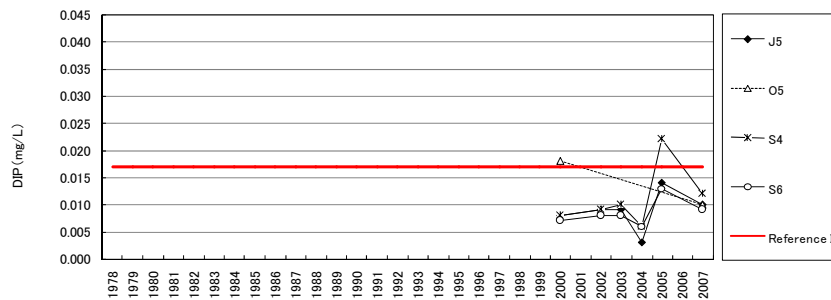

Fig. 4.6   Winter DIP concentration in Sub-area A

(9) Winter DIN/DIP ratio

Within the four stations, three stations (J5, S4 and S6) didn't show any trend in winter DIN/DIP ratio. Another station (O5) had data only for two years, so trend couldn't be calculated. The mean winter DIN/DIP ratio of the recent three years ranged between 18 and 52, and all stations were above the reference value of 16. Therefore, the status and trend of winter DIN/DIP ratio in Sub-area A 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.
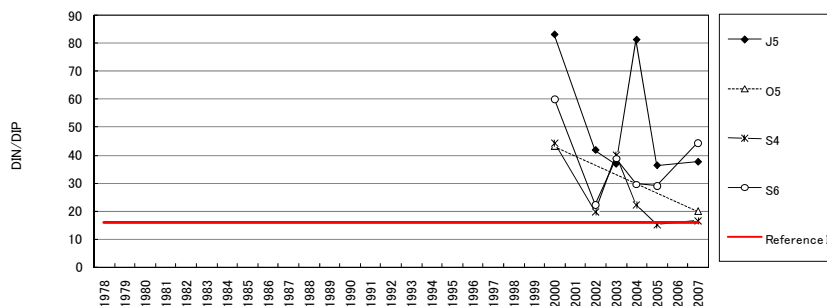

Fig. 4.7   Winter DIN/DIP ratio in Sub-area A

20

Assessment results of Category II parameters

(10) 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 9.9-13.7 μg/L, and all stations were below the reference value (20 μg/L). Therefore, the status and trend of annual maximum chlorophyll-*a* concentration in Sub-area A was classified as 'Low eutrophication status and No trend.'
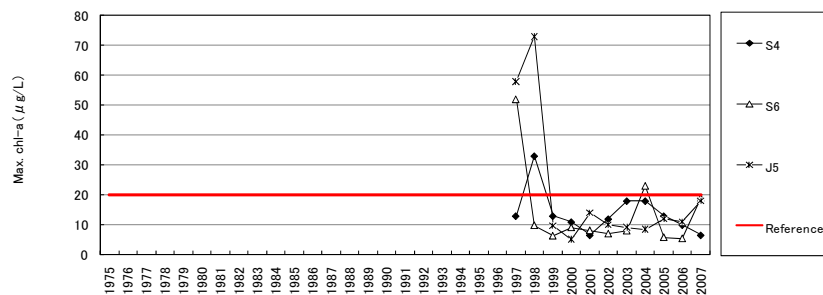

Fig. 4.8   Annual maximum chlorophyll-*a* concentration in Sub-area A

(11) 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 3.5-4.5 μg/L, and all stations were below the reference value (5 μg/L). Therefore, the annual mean chlorophyll-*a* concentration in Sub-area A was classified as 'Low eutrophication status and No trend.'
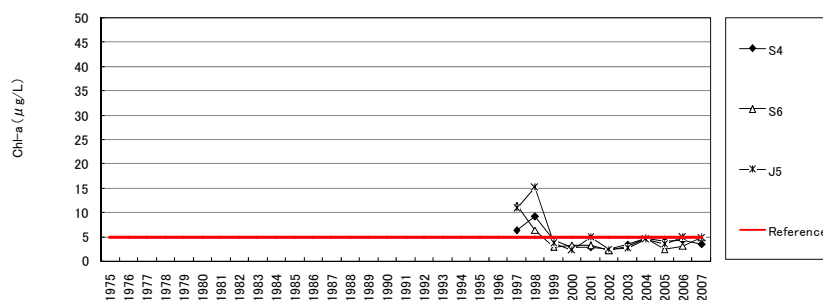

Fig. 4.9   Annual mean chlorophyll-*a* concentration in Sub-area A

21

(12) Red tide (diatom sp.)

The number of diatom red tide in Sub-area A 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 status and trend of diatom red tide in Sub-area A was classified as 'Low eutrophication status and Decreasing trend.'
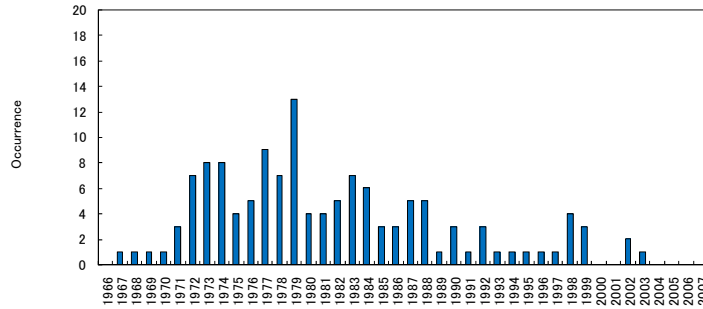

Fig. 4.10   Number of diatom red tide in Sub-area A

(13) Red tide (dinoflagellate sp.)

