A Case Study Report on

Assessment of Eutrophication Status

in Northwest Kyushu sea area, Japan

Northwest Pacific Region

Environmental Cooperation Center

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Contents

Ⅰ Background and objective

In the NOWPAP region, large populations are concentrated along the coast of China, South Korea and Japan. Industrial and economic activities are also rapidly growing in these areas. In some coastal areas, there have been reports of significant increase in inputs of land-based sources of nutrients (e.g. nitrogen and phosphorus), which as a consequence is inducing eutrophication related environmental problems. Although eutrophication is a phenomenon that occurs naturally in lakes, ponds and other enclosed waters, nowadays eutrophication is also caused by human activities such as: excessive use of fertilizers; overfeeding in aquaculture farms; and discharge of treated/untreated sewage and industrial wastewater. These eutrophication events are causing reduction in dissolved oxygen and light penetration levels, red tide/harmful algae blooms, fish kills and so on. Ironically in some sea areas of Japan, the reduction of agricultural fertilizer usage and increase in advanced sewage treatment facilities have resulted in oligotrophication (i.e. lack of nutrients essential for ecosystem sustenance) during certain seasons.

In the NOWPAP region, eutrophication is no longer a problem within each country as the seas in the region is a common asset shared by all member countries. Hence, measures against eutrophication must be developed under a common international framework. In June 2009, members (Japan, China, South Korea and Russia) of the Northwest Pacific Action Plan (NOWPAP; adopted by UNEP in 1994), through the lead of Special Monitoring and Coastal Environment Assessment Regional Activity Centre (CEARAC) and inputs from experts of member countries, have developed a common procedures "Procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region (hereinafter abbreviated as 'the Common Procedures')" for assessing the eutrophication status of the NOWPAP region. In 2010, case studies were implemented on selected sea areas of each member countries to evaluate the validity of the Common Procedures.

For Japan, the Northwest Kyushu sea area and Toyama Bay were selected for the case studies, and their eutrophication status were assessed by using the Common Procedures. This report shows the results of the above case studies, which was implemented by Northwest Pacific Region Environmental Cooperation Center in 2010, under the support of the Ministry of Environment. Although Fukuoka and Toyama Prefectures provided data for the case studies, it does not necessarily imply that both prefectures and the relevant cities/towns are in agreement with the assessment results.

II Case study of Northwest Kyushu sea area

1. Scope of the assessment

1.1 Objective of the assessment

The Northwest Kyushu sea area encompasses Hakata Bay (including Imazu Bay) and Dokai Bay. Hakata Bay is located adjacent to Fukuoka City, which has a population of 1.45 million. Dokai Bay is located adjacent to Kitakyushu City (population: 0.98 million), which includes the Kitakyushu industrial zone. Both bays have been affected by eutrophication that was induced by nutrient inputs from anthropogenic sources. Domestically, the area is also one of the most sensitive areas to environmental changes in East China Sea and Yellow Sea, since the area is prone to impacts from the Tsushima Current. In order to restore the ecosystem of Hakata Bay, Fukuoka City developed the Hakata Bay environmental conservation plan, and is working on various environmental improvement projects. Kitakyushu City is also actively involved in various environmental improvement projects of Dokai Bay. The water quality of both bays has improved significantly compared to the levels in the 1960-1970s.

The case study of Northwest Kyushu sea area was implemented to assess objectively its eutrophication status with the Common Procedures, and at the same time, to evaluate the validity of the Common Procedures for eutrophication assessment. In the assessment, data on eutrophication-related parameters such as nutrient input, nutrient concentration, chlorophyll-*a* and red tide were collected, and their annual trends were analyzed.

1.2 Selection of assessment area

For the case study of Northwest Kyushu sea area, the assessment areas were selected based on the availability of past survey results on eutrophication status and eutrophication impacts (see Fig.1.1-1.4). The boundary of Northwest Kyushu sea area was set as approximately 40 km offshore from the shoreline between east of Kanmon bridge (eastern boundary) and Itoshima Peninsula (western boundary). For the case study, in addition to the vast amount of data collection required, it will be necessary to consult the related organizations prior to publicizing the results. To minimize these restrictions, the assessment was conducted only for the sea areas that are or have been covered by the environmental survey programs of Fukuoka Prefecture, which includes Hakata Bay, Dokai Bay, Kanmon Strait, Hibikinada and Genkainada. Karatsu Bay was excluded because it extends over both Fukuoka and Saga Prefectures.

The Northwest Kyushu sea area is located next to the coastal side of the eastern channel of Tsushima Strait. The coastline of this area is comprised of peninsulas (e.g. Itoshima and Wakamatsu Peninsulas) and semi-enclosed bays (e.g. Hakata Bay). In the east of Fukuoka Prefecture, lies the Dokai Bay, which is connected to Kanmon Strait. The Northwest Kyushu sea area receives nutrients from rivers (there are in total 34 rivers (e.g. Onga River) that flow into the area) and from anthropogenic sources such as factories, households and livestock farms.

Hakata Bay is a semi-enclosed bay (surface area: approx. 134.2 km^2, width of bay entrance: 7.7 km, max. depth: 23 m) and receives large quantities of nutrients from Fukuoka City (population: 1.45 million).

Dokai Bay is a narrow bay (width: several hundred meters, length: 13 km, avg. depth: approx. 7 m) located in Kitakyushu City, and connects to Kanmon Strait (a strait that connects the Seto Inland Sea and the Sea of Japan). The bay faces the Kitakyushu Industrial Zone, where dredging and landfill activities were repeatedly conducted at its industrial port. The development of heavy industries in the 1960s resulted in water pollution, and the bay was one of the most eutrophicated in Japan.

The sea areas facing the Tsushima Strait is called Genkainada and Hibikinada. While 10 rivers directly flow into this area, inflow from Onga River predominates.