There was only one event of dinoflagellate red tide in 1970 in Sub-area A, and no trend was identified. Therefore, the status and trend of dinoflagellate red tide in Sub-area A was classified as 'Low eutrophication status and No trend.'
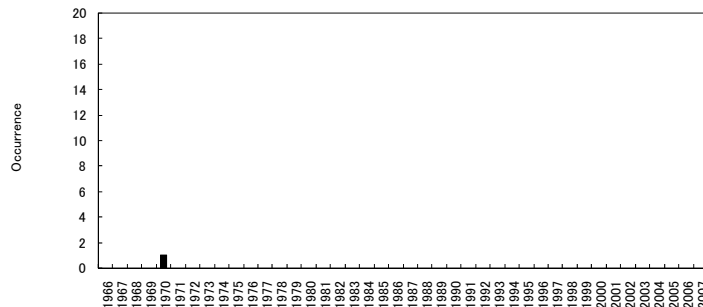

Fig. 4.11   Number of dinoflagellate red tide in Sub-area A

Assessment results of Category III parameters

(14) 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 6.6-7.2 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 status and trend of DO in Sub-area A was classified as 'Low eutrophication status and No trend.'
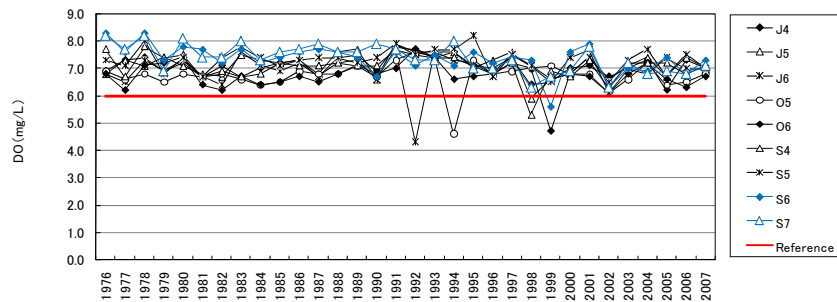

Fig. 4.12   DO concentration in Sub-area A

(15) Abnormal fish kill

Incidents of abnormal fish kill were not confirmed. Therefore, its status and trend in Sub-area A was classified as 'Low eutrophication status and No trend.'

(16) Chemical oxygen demand (COD)

Within nine stations, three stations (S5, S6 and S7) showed increasing trend in annual mean COD concentration. The other six stations (J4, J5, J6, O5, O6 and S4) didn't show any trend. The mean COD of the recent three years ranged between 1.5-1.9 mg/L, and all stations were below the reference value (3.0 mg/L). Therefore, the status and trend of COD in Sub-area A was classified as 'Low eutrophication status and No trend.'
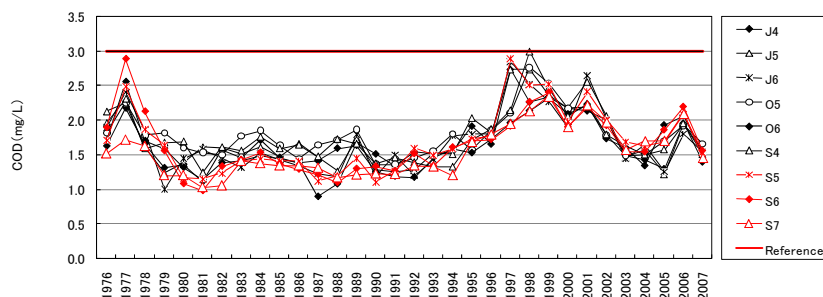

Fig. 4.13   COD concentration in Sub-area A

Assessment results of Category IV parameters

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

    From 1966 to 2007, *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 status and trend of *Noctiluca* red tide Sub-area A was classified as 'Low eutrophication status and No trend.'
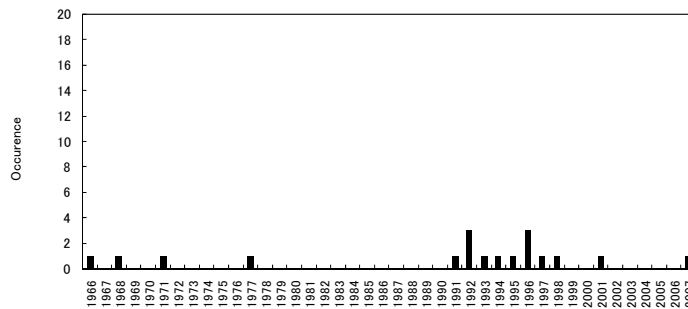

Fig. 4.14   Number of *Noctiluca* red tide in Sub-area A

(18) Shellfish poisoning

    Incidents of shellfish poisoning were not confirmed. Therefore, its status and trend in Sub-area A 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 Sub-area A (Coastal Area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
	Riverine input of TN	×	×	N	N	
	Riverine input of TP	×	×	D	D	
	Sewage plant input of TN	×	×	×	-	
	Sewage plant input of TP	×	×	×	-	
	TN concentration	L	×	N	LN	LN
	TP concentration	L	×	N	LN	
	Winter DIN concentration	L	×	N	LN	
	Winter DIP concentration	L	×	N	LN	
	Winter DIN/DIP ratio	H	×	N	HN*	
	Annual maximum of chlorophyll-*a*	L	×	N	LN	
	Annual mean of chlorophyll-*a*	L	×	N	LN	LN
	Red tide events (diatom sp.)	×	L	D	LD	
	Red tide events (dinoflagellate sp.)	×	L	N	LN	
	Dissolved oxygen (DO)	L	×	N	LN	
	Fish kill incidents	×	L	N	LN	LN
	Chemical oxygen demand (COD)	L	×	N	LN	
	Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	Shell 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.

Assessment results of Sub-area A (Coastal Area)

Toyama Bay is a semi-enclosed bay, located in the center of the eastern part of NOWPAP area, and five 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 (degree of nutrient enrichment) parameters: TN input from all of the Class-A rivers didn't show any trend. However, TN input from the Jinzu River and the Kurobe River showed increasing trends. Because of its size and location (the biggest and flowing into the closed-off section of the bay), the Jinzu River has significant influence over the Toyama Bay. Thus, it is required to address TN input from this river in order to prevent the bay from eutrophication. On the other hand, TP input from all of the Class-A rivers showed decreasing trend. All of the mean concentrations of TN, TP, 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 and mean of chlorophyll-*a* concentrations of the recent three years were below the reference values respectively, 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: DO in most stations satisfied the reference value, however, some stations showed decreasing trends. COD in all stations satisfied the reference value, however, some stations showed increasing trends.

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

Table 4.2   Reasons behind classification of each assessment category

in Sub-area A (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 increasing/decreasing trend - TP concentration: Low concentration, and no increasing/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 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 (1966-2007) - Shellfish poisoning: None	LN

4.2   Sub-area B (Intermediate Area)

Assessment results of Category I parameters

(1) TN input from river

Because of the location (the intermediate area of Toyama Bay), there are no rivers directly flowing into this area.

(2) TP input from river

Because of the location (the intermediate area of Toyama Bay), there are no rivers directly flowing into this area.

(3) TN input from sewage treatment plant

Because of the location (the intermediate area of Toyama Bay), there are no sewage treatment plants which directly input their water into this area.

(4) TP input from sewage treatment plant

Because of the location (the intermediate area of Toyama Bay), there are no sewage treatment plants which directly input their water into this area.

(5) TN concentration

There are seven stations in Sub-area B, and data of eleven years from 1997 to 2007 is available. Within seven stations, two stations (S1 and S3) showed increasing trends in annual mean of TN concentration. Other five stations (J7, O7, S2, S8 and S9) showed no trends. Mean TN concentration of the recent three years ranged between 0.12-0.21 mg/L, and they were all below the reference value (0.3 mg/L). Therefore, the status and trend of TN concentration in Sub-area B was classified as 'Low eutrophication status and No trend.'
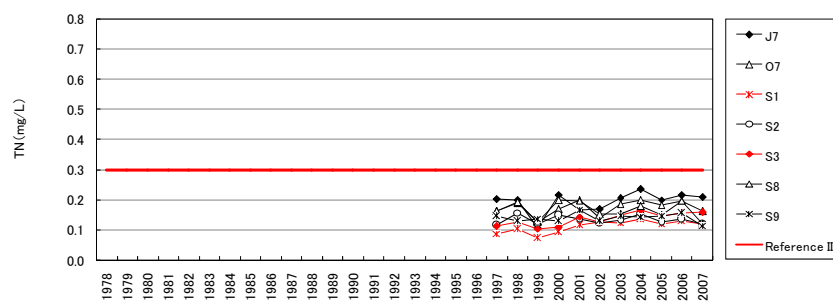

Fig. 4.15   TN concentration in Sub-area B

(6) TP concentration

Within seven stations, two stations (S1 and S3) showed increasing trends in annual mean of TP concentration. Other five stations (J7, O7, S2, S8 and S9) showed no trend. The mean TP concentration of the recent three years ranged between 0. 010-0.015 mg/L, and they were all below the reference value (0.03 mg/L). Therefore, the status and trend of TP concentration in Sub-area B was classified as 'Low eutrophication status and No trend.'
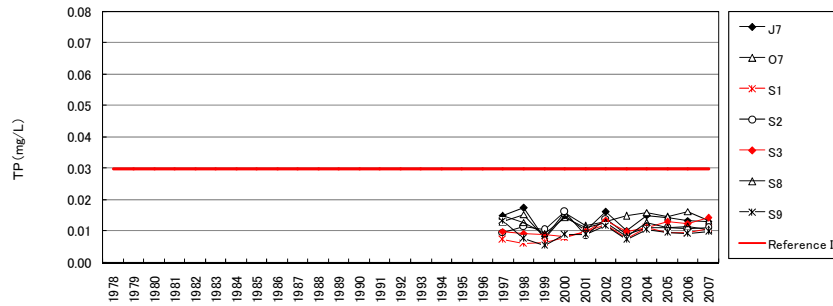
Fig. 4.16   TP concentration in Sub-area B

(7) Winter DIN concentration

There are two stations for assessing winter DIN concentration, and both stations showed no trends from 2000-2007. The mean concentration of winter DIN of the recent three years ranged between 0.05-0.10 mg/L, and they were all below the reference value (0.144 mg/L). Therefore, the status and trend of winter DIN concentration in Sub-area B was classified as "Low eutrophication status and No trend."
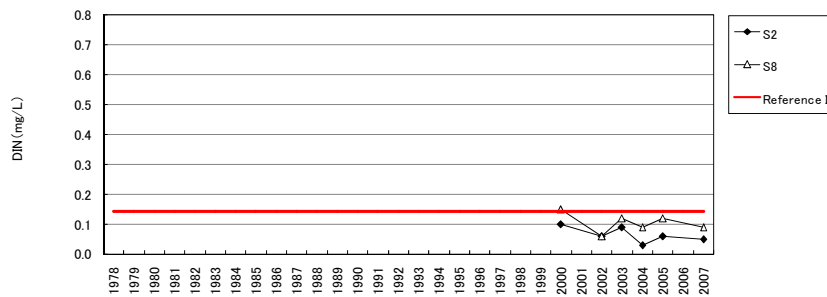
Fig. 4.17   Winter DIN concentration in Sub-area B

(8) Winter DIP concentration

There are also two stations for assessing winter DIP concentration, and both stations showed no trends from 2000-2007. The mean concentration of winter DIP ranged between 0.007-0.009 mg/L, and they were all below the reference value (0.017 mg/L). Therefore, the status and trend of winter DIN concentration in Sub-area B was classified as "Low eutrophication status and No trend."
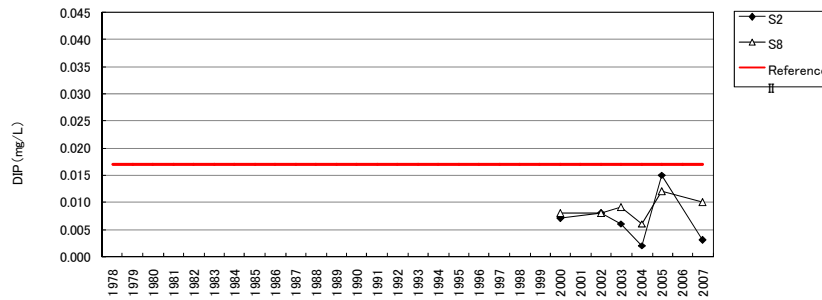

Fig. 4.18   Winter DIP concentration in Sub-area B

(9) Winter DIN/DIP ratio

There are also two stations for assessing winter DIN/DIP ratio, and both stations showed no trends from 2000 to 2007. The mean winter DIN/DIP ratio of the recent three years ranged between 25 and 26, and they exceeded the reference value of 16. Therefore, winter DIN/DIP ratio in Sub-area B was classified as 'High eutrophication status and No trend.' However, both 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.
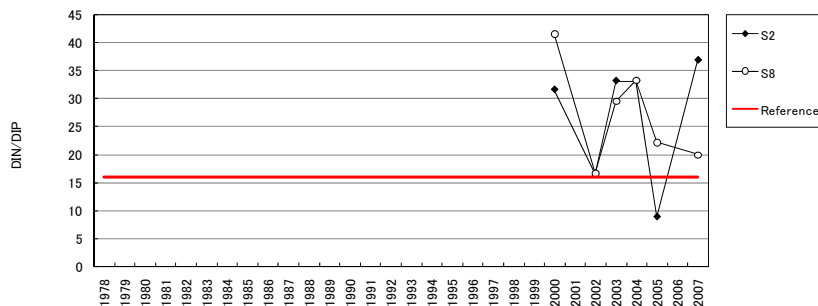