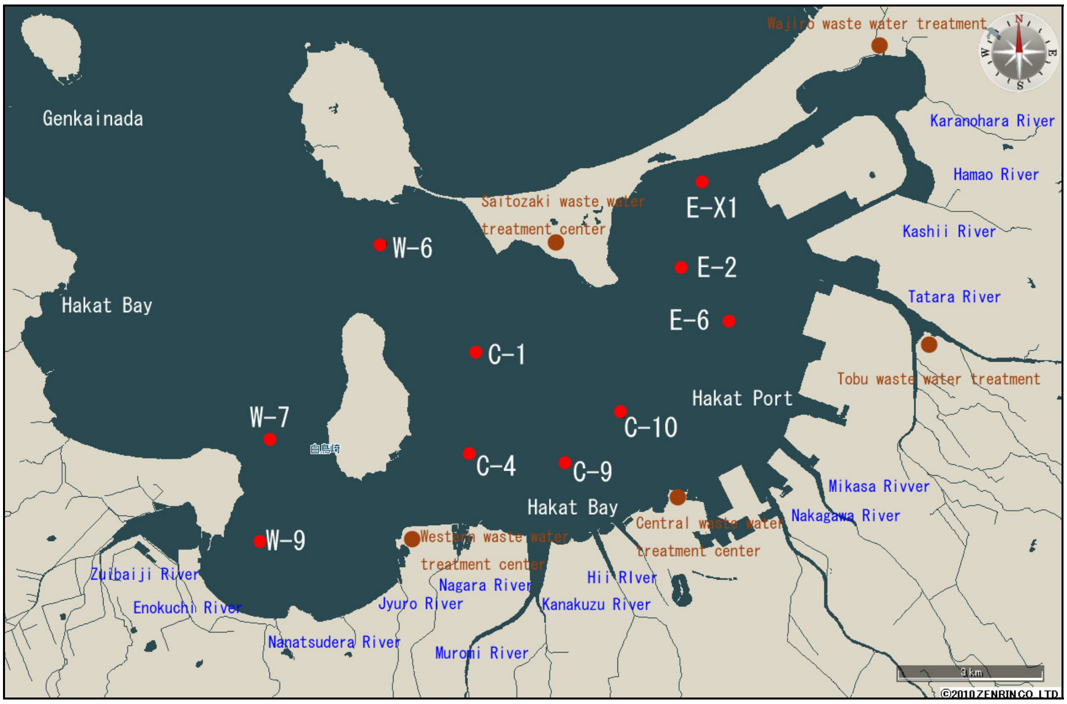

Fig. 1.1 Sub-area A of Northwest Kyushu sea area

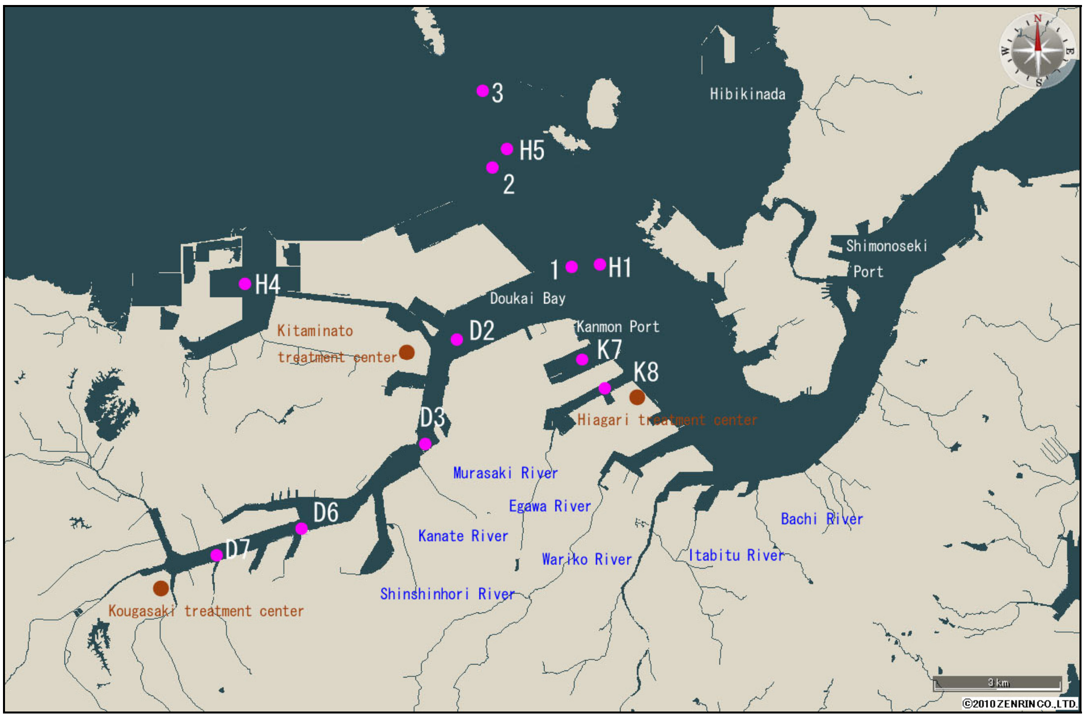

Fig. 1.2 Sub-area B of Northwest Kyushu sea area

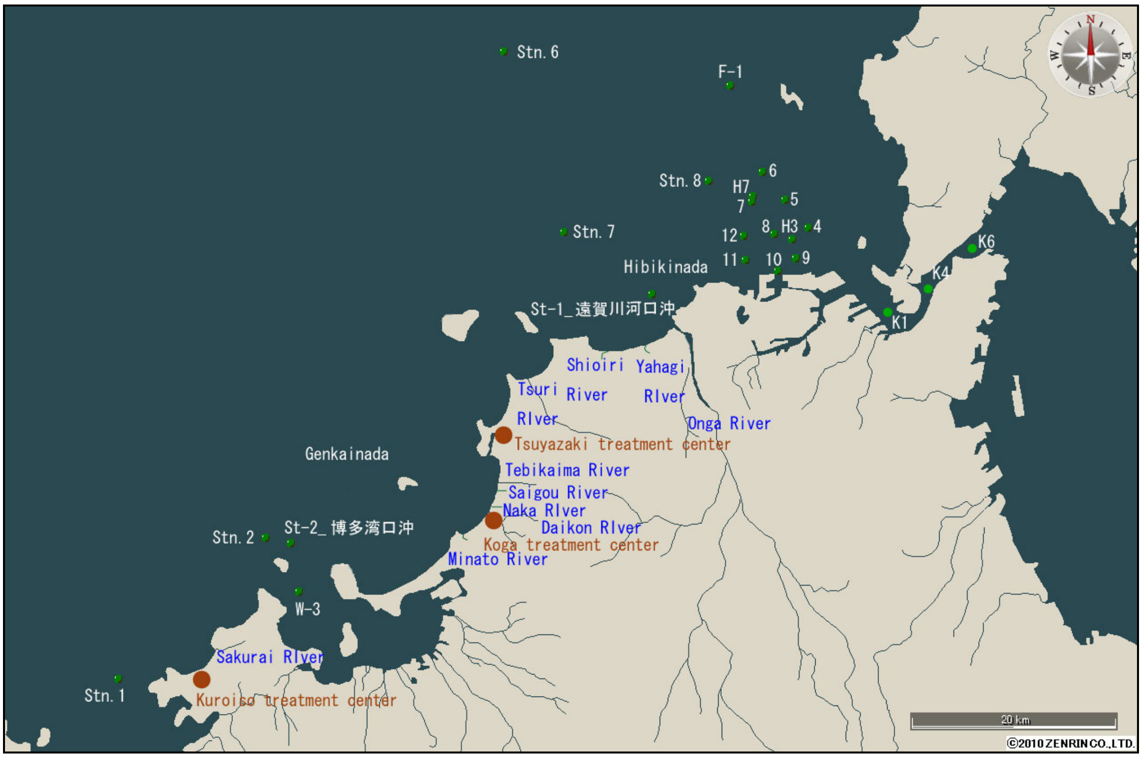

Fig. 1.3 Sub-area C of Northwest Kyushu sea area

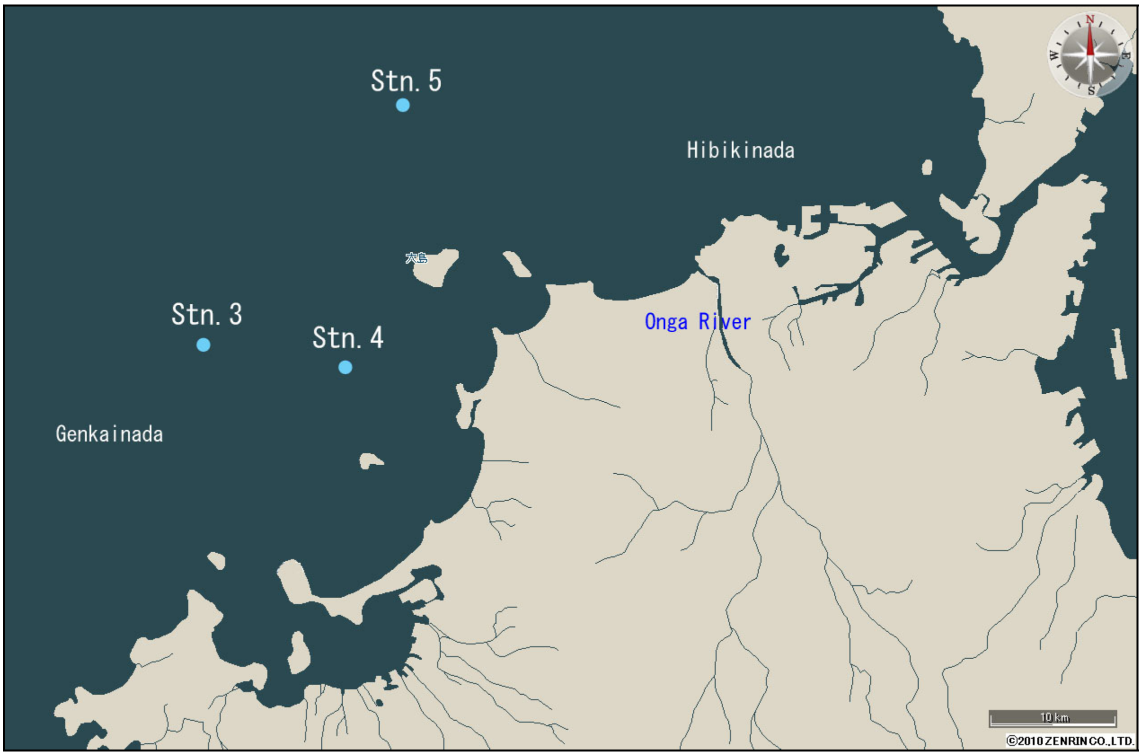

Fig.1.4 Sub-area D of Northwest Kyushu sea area

1.3 Collection of relevant information

Table 1.1 shows the information collected for the eutrophication assessment of Northwest Kyushu sea area.

Table 1.1 Information collected for the eutrophication assessment of Northwest Kyushu sea area

Survey type	Responsible organization	Survey name	Objective	Survey period	Main survey parameters	Survey frequency
Water quality monitoring by environmental authorities	Environmental Conservation Section, Environmental Bureau, Fukuoka Prefecture	Water quality survey of public waters	Regular monitoring of water quality status	1978-present (chlorophyll- *a*: 1981-present, DIN: 1978-1999, 2001-present)	Ph, BOD, COD, SS, DO, Coliform bacteria, general bacteria、n-Hex, TN, TP, NH_4-N, NO_2-N, NO_3-N, PO_4-P, chlorophyll- *a*, TOC, etc.	1-25/year
Environmental survey/research	Ministry of Environment	Monitoring survey of ocean environment	Monitoring of seawater pollution status	Chlorophyll- *a* and DO: 1998, 2001, 2004 DIN and DIP: 1996, 1998, 2001, 2004	Water temp., salinity, DO, nutrients, chlorophyll- *a*, pheophytin, boron, fluorine, etc.	1/year
Water pollution monitoring by fisheries authorities	Fukuoka Fisheries and Marine Technology Research Center	Fixed-line survey of shallow waters	Monitoring of ocean status between Nansei Islands and west of Japan Sea	1972-present (TN and TP: 1995-1997, chlorophyll- *a*: 1975-present)	NH_4-N, NO_2-N, NO_3-N, PO_4-P, DO, COD, chlorophyll- *a*	1-12/year
	Kyushu Fisheries Coordination Office, Fisheries Agency	Red-tide survey	Recording of red-tide incidents	1978-present	Red-tide status and duration, damage to fisheries	When red tide occurs
	Food Safety Promotion Section, Public Health & Welfare Bureau, Fukuoka City	Report on food-poisoning incidents	Monitoring of food-poisoning status	1970-present	Date, place, cause, facility of food-poisoning	When food poisoning occurs

1.4 Selection of assessment parameters

1.4.1 Assessment categories of Northwest Kyushu sea area case study

Based on the Common Procedures, the parameters used for the eutrophication assessment were categorized into the four assessment categories shown in Table 1.2.

Table 1.2 Assessment categories of the Northwest Kyushu sea area 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 the Northwest Kyushu sea area case study

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

Table 1.3 Assessment parameters used for the Northwest Kyushu sea area 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-area

The Northwest Kyushu sea area was divided into sub-areas by using the results of the preliminary eutrophication assessment, which was conducted with satellite data (see Fig. 1.5 for the results). The Northwest Kyushu sea area is connected to the Seto Inland Sea through the Kanmon Strait. Small bays such as Dokai Bay, Hakata Bay, Karatsu Bay are located on the side of the Sea of Japan. Along the coast of Hakata Bay is Fukuoka City, the capital of Fukuoka Prefecture. Kitakyushu City is located along the coast between Dokai Bay and Kanmon Strait.

Chlorophyll-*a* concentration was high (>5 μg/L) in Hakata Bay and Dokai Bay, and showed an increasing trend in some areas. Although chlorophyll-*a* concentration was low (<5 μg/L) in the adjacent offshore waters, trend wise, chlorophyll-*a* concentrations were increasing in some areas. Further offshore, chlorophyll-*a* concentration was low and showed no trend. For this case study, based on the results of the preliminary eutrophication assessment and geographic factors (e.g. sea boundary), the assessment area was divided into four sub-areas: A (Hakata Bay), B (Dokai Bay), C (intermediate area: area with low chlorophyll-*a* concentration (<5 μg/L) but increasing trend) and D (offshore area: area with low chlorophyll-*a* concentration but no trend). Fig. 1.6 shows the boundary of each sub-area. Kanmon Strait was included into the intermediate area (sub-area C). Although the offshore waters of Tsushima Strait showed some increasing trend in chlorophyll-*a* concentration (albeit low concentration), the area was not included in the assessment as it was not possible to obtain relevant field data of that area.

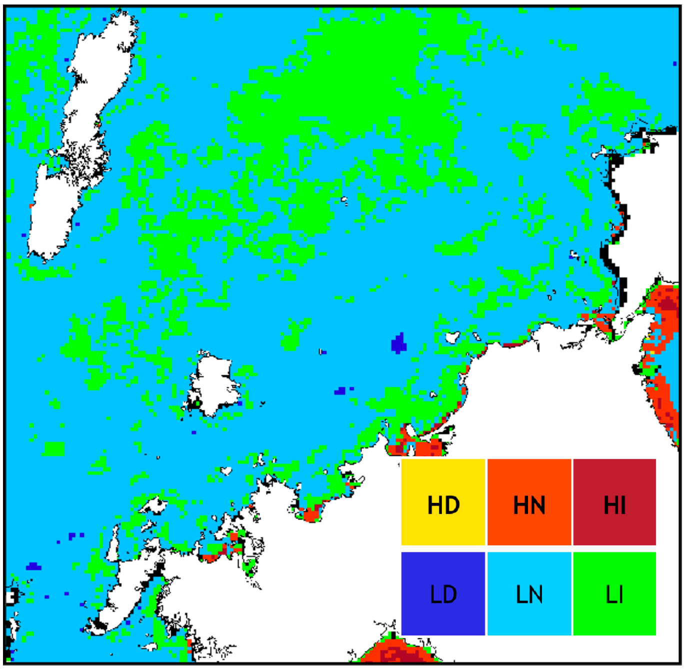

Fig. 1.5　Results of the preliminary eutrophication assessment of Northwest Kyushu sea area

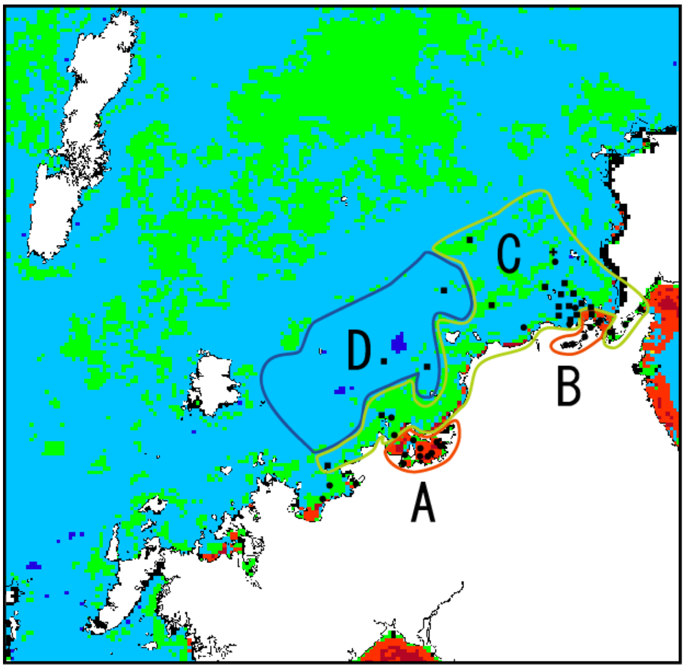

Fig. 1.6　Boundaries of the sub-areas of Northwest Kyushu sea area

A: Hakata Bay, B: Dokai Bay, C: intermediate area, D: offshore area

Table 1.4 List of data collection points

Sub-area	Station name	Station no.	Latitude	Longitude	Survey title
A Hakata Bay	E-2	40-611-01	33°38'37"	130°22'43"	Water quality survey of public waters
	E-6	40-611-03	33°38'00"	130°23'21"	
	E-X1	40-611-65	33°39'35"	130°23'01"	
	C-1	40-612-01	33°37'40"	130°19'52"	
	C-4	40-612-02	33°36'30"	130°19'47"	
	C-10	40-612-03	33°36'57"	130°21'54"	
	C-9	40-612-53	33°36'25"	130°21'08"	
	W-6	40-613-02	33°38'52"	130°18'36"	
	W-7	40-613-03	33°36'40"	130°17'03"	
	W-9	40-613-54	33°35'31"	130°16'55"	
B Dokai Bay	D6	40-601-01	33°53'01"	130°47'01"	
	D3	40-601-51	33°54'08"	130°49'01"	
	D7	40-601-54	33°52'47"	130°45'42"	
	K7	40-602-01	33°55'16"	130°51'31"	
	K8	40-603-01	33°54'51"	130°51'51"	
	D2	40-604-01	33°55'30"	130°49'30"	
	H1	40-605-01	33°56'25"	130°51'51"	
	H4	40-605-53	33°56'03"	130°46'21"	
	H5	40-605-02	33°57'54"	130°50'15"	
	1	—	33°56'12"	130°51'30"	Fixed-line survey of shallow waters
	2	—	33°57'30"	130°50'17"	
	3	—	33°58'30"	130°50'06"	
C Intermediate area	H3	40-605-52	33°58'24"	130°47'27"	Water quality survey of public waters
	H7	40-605-55	34°00'42"	130°44'51"	
	K1	40-616-51	33°54'48"	130°53'34"	
	K4	40-616-53	33°55'54"	130°56'12"	
	K6	40-616-54	33°58'06"	130°58'57"	
	W-3	40-613-01	33°39'38"	130°15'11"	
	St-1 Offshore of Onga rivermouth	40-615-01	33°55'30"	130°38'16"	
	St-2 Offshore of mouth of Hakata Bay	40-615-02	33°42'12"	130°14'40"	
	4	—	33°59'00"	130°48'30"	Fixed-line survey of shallow waters
	5	—	34°00'30"	130°47'00"	
	6	—	34°02'00"	130°45'30"	
	7	—	34°00'24"	130°44'47"	
	8	—	33°58'42"	130°46'17"	
	9	—	33°57'23"	130°47'42"	
	10	—	33°56'42"	130°46'30"	
	11	—	33°57'17"	130°44'23"	
	12	—	33°58'36"	130°44'17"	
	Stn.1	—	33°35'00"	130°03'24"	
	Stn.2	—	33°42'30"	130°13'00"	
	Stn.6	—	34°08'24"	130°28'36"	
	Stn.7	—	33°58'47"	130°32'30"	
	Stn.8	—	34°01'30"	130°42'00"	
	F-1	—	34°06'35"	130°43'23"	Monitoring survey of ocean environment
D Offshore area	Stn.3	—	33°50'30"	130°13'24"	Fixed-line survey of shallow waters
	Stn.4	—	33°49'36"	130°21'00"	
	Stn.5	—	34°01'00"	130°24'00"	

Table 1.5 Water use types of 'Environmental water quality standard' applied for each survey station

Sub-area	Station name	Total nitrogen	Total phosphorus	Note
A Hakata Bay	E-2	III (0.6 mg/L)	III (0.05 mg/L)	
	E-6			
	E-X1			
	C-1			
	C-4			
	C-10			
	C-9			
	W-6	II (0.3 mg/L)	II (0.03 mg/L)	
	W-7			
	W-9			
B Dokai Bay	D6	IV (1.0 mg/L)	IV (0.09 mg/L)	
	D3			
	D7			
	K7			
	K8			
	D2			
	H1	II (0.3 mg/L)	II (0.03 mg/L)	
	H4			
	H5			
	K1			
	K4			
	K6			
	1	II (0.3 mg/L)	II (0.03 mg/L)	
	2			
	3			
C Intermediate area	H3	II (0.3 mg/L)	II (0.03 mg/L)	
	H7			
	K1			
	K4			
	K6			
	W-3			
	St-1 Offshore of Onga rivermouth			
	St-2 Offshore of mouth of Hakata Bay			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	Stn.1			
	Stn.2			
	Stn.6			
	Stn.7			
	Stn.8			
	F-1			
D Offshore area	Stn.3	II (0.3 mg/L)	II (0.03 mg/L)	
	Stn.4			
	Stn.5			

2. Data processing

Eutrophication related information/data were collected from the following organizations: Ministry of the Environment; Kyushu Fisheries Coordination Office, Fisheries Agency; Environmental Conservation Section, Environmental Bureau, Fukuoka Prefecture; Fukuoka Fisheries and Marine Technology Research Center; and Food Safety Promotion Section, Public Health & Welfare Bureau, Fukuoka City. Data screening was not conducted in this case study, as the collected data were administrative data, and hence unreliable data were assumed to have been screened prior to publication.

Table 2.1-2.2 shows the data processing methodologies applied for each assessment parameter. Table 2.3 shows the laboratory analysis method of chemical assessment parameters.

Table 2.1 Data processing methodologies applied for the Northwest Kyushu sea area case study (category I)

	Assessment parameter	Data processing methodology
I	(1) TN input from river	Annual TN input was calculated by multiplying the annual mean TN concentration with annual discharge volume. The annual mean TN concentration was calculated by using the monthly data of 'water quality survey of public waters'. The trend of the annual TN input from the rivers was analyzed for the period from 1985 to 2007.
	(2) TP input from river	Annual TP input was calculated by multiplying the annual mean TP concentration with annual discharge volume. The annual mean TP concentration was calculated by using the monthly data of 'water quality survey of public waters'. The trend of the annual TP input from the rivers was analyzed for the period from 1985 to 2007.
	(3) TN input from sewage treatment plant	Annual TN input was calculated by multiplying the annual mean TN concentration with annual discharge volume. Data on TN concentration and discharge volume was collected from sewage statistic. TN and discharge volume are measured from 1995 and 1982 respectively. The trend of the annual TN input from the sewage treatment plants was analyzed for the period from 1995 to 2007.
	(4) TP input from sewage treatment plant	Annual TP input was calculated by multiplying the annual mean TP concentration with annual discharge volume. Data on TP concentration and discharge volume was collected from sewage statistic. TP and discharge volume are measured from 1995 and 1982 respectively. The trend of the annual TP input from the sewage treatment plants was analyzed for the period from 1995 to 2007.
	(5) TN concentration	Annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters' and 'fixed-line survey of shallow 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 1978 to 2007 was also analyzed.
	(6) TP concentration	Annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters' and 'fixed-line survey of shallow 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 1978 to 2007 was also analyzed.
	(7) Winter DIN concentration	Winter mean value was calculated by averaging the monthly data of three winter months (Jan.-Mar.). Data was acquired from the 'water quality survey of public waters' and 'fixed-line survey of shallow waters'. Reference value was set based on the relationship between TN and DIN. The mean value of the recent three years (2005-2007) was compared with the reference value. The trend of the winter mean value from 1972 to 2007 was also analyzed.
	(8) Winter DIP concentration	Winter mean value was calculated by averaging the monthly data of three winter months (Jan.-Mar.). Data was acquired from the 'water quality survey of public waters' and 'fixed-line survey of shallow waters'. Reference value was set based on the relationship between TP and DIP. The mean value of the recent three years (2005-2007) was compared with the reference value. The trend of the winter mean value from 1972 to 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. The trend of the winter mean value from 1972 to 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 value.

Table 2.2 Data processing methodologies applied for the Northwest Kyushu sea area case study (categories II-IV)

	Assessment parameter	Data processing methodology
II	(10) Annual maximum chlorophyll-*a* concentration	Annual maximum value was determined by the selecting maximum value of the monthly data of the 'water quality survey of public waters', 'fixed-line survey of shallow waters' and 'monitoring survey of ocean environment'. 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 1975 to 2007 was also analyzed.
	(11) Annual mean chlorophyll-*a* concentration	Annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters', 'fixed-line survey of shallow waters' and 'monitoring survey of ocean environment'. 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 1975 to 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 Kyushu Fisheries Coordination Office. The total number of diatom red tide in the recent three years was compared with the reference value. The trend of diatom red tide was analyzed from 1978 to 2007.
	(13) Red tide (dinoflagellate sp.)	The number of dinoflagellate red tide was counted by referring to the red tide survey of Kyushu Fisheries Coordination Office. The total number of dinoflagellate red tide in the recent three years was compared with the reference value. The trend of dinoflagellate red tide was analyzed from 1978 to 2007. *Noctiluca* sp. was not included.
III	(14) Annual minimum DO concentration	Annual minimum value was determined by selecting the minimum value of the monthly data of the 'water quality survey of public waters', 'fixed-line survey of shallow waters' and 'monitoring survey of ocean environment'. 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 1972 to 2007 was also analyzed.
	(15) Abnormal fish kill	The number of abnormal fish kill was counted by referring to the data collected by Fukuoka Prefecture. The total number of abnormal fish kill in the recent three years was compared with the reference value. The trend of abnormal fish kill was analyzed from 1970s to 2007.
	(16) COD	Annual mean value was calculated by averaging the twelve monthly data acquired through the 'water quality survey of public waters' and 'fixed-line survey of shallow 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 1972 to 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 Kyushu Fisheries Coordination Office. The total number of *Noctiluca* red tide in the recent three years was compared with the reference value. The trend of *Noctiluca* red tide was analyzed from 1978 to 2007.
	(18) Shellfish poisoning	The number of shellfish poisoning was counted by referring to the data collected by Fukuoka Prefecture. The total number of shellfish poisoning in the recent three years was compared with the reference value. The trend of shellfish poisoning was analyzed from 1970s to 2007.

Table 2.3 Analysis method of chemical assessment parameters

Category	Assessment parameter		Analysis method used in the 'Water quality survey of public waters'
I	TN concentration		Methods stipulated in 45.1, 45.2, 45.3 or 45.4 of JIS K0102.
	TP concentration		Method stipulated in 46.3 of JIS K0102.
	DIN	Ammonia nitrogen	-
		Nitrate nitrogen	Methods stipulated in 43.2.1, 43.2.3 or 43.2.5 of JIS K0102.
		Nitrite nitrogen	Methods stipulated in 43.1 of JIS K0102.
	DIP		-
II	Chlorophyll-*a* concentration		-
III	DO		Winkler sodium azide modification method
	COD		Methods stipulated in 17 of JIS K0102 (potassium permanganate method)

3. Setting of assessment criteria

3.1 Setting of reference standard

There are two types of water quality standards that can be applied for the eutrophication assessment in Japan namely: 'Environmental water quality standard' and 'Fisheries water quality standard' (see Table 3.1).

For the case study of Northwest Kyushu sea area, reference values were set for each assessment parameter by referring to the above water quality standards (see Table 3.2). For total nitrogen (TN) and total phosphorus (TP), the 'Environmental water quality standard' was applied. Note that in the 'Environmental water quality standard', different water quality standards are applied depending on the type of water use. The pre-designated 'Environmental water quality standard' was applied for the survey stations of the 'Water quality survey of public water'. The 'Environmental water quality standard' for Type II water use was applied for the survey stations of other surveys. The 'Fisheries water quality standard' was applied for DO. The 'Environmental water quality standard' for Type B water use was applied for COD. 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 the Northwest Kyushu sea area. Based on the identified relationship, the reference value of DIN (DIP) was calculated for each 'Environmental water quality standard' of TN (TP) (see Fig.s 3.1 and 3.2). The reference values of annual maximum/mean chlorophyll-*a* concentration 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 3.3).

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 ($COD_{OH} \fallingdotseq 0.6 \times COD_{MN}$)

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 Northwest Kyushu sea area 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 (Reference II)
		0.6 mg/l	Environmental water quality standard Type III (Reference III)
		1.0 mg/l	Environmental water quality standard Type IV (Reference IV)
	(6) TP concentration	0.03 mg/l	Environmental water quality standard Type II (Reference II)
		0.05 mg/l	Environmental water quality standard Type III (Reference III)
		0.09 mg/l	Environmental water quality standard Type IV (Reference IV)
	(7) Winter DIN concentration	0.169 mg/l	Correspond to 'Environmental water quality standard' Type II[1)]
		0.338 mg/l	Correspond to 'Environmental water quality standard' Type III
		0.562 mg/l	Correspond to 'Environmental water quality standard' Type IV
	(8) Winter DIP concentration	0.011 mg/l	Correspond to 'Environmental water quality standard' Type II[2)]
		0.017 mg/l	Correspond to 'Environmental water quality standard' Type III
		0.029 mg/l	Correspond to 'Environmental water quality standard' Type IV
	(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/3 year	
	(13) Red tide (dinoflagellate sp.)	1 event/3 year	
III	(14) DO	6.0 mg/l	Fisheries water quality standard
	(15) Abnormal fish-kill	1 event/3 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/3 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)

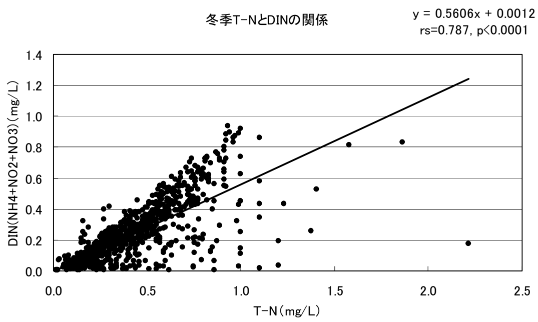

Fig. 3.1 Relationship between winter TN and DIN in the Northwest Kyushu sea area

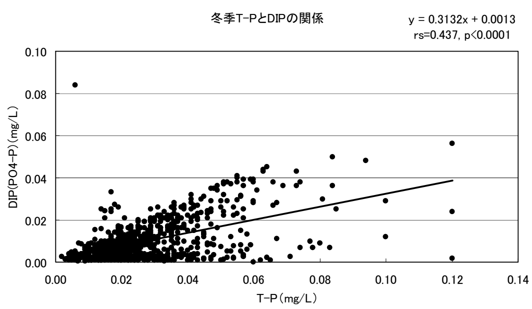

Fig. 3.2 Relationship between winter TP and DIP in the Northwest Kyushu sea area

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) was compared with the reference value 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 to 2007. The survey station in the sub-area was classified as 'High' when the three-year mean value 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 the sub-area were classified as 'High'; and 'Low' if less than 50% of the survey stations in the 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 values were above the reference value, and 'High' when the values were 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, their status were rated as 'High' when one or more incidents occurred 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 was assessed separately under category IV '(17) Red tide (*Noctiluca* sp.)'. The status of '(17) Red tide (*Noctiluca* sp.)' was rated as 'High' when three or more incidents occurred in the past three years, and 'Low' if less than three incidents occurred. This criterion was applied because 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 lower risk of misinterpreting the eutrophication status of '(17) Red tide (*Noctiluca* sp.)' if the criterion of 'three events in three years'' is applied, since a past event may not solely have been caused by eutrophication.