Fig. 4.19   Winter DIN/DIP ratio

Assessment results of Category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Data for the trend of annual maximum chlorophyll-*a* concentration is available in two stations between 1997 and 2007. Both stations showed no trend. Mean of annual maximum chlorophyll-*a* concentration of the recent three years ranged between 6.1-6.7 µg/L, and they were below the reference value (20 µg/L). Therefore, the status and trend of annual maximum chlorophyll-*a* concentration in Sub-area B was classified as "Low eutrophication status and No trend."
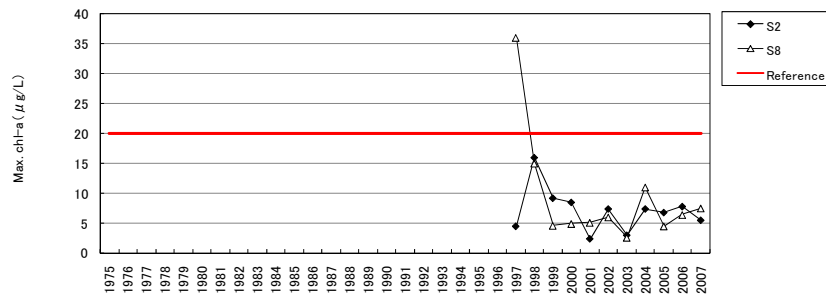

Fig. 4.20   Annual maximum chlorophyll-*a* concentration in Sub-area B

(11) Annual mean chlorophyll-*a* concentration

Two stations didn't show any trends in the annual mean chlorophyll-*a* concentration. The annual mean chlorophyll-*a* concentration of the recent three years ranged between 2.2-2.4 µg/L, and they were all below the reference value (5 µg/L). Therefore, the status and trend of the annual mean chlorophyll-*a* concentration in Sub-area B was classified as "Low eutrophication status and No trend."
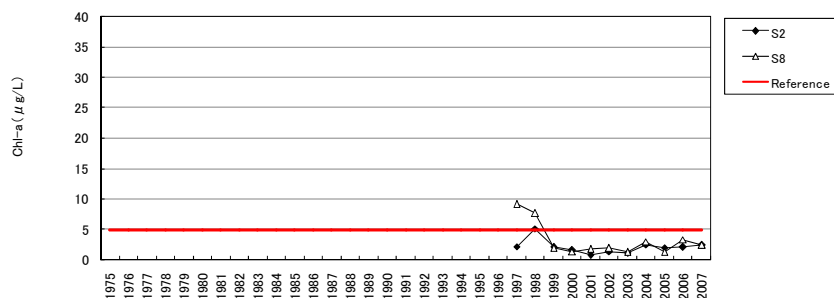

Fig. 4.21   Annual mean chlorophyll-*a* concentration in Sub-area B

(12) Red Tide (diatom sp.)

There were 0-9 events of diatom red tide in Sub-area B. The number was high from 1970s to 1980s. However, the number decreased since then, and no diatom red tide events were confirmed after 2004. Therefore, the status and trend of diatom red tide in Sub-area B was classified as 'Low eutrophication status and Decreasing trend.'
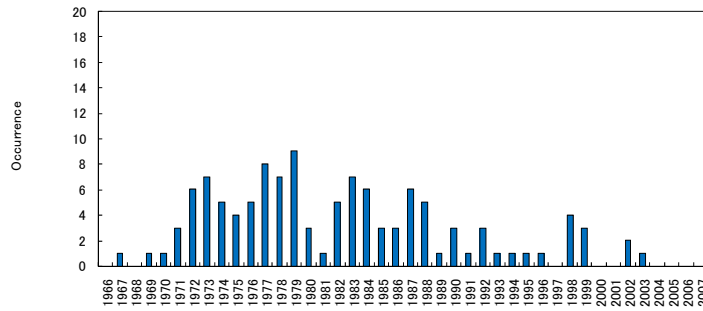
Fig. 4.22 Number of diatom red tide in Sub-area B

(13) Red tide (dinoflagellate sp.)

From 1966 to 2007, only one event of dinoflagellate red tide was confirmed in 1970 in Sub-area B. There was no trend in dinoflagellate red tide. Overall, the status and trend of dinoflagellate red tide in Sub-area B was classified as 'Low eutrophication status and No trend.'
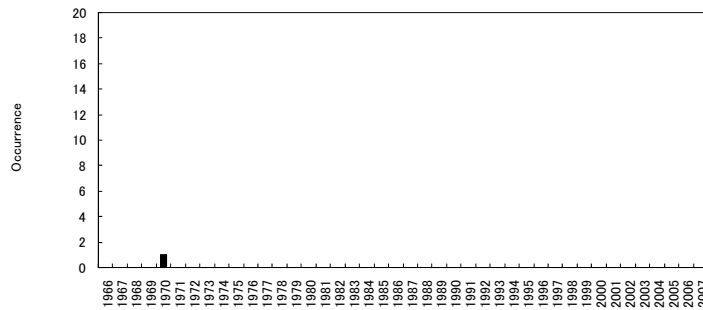
Fig. 4.23 Number of dinoflagellate red tide in Sub-area B

Assessment results in Category III parameters

(14) Dissolved oxygen (DO)

Within seven stations, three stations (S2, S8 and S9) showed decreasing trends in the annual minimum DO concentration. Other four stations (J7, O7, S1 and S3) showed no trends. The mean DO of the recent three years ranged between 6.5-7.0 mg/L, and all the stations exceeded 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 status and trend of annual mean DO concentration in Sub-area B was classified as 'Low eutrophication status and No trend.'
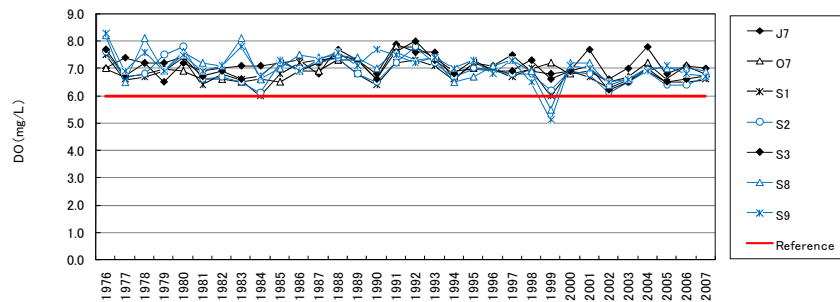

Fig. 4.24   DO concentration in Sub-area B

(15) Abnormal fish kill

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

(16) Chemical oxygen demand (COD)