The 'trend' tool was used to analyze the yearly trends of the assessment parameters. The trend was analyzed by using the non-parameteric method of Mann-Kendall. Calculation was conducted wih MAKESENS (Salmi *et al*., 2002). The results were indicated by red, blue and black lines when the trend analysis showed, at a 5% level, significant increasing, significant decreasing and no significant, respectively. Trend analysis was not conducted with survey stations that had less then five years of data; in such case their values were indicated in the graph with dotted lines. The most dominant trend in the sub-area was considered to represent the trend of the respective assessment parameter.

Table 3.4 shows the combination of identification tools applied for each assessment parameter. For most parameters, assessment 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 determined by selecting the classifications that occurred most frequently with the 'comparison/occurrence' tools (H or L) and 'trend' tool (I, N or D). In case the above frequency was equivalent, the status of the category was classified with a range (e.g. HD-HN).

Table 3.4 The identification tools applied for the assessment parameters of the Northwest Kyushu sea area 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				

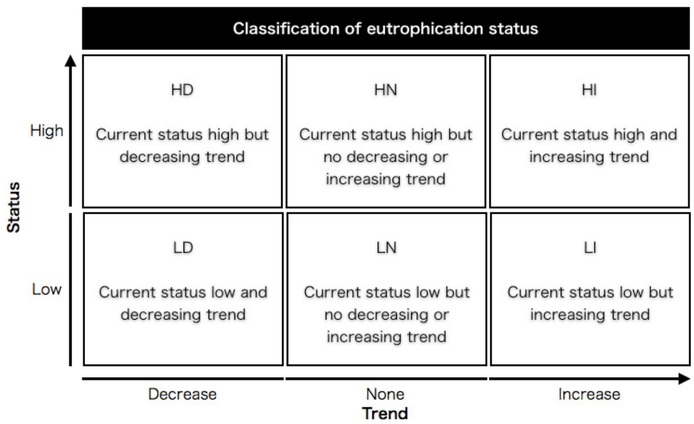

Fig. 3.3 The six classification categories stipulated in the Common Procedures (for 'status' and 'trend')

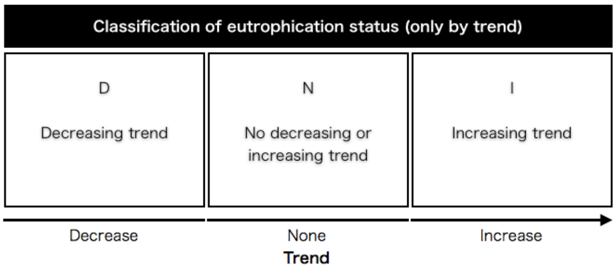

Fig. 3.4 The three classification categories stipulated in the Common Procedures (for 'trend' only)

4. Results

4.1 Sub-area A (Hakata Bay)

Assessment results of category I parameters

(1) TN input from river

There are thirteen rivers that discharge into sub-area A (Naka River, Mikasa River, Tatara River, Hii River, Muromi River+Kanakuzu River, Nagara River, Jyuro River, Zuibaiji River, Karanohara River, Nanatsudera River, Enokuchi River, Hamao River and Kashii River). The sum of TN input from these rivers has decreased from 5,385 ton/year to 2,207 ton/year during the period from 1993 to 2007. Within the thirteen rivers, inputs from Mikasa River and Tatara River contributed to 57-83% of the sum of TN input. Within the thirteen rivers, TN input from eleven rivers showed a decreasing trend. No trend was identified with Tatara River and Zuibaiji River. Since the total TN input from the rivers showed a decreasing trend, the trend of TN input from the rivers of sub-area A was classified as 'Decreasing trend'.

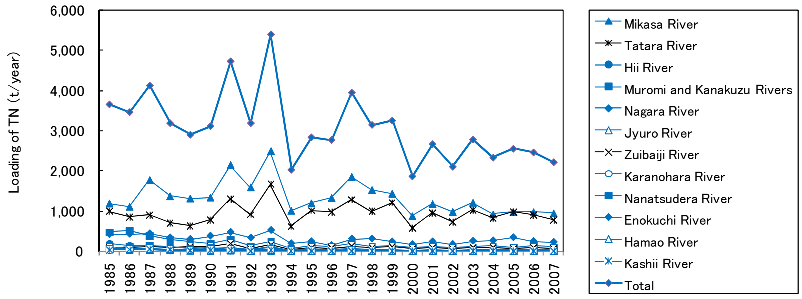

Fig. 4.1 TN input from the rivers of sub-area A

(2) TP input from river

The sum of TP input from the rivers of sub-area A has decreased from 375 ton/year to 129 ton/year during the period from 1993 to 2007. As it was the case with TN, inputs from Mikasa River and Tatara River dominated, contributing to 58-79% of the sum of TP input. Within the thirteen rivers, TP input from twelve rivers showed a decreasing trend. No trend was identified with Zuibaiji River. Since the sum of TP inputs from the rivers showed a decreasing trend, the trend of TP input from the rivers of sub-area A was classified as 'Decreasing trend'.

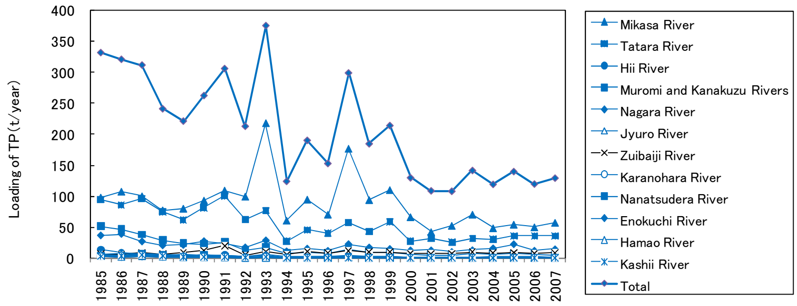

Fig. 4.2 TP input from the rivers of sub-area A

(3) TN input from sewage treatment plant

There are five sewage treatment plants that discharge directly into sub-area A (Western wastewater treatment center, Central wastewater treatment center, Eastern wastewater treatment center, Wajiro wastewater treatment center and Saitozaki wastewater treatment center). The sum of TN input from these plants ranged between 2,303-5,043 ton/year. TN input from the Central wastewater treatment center contributed to 58-80% of the sum of TN input. TN input from the Western wastewater treatment center showed an increasing trend. No trend was identified with the other four plants. Since the sum of TN input from the five plants showed an increasing trend, the trend of TN input from the sewage treatment plants of sub-area A was classified as 'Increasing trend'.

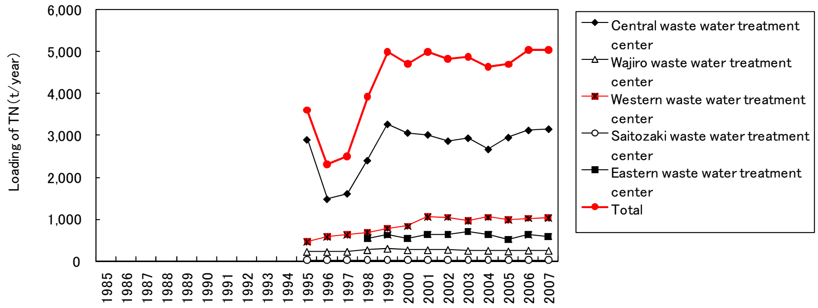

Fig. 4.3 TN input from the sewage treatment plants of sub-area A

(4) TP input from sewage treatment plant

The sum of TP input from the sewage treatment plants of sub-area A ranged between 53-137 ton/year. TP input from the Central wastewater treatment center contributed to 50-74% of the sum of TP input. TP input from the Western wastewater treatment center and Saitozaki wastewater treatment center showed a decreasing trend. No trend was identified with the other three plants. Since the sum of TP input from the five plants showed no trend, the trend of TP input from the sewage treatment plants of sub-area A was classified as 'No trend'. However, TP input from the Central wastewater treatment center, which contributed to over half of the sum of TP input, has decreased significantly from 2002.

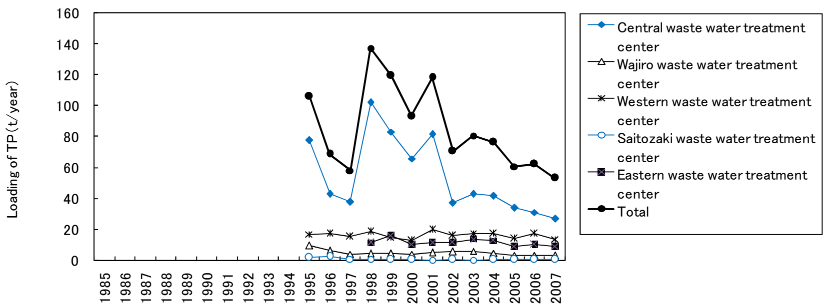

Fig. 4.4 TP input from the sewage treatment plants of sub-area A

(5) TN concentration

In sub-area A, there are ten survey stations, and data were available for the past thirty years from 1978 to 2007. Within the ten stations, annual mean TN concentrations showed increasing trends with eight stations (C-1, C-9, C-10, E-2, E-6, W-6, W-7 and W-9), and no trends with two stations (C-4 and E-X1). The mean TN concentrations of the recent three years of east (E-2, E-6 and E-X1), central (C-1, C-10 and C-4) and west (W-6, W-7 and W-9) sea areas were compared with their respective reference values (0.6 mg/L: east and central sea areas, 0.3 mg/l: west sea area). Two stations (E-X1 and W-6) were above and eight stations were below their reference values. Overall, the status and trend of TN concentration in sub-area A was classified as 'Low eutrophication status and Increasing trend'.

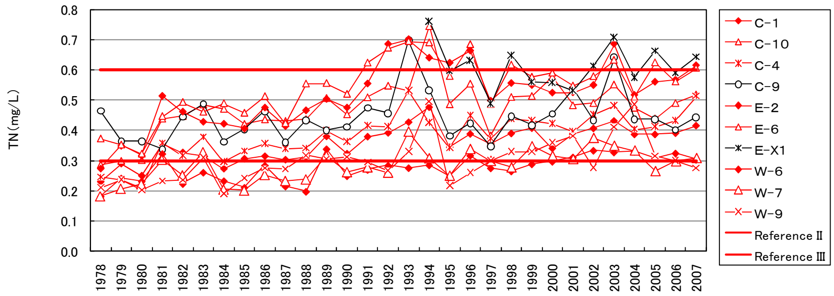

Fig. 4.5 TN concentration in sub-area A

(6) TP concentration

Within the ten stations, five stations (C-10, C-4, C-9, E-6 and E-X1) showed decreasing trends in annual mean TP concentrations. The other five stations (C-1, E-2, W-6, W-7 and W-9) showed no trends. Mean TP concentrations of the recent three years of east (E-2, E-6 and E-X1), central (C-1, C-10 and C-4) and west (W-6, W-7 and W-9) sea areas were compared with their respective reference values (0.05 mg/L: east and central sea areas, 0.03 mg/L: west sea area). All stations were below the reference values. Overall, the status and trend of TP concentration in sub-area A was classified as 'Low eutrophication status and No trend'.

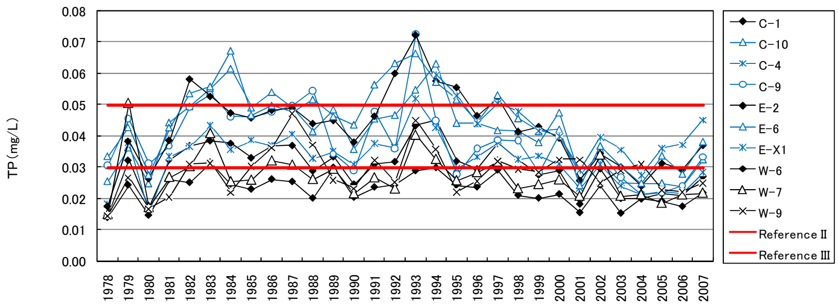

Fig. 4.6 TP concentration in sub-area A

(7) Winter DIN concentration

Within the ten stations, eight stations showed increasing trends in winter DIN concentrations. The other two stations (C-9 and W-7) showed no trends. Mean winter DIN concentrations of the recent three years of east (E-2, E-6 and E-X1), central (C-1, C-10 and C-4) and west (W-6, W-7 and W-9) sea areas were compared with their respective reference values (0.338 mg/L: east and central sea areas, 0.169 mg/L: west sea area). Within the ten stations, eight stations were above the reference values. Overall, the status and trend of winter DIN concentration in sub-area A was classified as 'High eutrophication status and Increasing trend'.

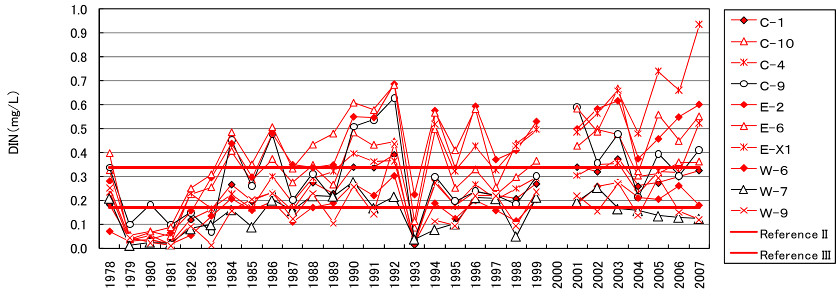

Fig. 4.7 Winter DIN concentration in sub-area A

(8) Winter DIP concentration

There were no trends in winter DIP concentrations with all the stations. Mean winter DIP concentrations of the recent three years of east (E-2, E-6 and E-X1), central (C-1, C-10 and C-4) and west (W-6, W-7 and W-9) sea areas were compared with their respective reference values (0.017 mg/L: east and central sea areas, 0.011 mg/L: west sea area). Within the ten stations, only one station (E-X1) was above the reference value. Overall, the status and trend of winter DIP concentration in sub-area A was classified as 'Low eutrophication status and No trend'.

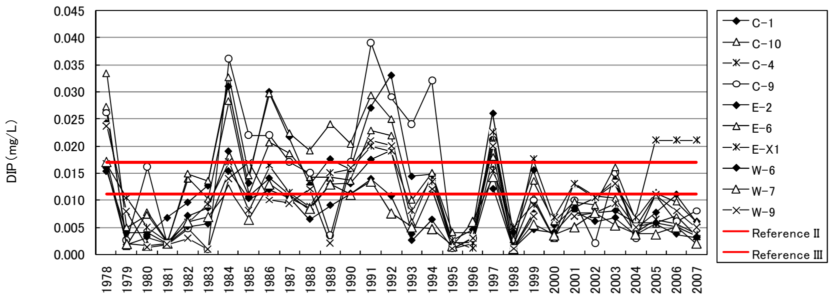

Fig. 4.8 Winter DIP concentration in sub-area A

(9) Winter DIN/DIP ratio

Within the ten stations, eight stations showed increasing trends in winter DIN/DIP ratio. The other two stations (C-9 and E-X1) showed no trends. Mean winter DIN/DIP ratio of the recent three years ranged from 51 to 184. All stations were above the reference value of 16. Overall, the status and trend of winter DIN/DIP ratio in sub-area A was classified as 'High eutrophication status and Increasing trend'.

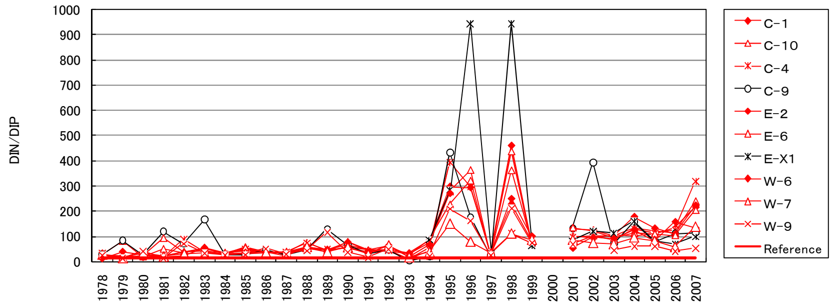

Fig. 4.9 Winter DIN/DIP ratio in sub-area A

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Within the ten stations, six stations (C-1, C-10, C-9, E-2, E-6, E-X1) showed decreasing trends in annual maximum chlorophyll-*a* concentrations. The other four stations (C-4, W-6, W-7 and W-9) showed no trends. The mean of the annual maximum chlorophyll-*a* concentrations of the recent three years ranged between 9.9-24.6 µg/L. Five stations (C-1, C-4, C-10, E-6 and W-6) were above the reference value (20 µg/L), and the other five stations (C-9, E-2, E-X1, W-7 and W-9) were below the reference value. Overall, the status and trend of annual maximum chlorophyll-*a* concentration in sub-area A was classified as 'High eutrophication status and Decreasing trend'.

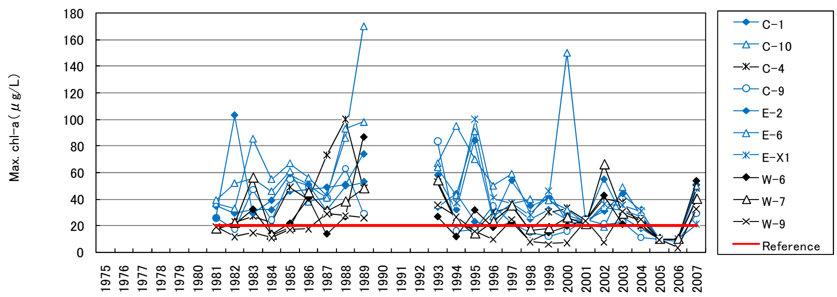

Fig. 4.10 Annual maximum chlorophyll-*a* concentration in sub-area A

(11) Annual mean chlorophyll-*a* concentration

Within the ten stations, seven stations (C-1, C-10, C-4, C-9, E-2, E-6 and E-X1) showed decreasing trends in annual mean chlorophyll-a concentrations. The other three stations (W-6, W-7 and W-9) showed no trends. The mean of the annual mean chlorophyll-*a* concentration of the recent three years ranged between 6.6-10.1 μg/L; hence all stations were above the reference value (5 μg/L). Overall, the status and trend of annual mean chlorophyll-*a* concentration in sub-area A was classified as 'High eutrophication status and Decreasing trend'.

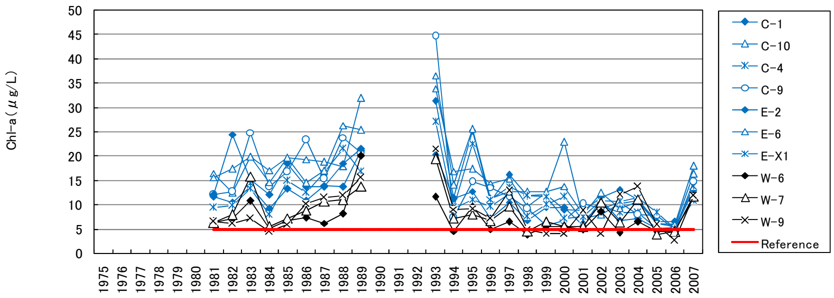

Fig. 4.11 Annual mean chlorophyll-*a* concentration in sub-area A

(12) Red tide (diatom sp.)

Except 1989, the number of diatom red tide in sub-area A ranged between 1-18 events/year. No trend was identified. Within the recent three years, the number of diatom red tide ranged between 4-10 events/year. Overall, the status and trend of diatom red tide in sub-area A was classified as 'High eutrophication status and No trend'.

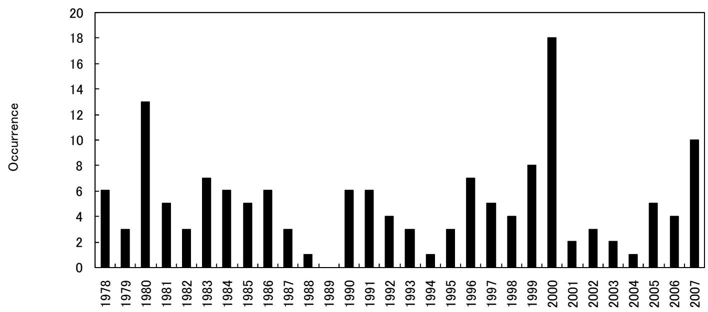

Fig. 4.12 Number of diatom red tide in sub-area A

(13) Red tide (dinoflagellate sp.)

Except 1998, the number of dinoflagellate red tide in sub-area A ranged between 1-10 events/year. No trend was identified. Within the recent three years, the number of dinoflagellate red tide ranged between 1-6 events/year. Overall, the status and trend of dinoflagellate red tide in sub-area A was classified as 'High eutrophication status and No trend'.

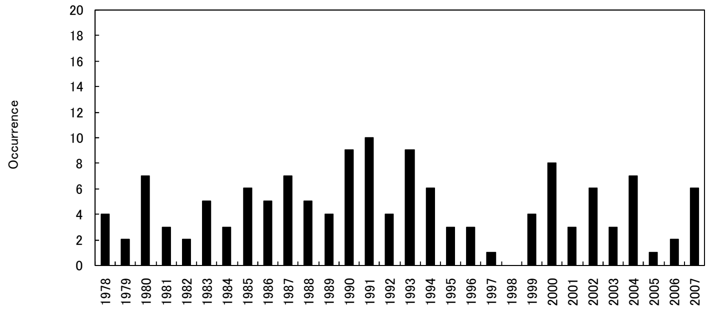

Fig. 4.13 Number of dinoflagellate red tide in sub-area A

Assessment results of category III parameters

(14) Dissolved oxygen (DO)

There were no trends in annual minimum DO concentrations with all the stations. The mean DO concentrations of the recent three years ranged between 6.0-7.2 mg/L; hence all stations satisfied the reference value of 6.0 mg/L. Overall, the status and trend of DO in sub-area A was classified as 'Low eutrophication status and No trend'.

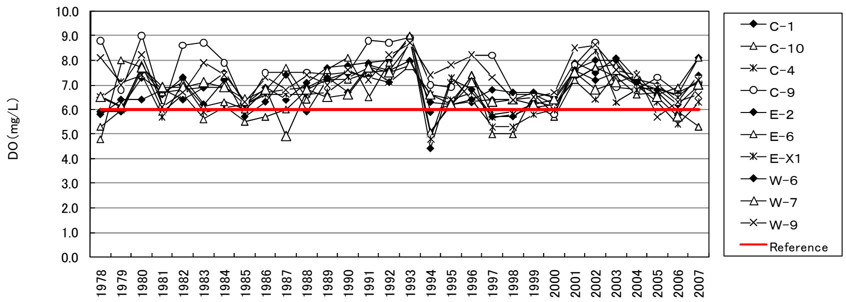

Fig. 4.14 DO concentration in sub-area A

(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 the ten stations, six stations (C-1, C-10, C-4, W-6, W-7 and W-9) showed increasing trends in annual mean COD. The other four stations (C-9, E-2, E-6 and E-X1) showed no trends. The mean COD of the recent three years ranged between 2.0-2.9 mg/L; hence all stations were below the reference value (3.0 mg/L). Overall, the status and trend of COD in sub-area A was classified as 'Low eutrophication status and Increasing trend'.

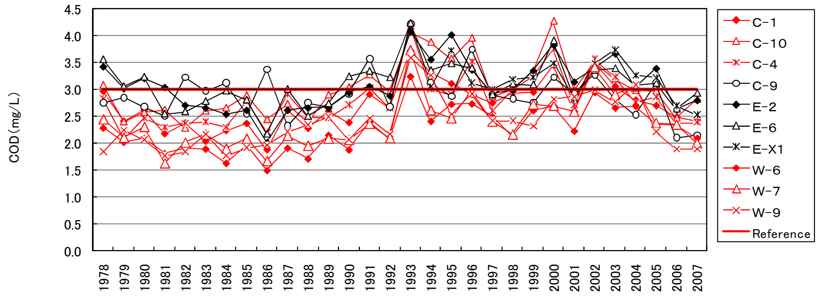

Fig. 4.15 COD concentration in sub-area A

Assessment results of category IV parameters

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

From 1978-2007, *Noctiluca* red tide occurred in six years at a frequency of 1-2 times per year. No trend was identified. Within the recent three years, only one *Noctiluca* red tide was confirmed in 2005. Overall, the status and trend of *Noctiluca* red tide in sub-area A was classified as 'Low eutrophication status and No trend'.