Within seven stations, six stations (J7, O7, S1, S2, S3 and S9) showed increasing trends in the annual mean of COD concentration, and only one station (S8) didn't show any trend. The mean COD of the recent three years ranged between 1.3-1.8 mg/L, and all stations were below the reference value (3.0 mg/L). Therefore, the status and trend of COD concentration in Sub-area B was classified as 'Low eutrophication status and Increasing trend.'
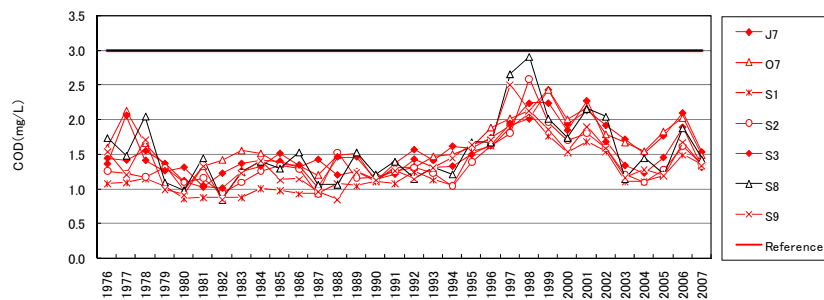

Fig. 4.25   COD concentration in Sub-area B

Assessment results of Category IV parameters

(17) Red Tide (*Noctiluca* sp.)

In Sub-area B, *Noctiluca* red tide occurred at a frequency of 0-3 times per year between 1966 and 2007. No trend was identified. Overall, the status and trend of *Noctiluca* red tide in Sub-area B was classified as 'Low eutrophication status and No trend.'
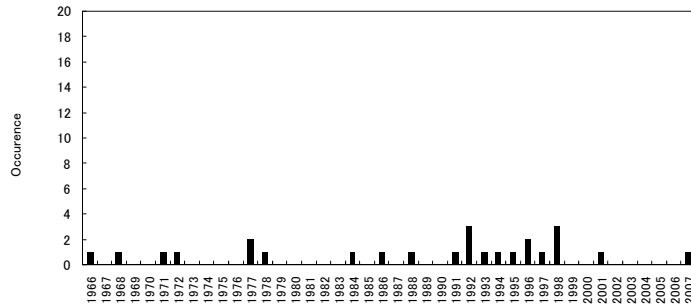

Fig. 4.26   Number of *Noctiluca* red tide in Sub-area B

(18) Shellfish poisoning

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

Assessment results of each assessment category

Table 4.3   Assessment results of each assessment category in Sub-area B (Intermediate Area)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
	Riverine input of TN	×	×	×	-	
	Riverine input of TP	×	×	×	-	
	Sewage plant input of TN	×	×	×	-	
	Sewage plant input of TP	×	×	×	-	
	TN concentration	L	×	N	LN	LN
	TP concentration	L	×	N	LN	
	Winter DIN concentration	L	×	N	LN	
	Winter DIP concentration	L	×	N	LN	
	Winter DIN/DIP ratio	H	×	N	HN*	
	Annual maximum of chlorophyll-*a*	L	×	N	LN	
	Annual mean of chlorophyll-*a*	L	×	N	LN	LN
	Red tide events (diatom sp.)	×	L	D	LD	
	Red tide events (dinoflagellate sp.)	×	L	N	LN	
	Dissolved oxygen (DO)	L	×	N	LN	
	Fish kill incidents	×	L	N	LN	LN
	Chemical oxygen demand (COD)	L	×	I	LI	
	Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	Shellfish 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.

Assessment results of Sub-area B (Intermediate Area)

Sub-area B (the intermediate area of Toyama Bay) is to the offshore side of Sub-area A (the coastal area of the bay), and it is considered that influences of eutrophication occurred in the coastal area spread to this area as any influence spreads to that directions.

Category I (degree of nutrient enrichment) parameters: No direct nutrient input from rivers or sewage treatment plants. Both TN and TP concentrations in this area satisfied the reference values respectively. However, they showed increasing trends at stations in the western part of the bay. The winter DIN and DIP concentrations satisfied the reference values respectively, and no trend was shown.

Category II (direct effects of nutrient enrichment) parameters: Both annual maximum and annual means of chlorophyll-*a* were below the reference values, but no trends were shown. The number of diatom red tide decreased from 1970s, and there were no events in the recent three years. There were also no events of dioflagellate red tide in the recent three years.

Category III (indirect effects of nutrient enrichment) parameters: DO concentrations in all stations exceeded the reference value, however, some stations showed decreasing trends. COD concentration satisfied the reference value, however, six stations out of seven showed decreasing trends.

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

Same as Sub-area A, all categories were classified as 'Low eutrophication status and No trend'. However, two stations (S1 and S3) located in the western part of the bay showed increasing trends in all TN and TP concentrations. So, it is possible that eutrophication expands. In addition, some stations showed decreasing trends of DO and increasing trends of COD. These trends were also shown in Sub-area A. Therefore, it is expected that implementation of countermeasures in Sub-area A can lead improvement of the marine environment of Sub-area B.

Table 4.4   Reasons behind classification of each assessment category
in Sub-area B (Intermediate Area)

Category	Reason	Classification
I Degree of nutrient enrichment	- TN and TP inputs from river and sewage treatment plant: It is considered that influences in Sub-area A are spreading to Sub-area B. - TN and TP concentrations: Low concentration, but no trend - Winter DIN and DIP concentrations: Low concentration, and no trend	LN
II Direct effects of nutrient enrichment	- Annual maximum and mean of chlorophyll-*a*: Low concentration, and no trend. - Diatom red tide: decreasing numbers, and no occurrences in the recent three years - Dinoflagellate red tide: Low occurrences and no occurrence in the recent three years	LN
III Indirect effects of nutrient enrichment	- DO: Relatively high concentration, but decreasing trends at some stations - COD: Low concentration, but increasing trends at some stations	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: Low occurrences - Shellfish poisoning: None	LN

4.3   Sub-area C (Offshore Area)

Assessment results of Category I parameters

(1) TN input from river

Because of the location (the offshore area of Toyama Bay), there are no rivers directly flowing into this area.

(2) TP input from river

Because of the location (the offshore area of Toyama Bay), there are no rivers directly flowing into this area.

(3) TN input from sewage treatment plant

Because of the location (the offshore area of Toyama Bay), there are no sewage treatment plants which directly input their water into this area.

(4) TP input from sewage treatment plant

Because of the location (the offshore area of Toyama Bay), there are no sewage treatment plants which directly input their water into this area.

(5) TN concentration

There are two survey stations in Sub-area C, and both stations showed no trends in TN concentration. The annual mean of TN concentration in the recent three years ranged between 0.11-0.12 mg/L, and they were below the reference value (0.3 mg/L). Therefore, the status and trend of TN concentration in Sub-area C was classified as 'Low eutrophication status and No trend.'

Fig. 4.27   TN concentration in Sub-area C

(6) TP concentration

Both stations didn't show any trends in the annual mean of TP concentration. The annual mean of TP concentration in the recent three years ranged between 0.008-0.009 mg/L, and they were below the reference value (0.03 mg/L). Therefore, the status and trend of TP concentration in Sub-area C was classified as 'Low eutrophication status and No trend.'
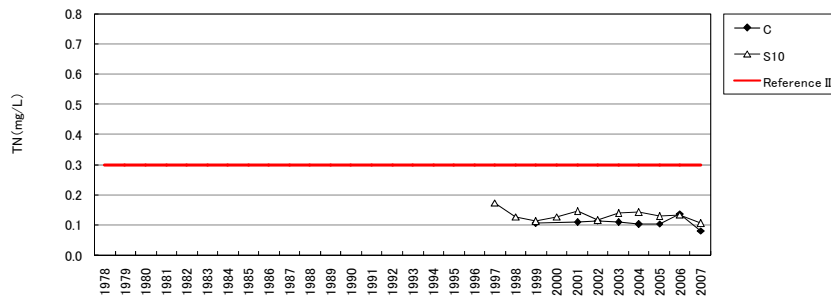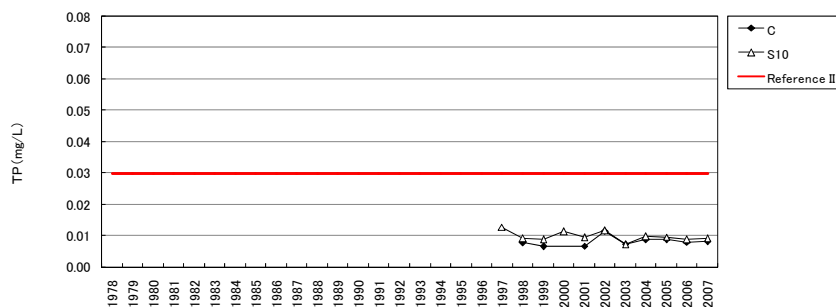

Fig. 4.28   TP concentration in Sub-area C

(7) Winter DIN concentration

Both stations didn't show any trends in winter DIN concentration. The annual mean of winter DIN concentration in the recent three years ranged between 0.06-.08 mg/L, and they were below the reference value (0.144 mg/L). Therefore, the status and trend of winter DIN concentration in Sub-area C was classified as 'Low eutrophication status and No trend.'
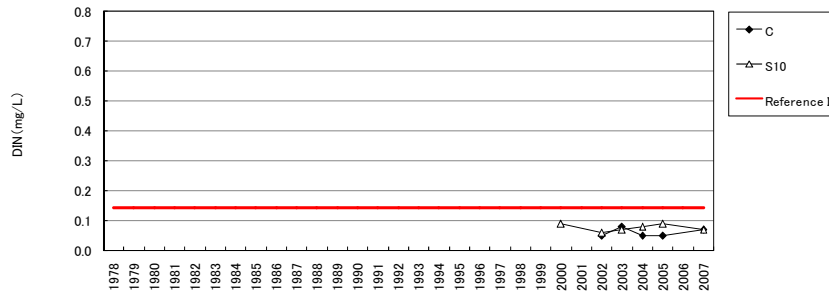

Fig. 4.29   Winter DIN concentration in Sub-area C

(8) Winter DIP concentration

Both stations didn't show any trends in winter DIP concentration. The annual mean of winter DIP concentration in the recent three years was 0.009 mg/L, and they were below the reference value (0.017 mg/L). Therefore, the status and trend of winter DIP concentration in Sub-area C was classified as 'Low eutrophication status and No trend.'
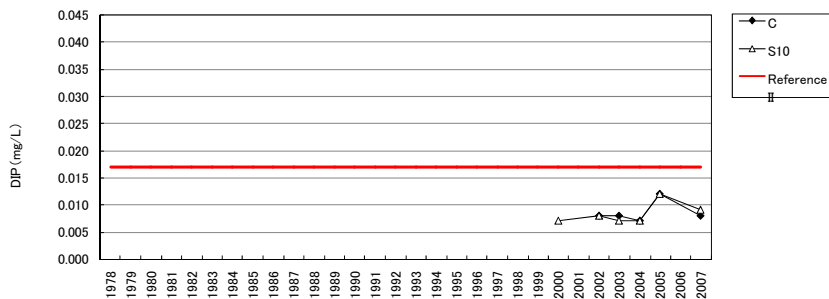

Fig. 4.30   Winter DIP concentration in Sub-area C

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(9) Winter DIN/DIP ratio

Both stations didn't show any trends in winter DIN/DIP ratio. The annual mean of winter DIN/DIP ratios of the recent three years ranged between 15 and 20. One station (S10) exceeded the reference value of 16. Overall, the status and trend of winter DIN/DIP ratio 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.
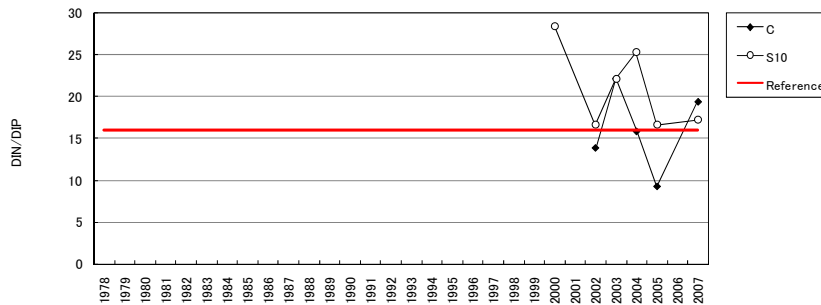

Fig. 4.31   Winter DIN/DIP ratio

Assessment results of Category II parameters
(10) Annual maximum chlorophyll-*a* concentration

Both stations didn't show any trends in the annual maximum chlorophyll-*a* concentration. The annual maximum in the recent three years ranged between 5.5-7.2 μg/L, and they were below the reference value (20 μmg/L). Therefore, the status and trend of annual maximum chlorophyll-*a* concentration in Sub-area C was classified as 'Low eutrophication status and No trend.'
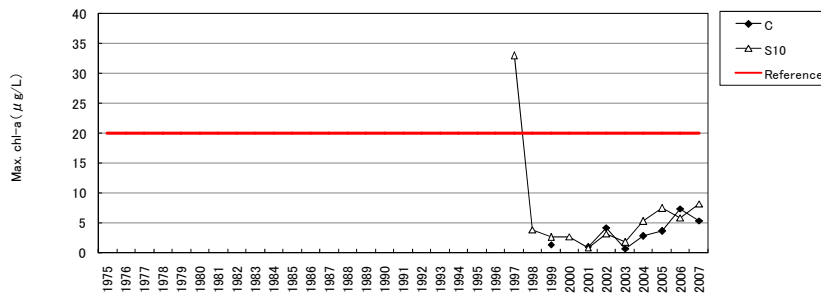