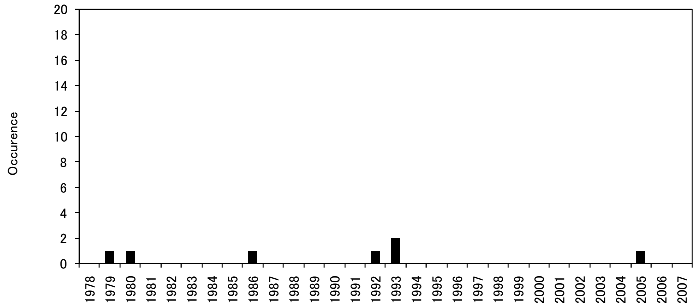

Fig. 4.16 Number of *Noctiluca* red tide in sub-area A

(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 4.1 Assessment results of each assessment category (sub-area A)

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

Assessment results of sub-area A (Hakata Bay)

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

Category I (degree of nutrient enrichment) parameters: TN and TP inputs from the rivers showed decreasing trends. TN input from the sewage treatment plants showed an increasing trend. TP input from the sewage treatment plants showed no trend. Winter DIN concentration was above the reference value and on increasing trends at many stations. On the other hand, winter DIP concentrations were below the reference value at many stations. Consequently, the winter DIN/DIP ratio was higher than the Redfield ratio of 16.

Category II (direct effects of nutrient enrichment) parameters: Annual maximum and mean of chlorophyll-*a* concentrations showed decreasing trends, despite exceedance of reference value in some years. Diatom and dinoflagellate red tides were also confirmed.

Category III (indirect effects of nutrient enrichment) parameters: DO satisfied the reference value. While COD was below the reference value, many stations showed an increasing trend in COD level.

Category IV (other possible effects of nutrient enrichment) parameters: *Noctiluca* red tide was confirmed, but at limited frequency. No shellfish poisoning incidents were confirmed.

In sub-area A, the concentration of nitrogen and phosphorus should be balanced by adjusting the level of nitrogen and phosphorus inputs. The number of diatom and dinoflagellate red tides should also be reduced.

Table 4.2 Reasons behind the classification of each assessment category (sub-area A)

Category	Reason	Classification
I Degree of nutrient enrichment	- TN and TP inputs from river: Decreasing trend - TN input from sewage treatment plant: Increasing trend - TP input from sewage treatment plant: No trend - TN concentration: Majority of stations below reference value but increasing trend - TP concentration: Majority of stations below reference value and many stations showed no trend - Winter DIN concentration: High concentration and increasing trend - Winter DIP concentration: Low concentration and no trend - Winter DIN/DIP ratio: High ratio and increasing trend	LI
II Direct effects of nutrient enrichment	- Annual max./mean of chlorophyll-*a*: High concentration and decreasing trend. High concentration in 2007. - Diatom and dinoflagellate red tides: No trend but high frequency of both red tides.	HD-HN
III Indirect effects of nutrient enrichment	- DO: High concentration and no trend - Abnormal fish kill: None - COD: Low concentration but increasing trend	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: Low frequency throughout the period - Shellfish poisoning: None	LN

4.2 Sub-area B (Dokai Bay)

Assessment results of category I parameters

(1) TN input from river

There are four rivers that discharge into sub-area B (Egawa River, Shinshinhori River, Murasaki River, Kanate River). The sum of TN inputs from these rivers has decreased from 733 ton/year to 196 ton/year during the period from 1991 to 2007. Within the four rivers, inputs from Shinshinhori River contributed to 43-78% of the sum of TN input. Within the four rivers, TN input from three rivers showed decreasing trends. No trend was found with Murasaki River. Since the sum of TN input from the rivers showed a decreasing trend, the trend of TN input from the rivers of sub-area B was classified as 'Decreasing trend'.

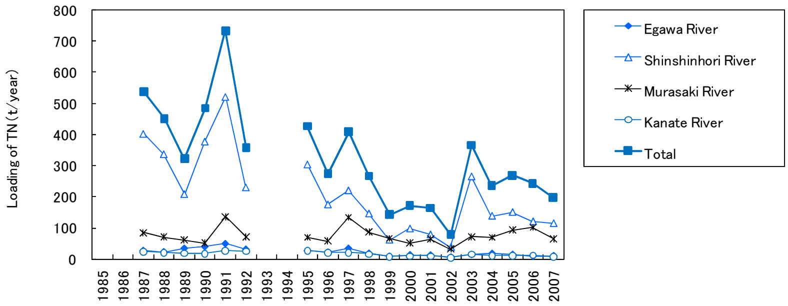

Fig. 4.17 TN input from the rivers of sub-area B

(2) TP input from river

The sum of TP input from the rivers of sub-area B has decreased from 29 ton/year to 13 ton/year during the period from 1987 to 2007. As it was the case with TN, inputs from Shinshinhori River dominated, contributing to 54-74% of the sum of TP input. TP input from Egawa River and Shinshinhori River showed decreasing trends. No trends were identified with Murasaki River and Kanate River. Since the sum of TP input from the rivers showed a decreasing trend, the trend of TP input from the rivers of sub-area B was classified as 'Decreasing trend'.

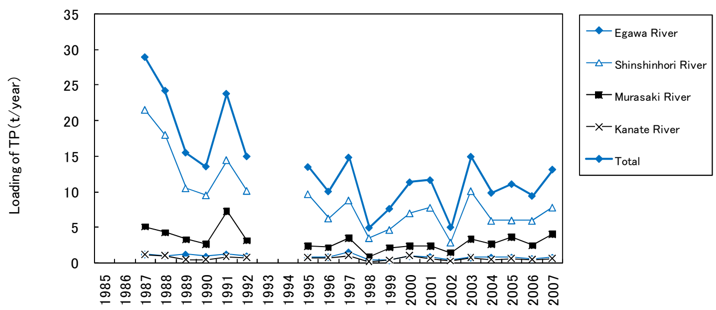

Fig. 4.18 TP input from the rivers of sub-area B

(3) TN input from sewage treatment plant

There are two sewage treatment plants that discharge directly into sub-area B namely: Kougasaki treatment center and Kitaminato treatment center. The sum of TN input from these plants has decreased from 885 ton/year to 651 ton/year during the period from 1998 to 2007. TN input from the Kitaminato treatment center showed a decreasing trend. No trend was identified with Kougasaki treatment center. Since the sum of TN input from the two sewage treatment plants showed no trends, the trend of TN input from the sewage treatment plants of sub-area B was classified as 'No trend'.

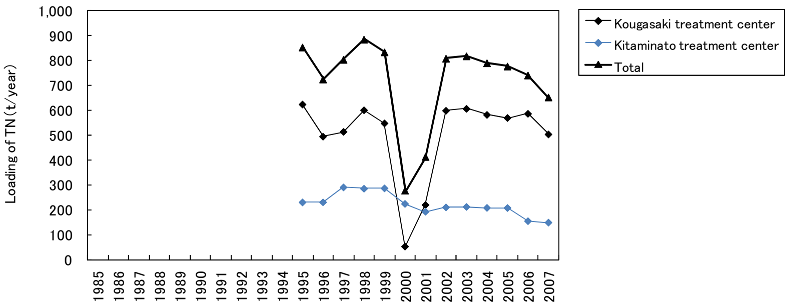

Fig. 4.19 TN input from the sewage treatment plants of sub-area B

(4) TP input from sewage treatment plant

The sum of TP input from the sewage treatment plants of sub-area B has decreased from 62 ton/year to 15 ton/year during the period from 1997 to 2007. TP input from the Kougasaki treatment center showed a decreasing trend. No trend was identified with the Kitaminato treatment center. Since the sum of TP input from the two sewage treatment plants showed a decreasing trend, the trend of TP input from the sewage treatment plants of sub-area B was classified as 'Decreasing trend'.

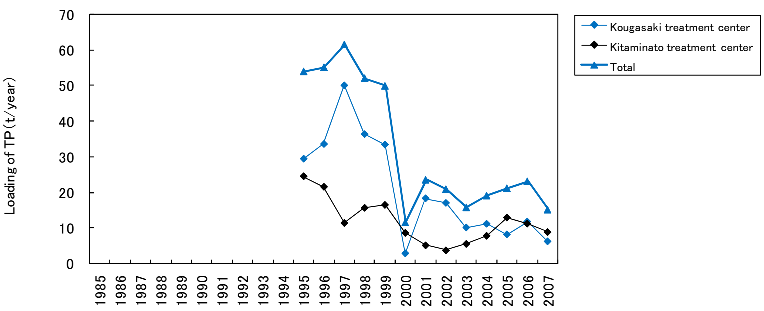

Fig. 4.20 TP input from the sewage treatment plants of sub-area B

(5) TN concentration

In sub-area B, there are eleven survey stations, and data were available for the past thirteen years from 1978 to 2007. However, with two stations (stations 1 and 9) data were limited from 1995 to 1997. Hence trend analysis was not conducted for these stations. Within the nine stations, annual mean TN concentration showed decreasing trends with six stations (D2, D3, D6, D7, H1 and H5), and no trends with three stations (H4, K7 and K8). The mean TN concentrations of the recent three years of six stations (D2, D3, D6, D7, K7 and K8) were compared with reference value of 1.0 mg/L; the other three stations were compared with reference value of 0.3 mg/L. Within the nine stations, two stations (D6 and D7) were above the reference value; and seven stations were below the reference value. Overall, the status and trend of TN in sub-area B was classified as 'Low eutrophication status and Decreasing trend'.

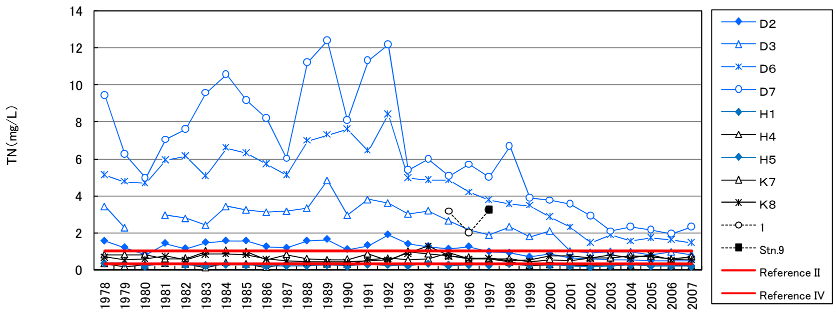

Fig. 4.21 TN concentration in sub-area B

(6) TP concentration

Within the eleven stations, six stations (D2, D3, D6, D7, K7 and K8) showed decreasing trends in annual mean TP concentrations. No trends were identified with three stations (H1, H4 and H5). Trend analysis was not conducted for stations 1 and 9 due to limited data. The mean TP concentrations of the recent three years of six stations (D2, D3, D6, D7, K7 and K8) were compared with reference value of 0.09 mg/L; the other three stations were compared with reference value of 0.03 mg/L. Within the eleven stations, one station (D7) was above the reference value; and ten stations were below the reference value. Overall, the status and trend of TP concentration in sub-area B was classified as 'Low eutrophication status and Decreasing trend'.

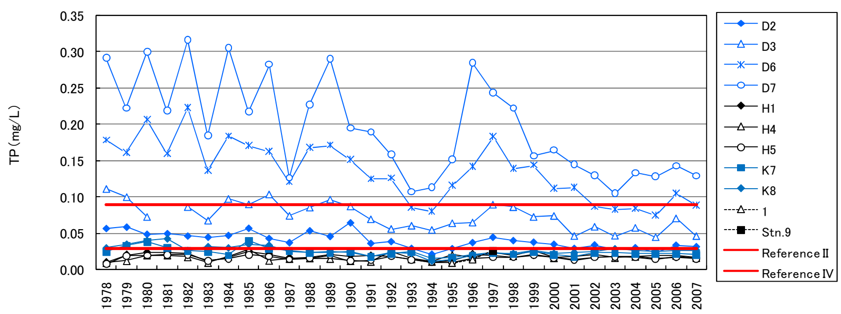

Fig. 4.22 TP concentration in sub-area B

(7) Winter DIN concentration

There was only one station that monitored winter DIN concentration. An increasing trend was identified between 1978 and 1998. The status of the recent three years and the trend from 1999 was not analyzed as data were not available from 1999 onwards. Therefore, the status and trend of winter DIN in sub-area B was not classified.