Fig. 4.32   Annual maximum chlorophyll-*a* in Sub-area C

(11) Annual mean chlorophyll-*a* concentration

Both stations didn't show any trends in annual mean chlorophyll-*a* concentration. The annual mean in the recent three years ranged between 1.3-1.9 µg/L, and they were below the reference value (5 µmg/L). Therefore, the status and trend of annual mean chlorophyll-*a* concentration in Sub-area C was classified as 'Low eutrophication status and No trend.'
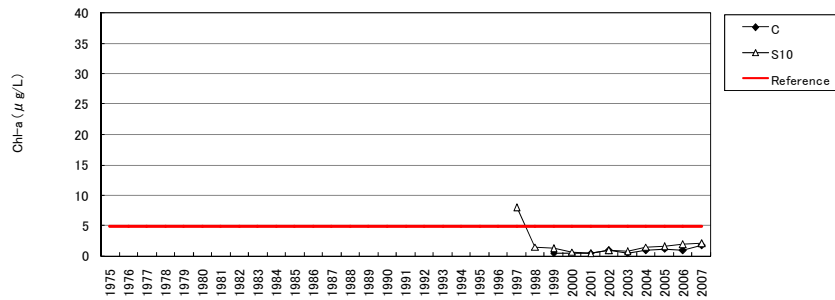

Fig. 4.33   Annual mean chlorophyll-*a* concentration in Sub-area C

(12) Red tide (diatom sp.)

The number of diatom red tide in Sub-area C ranged between 0-5 events per year. However, there were no events confirmed after 1997. No trend was identified. Therefore, the status and trend of diatom red tide in Sub-area C was classified as 'Low eutrophication status and No trend.'
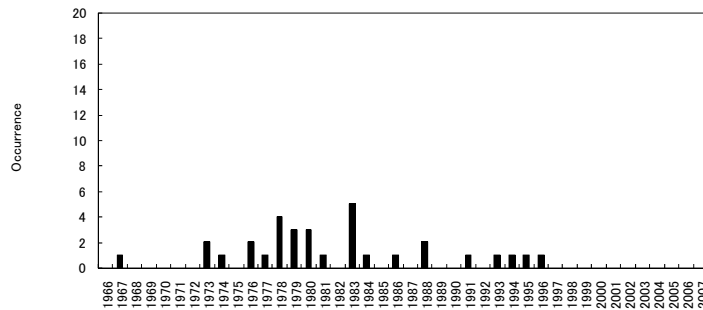

Fig. 4.34   Number of diatom red tide in Sub-area C

(13) Red tide (dinoflagellate sp.)

In Sub-area C, dinoflagellate red tide was not confirmed at all. Therefore, the status and trend of dinoflagellate red tide in Sub-area C was classified as 'Low eutrophication status and No trend.'

Assessment results of Category III parameters

(14) Dissolved oxygen (DO)

There were data for showing trends in the annual minimum DO at two stations (S10 and S). The station S10 showed decreasing trend while the station C has data only for four years. Therefore, the trend in C was not calculated. The annual mean of DO in the recent three years ranged between 6.5-6.9 mg/L, and they exceeded 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 status and trend of annual mean DO concentration in Sub-area C was classified as 'Low eutrophication status and Increasing trend.'

Fig. 4.35   DO concentration in Sub-area C

(15) Abnormal fish kill

Incidents of abnormal fish kill were not confirmed. Therefore, its status and trend in Sub-area C was classified as 'Low eutrophication status and No trend.'

(16) Chemical oxygen demand (COD)

There were data for showing trends in annual mean of COD at two stations (S10 and S). The station S10 showed increasing trend while the station C didn't show any trend. The annual mean of COD in the recent three years ranged between 1.2-1.4 mg/L, and they were below the reference value (3.0 mg/L). Therefore, the status and trend of annual mean COD concentration in Sub-area C was classified as 'Low eutrophication status and Increasing trend.'
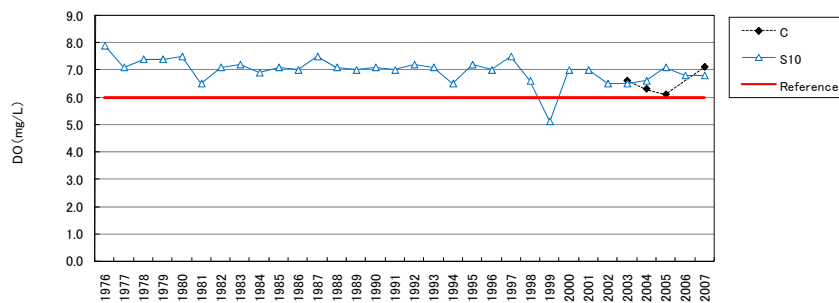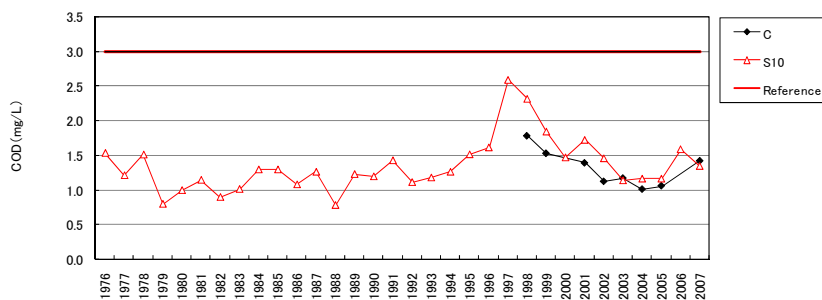
Fig. 4.36   COD concentration in Sub-area C

Assessment results of Category IV parameters

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

The number of *Noctiluca* red tide in Sub-area C ranged between 0-1 event per year, and no trend was identified. There were no events in the recent three years. Therefore, the status nad trend of *Noctiluca* red tide in Sub-area C was classified as 'Low eutrophication status and No trend.'
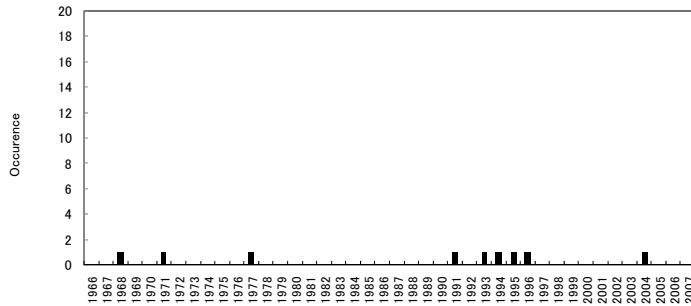

Fig. 4.37   Number of *Noctiluca* red tide in Sub-area C

(18) Shellfish poisoning

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

Assessment results of each assessment category

Table 4.5   Assessment results of each assessment category (Sub-area C)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Category identification
	Riverine input of TN	×	×	×	-	
	Riverine input of TP	×	×	×	-	
	Sewage plant input of TN	×	×	×	-	
	Sewage plant input of TP	×	×	×	-	
	TN concentration	L	×	N	LN	LN
	TP concentration	L	×	N	LN	
	Winter DIN concentration	L	×	N	LN	
	Winter DIP concentration	L	×	N	LN	
	Winter DIN/DIP ratio	H	×	N	HN	
	Annual maximum of chlorophyll-*a*	L	×	N	LN	
	Annual mean of chlorophyll-*a*	L	×	N	LN	LN
	Red tide events (diatom sp.)	×	L	N	LN	
	Red tide events (dinoflagellate sp.)	×	L	N	LN	
	Dissolved oxygen (DO)	L	×	I	LI	
	Fish kill incidents	×	L	N	LN	LI
	Chemical oxygen demand (COD)	L	×	I	LI	
	Red tide events (*Noctiluca* sp.)	×	L	N	LN	LN
	Shellfish poisoning incidents	×	L	N	LN	

Assessment results of Sub-area C (Offshore Area)

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

Category I (degree of nutrient enrichment) parameters: Concentrations of TN, TP, winter DIN and winter DIP were below the reference values respectively, and no trends were identified in any parameters.

Category II (direct effects of nutrient enrichment) parameters: Both annual maximum and mean of chlorophyll-*a* concentrations were below the reference values respectively, and no trends were identified. There were no events of diatom and dinoflagellate red tides in the recent three years.

Category III (indirect effects of nutrient enrichment) parameters: DO concentration exceeded the reference value, however, it showed decreasing trend. COD concentration was also below the reference value, however, it showed increasing trend.

Category IV (other possible effects of nutrient enrichment) 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 decreasing trend, and COD concentration showed 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 4.6   Reasons behind classification of each assessment category
in Sub-area C (Offshore Area)

Category	Reason	Classification
I Degree of nutrient enrichment	- TN and TP inputs from river and sewage treatment plant: No direct input - TN and TP concentrations and Winter DIN and DIP concentrations: Low concentration and no trend	LN
II Direct effects of nutrient enrichment	- The annual maximum and mean of chlorophyll-*a*: Low concentration, and no trend - Diatom and dinoflagellate red tides: No trend, and no occurrence in the recent three years	LN
III Indirect effects of nutrient enrichment	- DO: exceeding the reference standard while decreasing trend identified - COD: below the reference standard while increasing trend identified	LI
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: only one occurrence in the recent three years and low frequency - Shellfish poisoning: None	LN

5. Review and Validation of assessment results of Toyama Bay

Table 4.7 shows all of the results of Sub-area A, B and C in every Category.

With Category I (degree of nutrient enrichment) parameters, all sub-areas were classified as "Low eutrophication status" in 'comparison and occurrence' and "No trends".

In Category II (direct effects of nutrient enrichment), all sub-areas were also classified as "Low eutrophication status" in 'comparison and occurrence' and "No trend".

In category III (indirect effects of nutrient enrichment), all sub-areas were classified as "Low eutrophication status" in 'comparison and occurrence.' However, while Sub-areas A and B showed "No trend". Sub-area C showed increasing trend. This increasing trend caused by combination of decreasing trend of DO and increasing trend of COD.

In Category IV (other possible effects of nutrient enrichment), all sub-areas were classified as "Low eutrophication status" in 'comparison and occurrence' and "No trend".

Based on the overall classification results in Toyama Bay, as TN input from the Jinzu River was increasing trend, it is necessary to develop effective countermeasures against reduction of nutrient enrichment. In Sub-areas B and C, parameters for identifying eutrophication stayed in low levels, however, the influences of Sub-area A may be spreading to these adjacent areas. As a common trend in Sub-area A, B and C, decreasing DO and increasing COD were shown. Decreasing trend in DO concentration may be caused by decreasing of oxygen saturation concentration which occurs by temperature increase of seawater influenced by the global warming. On the other hand, increasing trend in COD may be led by internal production of COD occurring with increase of nutrient loads (Toyama Bay Water Quality Preservation Research Committee, 2001). Thus, it is necessary to address nutrient loads immediately.

Table 4.7   Assessment results of Toyama Bay by assessment category and sub-read

Category	Sub-area			Comment on category classification
	A	B	C	
I Degree of nutrient enrichment	LN	LN	LN	All sub-areas showed Low in 'comparison and occurrence' and No in `trend.'
II Direct effects of nutrient enrichment	LN	LN	LN	All sub-areas showed Low in 'comparison and occurrence' and No in 'trend.'
III Indirect effects of nutrient enrichment	LN	LN	LI	All sub-areas showed Low in 'comparison and occurrence.' Sub-area A showed increasing, and Sub-areas B and C showed No in 'trend.'
IV Other possible effects of nutrient enrichment	LN	LN	LN	All sub-areas showed low in 'comparison and occurrence' and No in 'trend.'

6. Conclusion and recommendation

Through the eutrophication assessment in Toyama Bay, it was concluded that the degree of eutrophication in the coastal, intermediate, and offshore areas of the bay were low in general. Many parameters didn't show any trends. TN input from Class-A rivers to the coastal area of the bay didn't show any trend either, however, the Jinzu River showed increasing trend. All of the sub-areas had stations which showed decreasing DO and increasing COD.

Therefore, in order to address negative effects of eutrophication on Toyama Bay, it is essential to pay close attention to TN input from the Jinzu River. According to Toyama Prefectural government (2008), the main sources of TN emission to this river are calculated: factories and plants (68%), domestic life (4%) and diffuse sources (28%). It means that for effective reduction of TN input, it is expected to develop countermeasures against emission from factories, plants and diffuse sources.

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