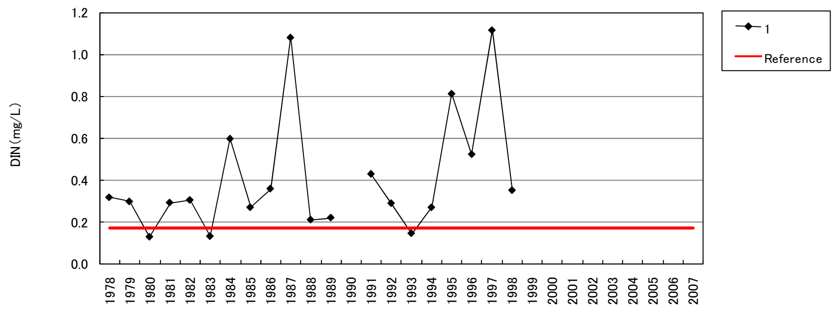

Fig. 4.23 Winter DIN concentration in sub-area B

(8) Winter DIP concentration

There was only one station that monitored winter DIP concentration. A decreasing trend was identified between 1978 and 1998. The status of the recent three years and the trend from 1999 was not analyzed as data were not available from 1999 onwards. Therefore, the status and trend of winter DIP in sub-area B was not classified.

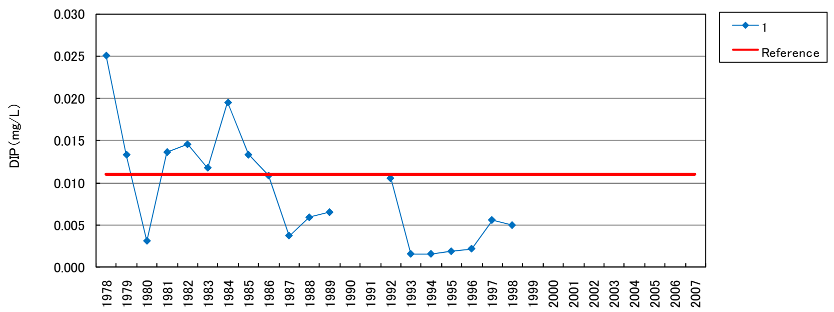

Fig. 4.24 Winter DIP concentration in sub-area B

(9) Winter DIN/DIP ratio

There was only one station that monitored winter DIN and DIP concentration. Winter DIN/DIP ratio showed an increasing trend between 1978 and 1998. The status of the recent three years and the trend from 1999 was not analyzed as data were not available from 1999 onwards. Therefore, the status and trend of winter DIN/DIP ratio in sub-area B was not classified.

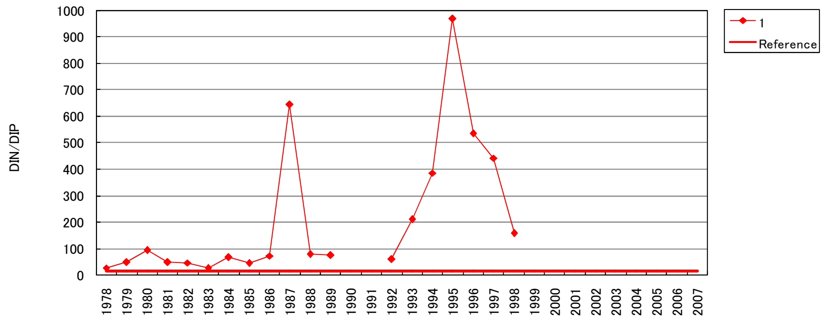

Fig. 4.25 Winter DIN/DIP ratio in sub-area B

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Data availability of annual maximum chlorophyll-*a* concentration varied with the survey stations. Four stations (D2, D6, H5 and 1) had data upto 2007, and three stations (D7, 2 and 3) had no recent data. Within the above four stations (D2, D6, H5 and 1), one station showed increasing trend, and the other three stations showed no trends. Trend analysis was not conducted for stations D7, 2 and 3 due to limited data availability. Station D7 had data only for one year. Stations 2 and 3 had no data from 1996 onwards (an increasing trend was identified upto 1996). The mean of the annual maximum chlorophyll-*a* concentration of the recent three years of four stations (D2, D6, H5 and 1) ranged between 5.2-48 μg/l. Three of these stations (D2, D6 and 1) were above the reference value (20 μg/l). Overall, the status and trend of annual maximum chlorophyll-*a* concentration in sub-area B was classified as 'High eutrophication status and No trend'.

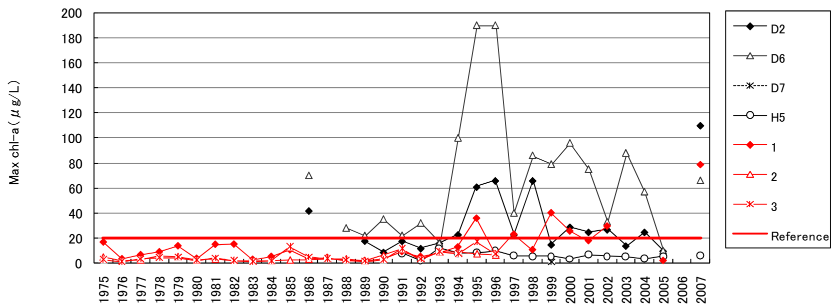

Fig. 4.26 Annual maximum chlorophyll-*a* concentration in sub-area B

(11) Annual mean chlorophyll-*a* concentration

Data availability of annual mean chlorophyll-*a* concentration varied with the survey stations. Four stations (D2, D6, H5 and 1) had data upto 2007, and three stations (D7, 2 and 3) had no recent data. No trends were identified with the above four stations (D2, D6, H5 and 1). Trend analysis was not conducted for stations D7, 2 and 3 due to limited data availability. Station D7 had data only for one year. Stations 2 and 3 had no data from 1996 onwards (an increasing trend was identified upto 1996). The mean of the annual mean chlorophyll-*a* concentration of the recent three years of four stations (D2, D6, H5 and 1) ranged between 2.3-31 μg/l. Three of these stations (D2, D6 and 1) were above the reference value (5 μg/l). Overall, the status and trend of annual mean chlorophyll-*a* concentration in sub-area B was classified as 'High eutrophication status and No trend'.

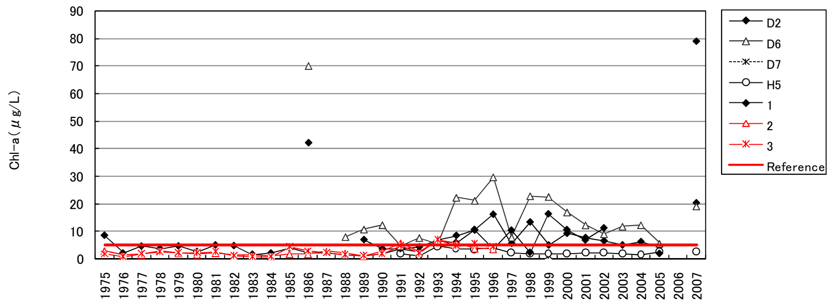

Fig. 4.27 Annual mean chlorophyll-*a* concentration in sub-area B

(12) Red tide (diatom sp.)

In sub-area B, diatom red tide was not confirmed between 1978 and 2007. Overall, the status and trend of diatom red tide in sub-area B was classified as 'Low eutrophication status and No trend'.

(13) Red tide (dinoflagellate sp.)

From 1978 to 2007, dinoflagellate red tide occurred in six years at a frequency of 1-2 times per year. No trend was identified. Overall, the status and trend of dinoflagellate red tide in sub-area B was classified as 'Low eutrophication status and No trend'.

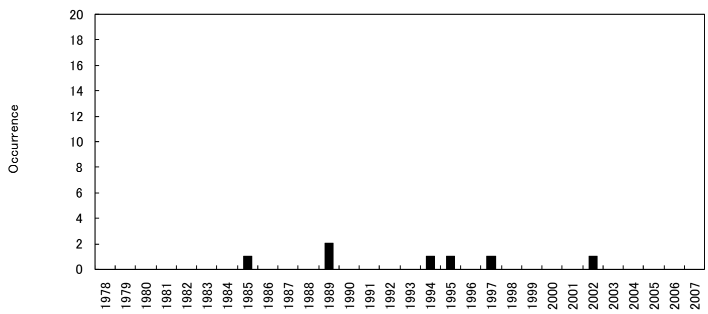

Fig. 4.28 Number of dinoflagellate red tide in sub-area B

Assessment results of category III parameters

(14) Dissolved oxygen (DO)

Within the ten survey stations, annual minimum DO concentrations showed increasing trends at two stations (D2 and D6); a decreasing trend at one station (1); and no trends at seven stations (D3, D7, H1, H4, H5, K7 and K8). Mean DO concentrations of the recent three years, ranged between 4.7-7.4 mg/L. Within the ten stations, only one station (D6) was below the reference value of 6.0 mg/L, and the other nine stations were above the reference value. Overall, the status and trend of DO in sub-area B was classified as 'Low eutrophication status and No trend'.

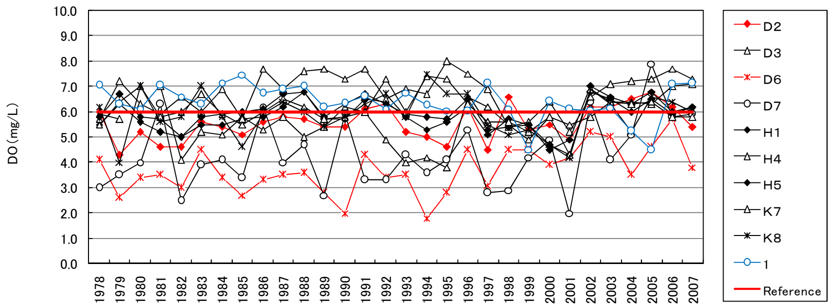

Fig. 4.29 DO concentration in sub-area B

(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 the ten stations, four stations (D3, D6, D7 and 1) showed decreasing trends in annual mean COD; and five stations (C-9, E-2, E-6 and E-X1) showed no trends. The mean COD of the recent three years ranged between 1.1-4.5 mg/L. Within the ten stations, three stations (D3, D6 and D7) were above the reference value (3.0 mg/L), and seven stations were below the reference value. Overall, the status and trend of COD in sub-area B was classified as 'Low eutrophication status and No trend'.

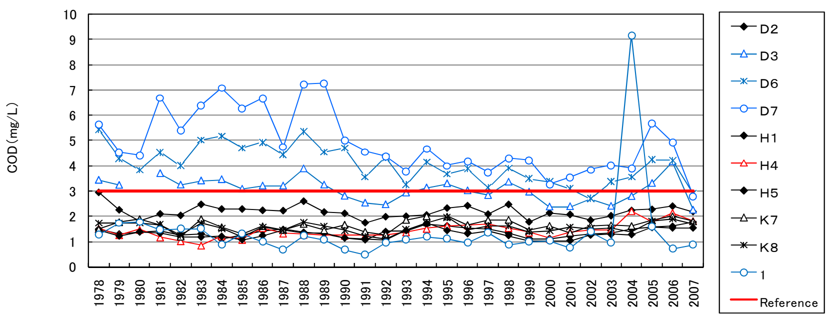

Fig. 4.30 COD concentration in sub-area B

Assessment results of category IV parameters

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

In sub-area B, *Noctiluca* red tide occurred once each in 1982 and 1989. 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'.

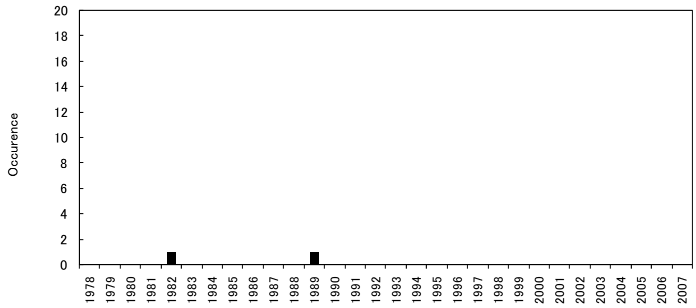

Fig. 4.31 Number of *Noctiluca* red tide in sub-area B

(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 (sub-area B)

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

Assessment results of sub-area B (Dokai Bay)

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

Category I (degree of nutrient enrichment) parameters: TN and TP inputs from the rivers showed decreasing trends. TN input from the two sewage treatment plants showed no trends. TP input from sewage treatment plants showed decreasing trend. TN and TP concentrations showed decreasing trends, and most stations satisfied the reference value. However, note that the reference value for TN and TP was set as Type IV water use, which is the most lenient level in the 'Environmental water quality standard'. Winter DIN/DIP concentration was not assessed due to lack of recent data.

Category II (direct effects of nutrient enrichment) parameters: Annual maximum and mean of chlorophyll-*a* concentrations exceeded the reference values in some years. The number of diatom and dinoflagellate red tides were low.

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

Category IV (other possible effects of nutrient enrichment) parameters: *Noctiluca* red tide occurred once each in 1982 and 1989. No shellfish poisoning incidents were confirmed.

In sub-area B, survey stations are located in Dokai Bay. In Dokai Bay, TN and TP concentrations decreased significantly between the 1970s and 1990s, and has remained stable in the recent ten years.

Table 4.4 Reasons behind the classification of each assessment category (sub-area B)

Category	Reason	Classification
I Degree of nutrient enrichment	- TN and TP inputs from river: Decreasing trend - TN input from sewage treatment plant: No trend - TP input from sewage treatment plant: Decreasing trend - TN and TP concentration: Low concentration and decreasing trend	LD
II Direct effects of nutrient enrichment	- Annual max./mean of chlorophyll-*a*: High concentration and no trend. - Diatom and dinoflagellate red tides: Low occurrences and no trend	LN-HN
III Indirect effects of nutrient enrichment	- DO: Most stations satisfied the reference value and had no trend - Abnormal fish kill: None - COD: Most stations satisfied the reference value and had no trend	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: Low frequency throughout the period. - Shellfish poisoning: None	LN

4.3 Sub-area C (intermediate area)

Assessment results of category I parameters

(1) TN input from river

There are thirteen rivers that discharge into sub-area C (Itabitsu River, Bachi River, Wariko River, Onga River, Yahagi River, Shioiri River, Tsuri River, Saigou River, Daikon River, Minato River, Sakurai River, Naka River, Tebikaima River). While the sum of TN inputs from these rivers has decreased from 4,842 ton/year to 2,808 ton/year during the period from 1985 to 2007, no trend was identified. Within the thirteen rivers, inputs from Onga River contributed to 62-90% of the sum of TN input. Within the thirteen rivers, TN input from nine rivers showed no trends; three rivers (Yahagi River, Naka River and Tebikaima River) showed increasing trends; and one river (Wariko River) showed a decreasing trend. Since the sum of TN input from the rivers showed no trend, the trend of TN input from the rivers of sub-area C was classified as 'No trend'.

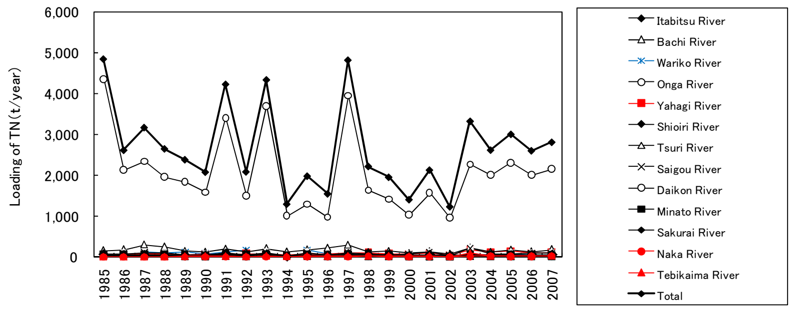

Fig. 4.32 TN input from the rivers of sub-area C

(2) TP input from river

The sum of TP input from the rivers of sub-area C has decreased from 412 ton/year to 168 ton/year during the period from 1987 to 2007. As it was the case with TN, inputs from Onga River was dominant and contributed to 44-87% of the total TP input. Within the thirteen rivers, TN input from nine rivers showed no trend; Minato River showed decreasing trend; and Yahagi River, Naka River and Tebikaima River showed increasing trends. Since the sum of TP input from the rivers showed no trend, the trend of TP input from the rivers of sub-area C was classified as 'No trend'.

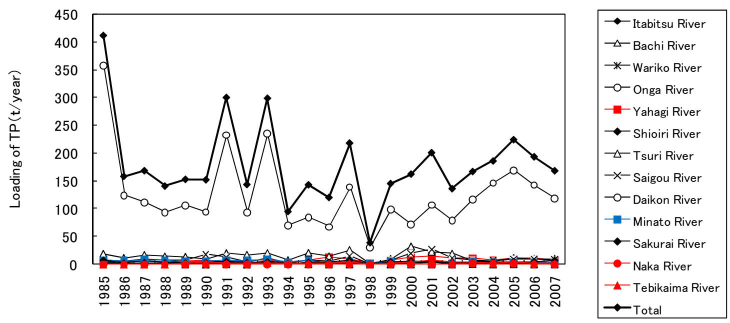

Fig. 4.33 TP input from the rivers of sub-area C

(3) TN input from sewage treatment plant

There are four sewage treatment plants that discharge directly into sub-area C namely: Koga treatment center, Tsuyazaki treatment center, Kuroiso treatment center and Hiagari treatment center. The sum of TN input from these plants has decreased from 1,227 ton/year to 942 ton/year during the period from 1995 to 2007. Within the four sewage treatment plants, Hiagari treatment center contributed to 88-95 % of the sum of TN input. Although TN input from Kuroiso treatment center showed an increasing trend, its contribution to the sum of TN input was small. Since the sum of TN input from the four sewage treatment plants showed a decreasing trend, the trend of TN input from the sewage treatment plants of sub-area C was classified as 'Decreasing trend'.

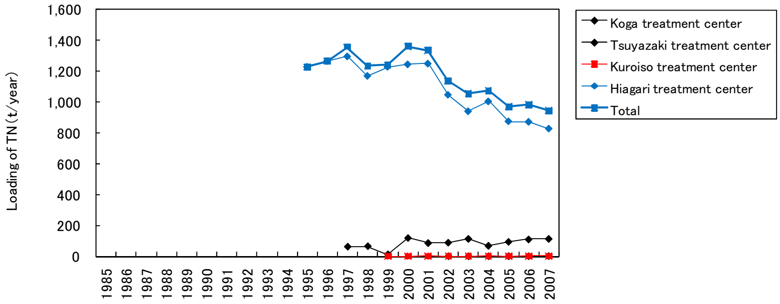

Fig. 4.34 TN input from the sewage treatment plants of sub-area C

(4) TP input from sewage treatment plant

The sum of TP input from the sewage treatment plants of sub-area C has increased from 51 ton/year to 92 ton/year during the period from 1995 to 2007. Within the four sewage treatment plants, Hiagari treatment center contributed to 96-100 % of the sum of TP input. While TP input from the Koga and Kuroiso treatment centers showed no trends, Tsuyazaki and Hiagari treatment centers showed increasing trends. Since the sum of TP input from the four sewage treatment plants showed an increasing trend, the trend of TP input from the sewage treatment plants of sub-area C was classified as 'Increasing trend'.

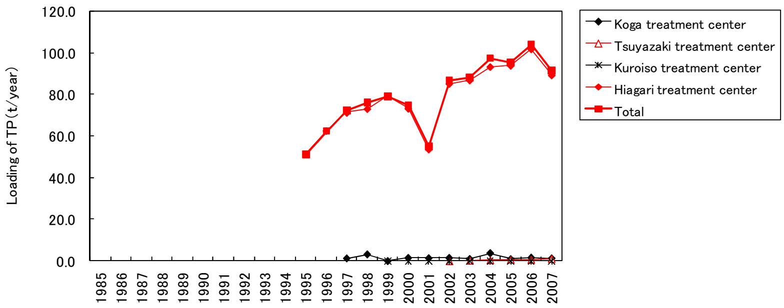

Fig. 4.35 TP input from the sewage treatment plants of sub-area C

(5) TN concentration

In sub-area C, there are twenty-two survey stations. Eight stations had data for the past thirty years from 1978 to 2007. However, data were limited to 1995 to 1997 at fourteen stations. Trend analysis was not conducted for these fourteen stations (4, 6, 8, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7, Stn.8, Stn.10, Stn.11, Stn.12 and Stn.13) as data was limited to less than three years. As for the other eight stations (H3, H7, K1, K4, K6, St-1, St-2 and W-3), no trends of annual mean TN concentration were identified. The mean TN concentrations of the recent three years were compared with reference value of 0.3 mg/L. The mean TN concentrations of the recent three years ranged between 0.15-0.29 mg/L; hence all stations were below the reference value of 0.3 mg/L. Overall, the status and trend of TN in sub-area C was classified as 'Low eutrophication status and No trend'.

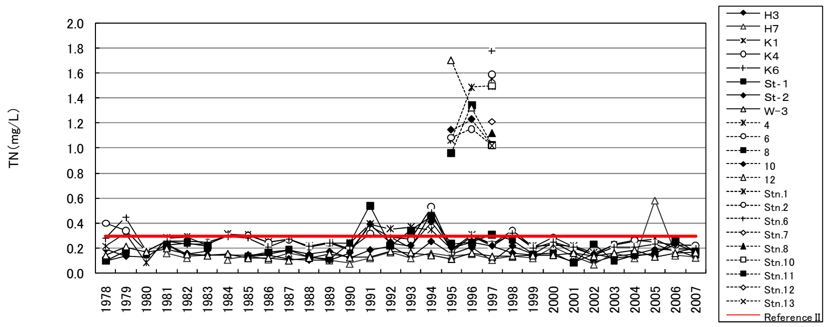

Fig. 4.36 TN concentration in sub-area C

(6) TP concentration

Within the twenty-two stations, seven stations (H3, H7, K1, K4, K6, St-1 and St-2) showed no trends in annual mean TP concentrations; and one station (W-3) showed decreasing trend. Trend analysis was not conducted with fourteen stations (4, 6, 8, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7, Stn.8, Stn.10, Stn.11, Stn.12 and Stn.13) as data were limited to less than three years. The mean TP concentrations of the recent three years were compared with reference value of 0.03 mg/L. The mean TP concentrations of the recent three years ranged between 0.013-0.02 mg/L; hence all stations were below the reference value. Overall, the status and trend of TP in sub-area C was classified as 'Low eutrophication status and No trend'.

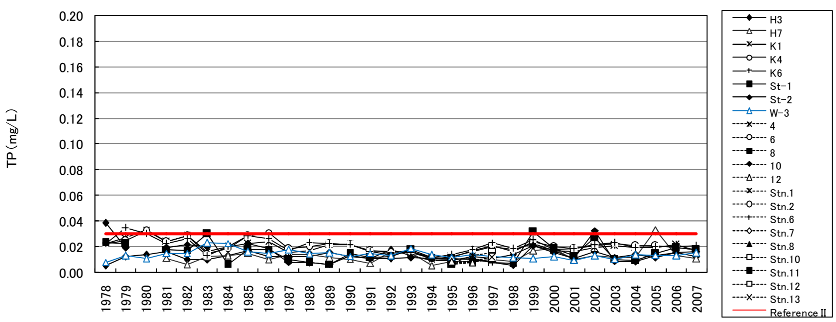

Fig. 4.37 TP concentration in sub-area C

(7) Winter DIN concentration

Although 17 stations had data on winter DIN concentration, 16 stations had data only upto 1998. Only one station (W-3) had sufficient data to analyze the mean of the recent 3 years and trend. No increasing or decreasing trend was identified with station W-3. The mean winter DIN concentration of the recent 3 years was compared with reference value of 0.169 mg/L. The mean winter DIN concentration of the recent 3 years was 0.063 mg/L; hence was below the reference value. Overall, the status/trend of winter DIN concentration in sub-area C was classified as 'LN'.

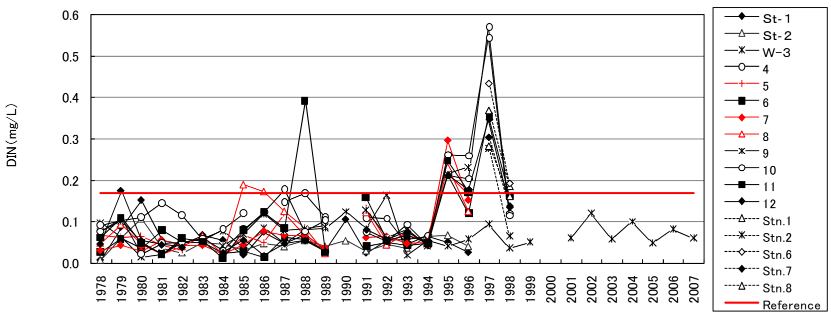

Fig. 4.38 Winter DIN concentration in sub-area C

(8) Winter DIP concentration

Although 17 stations had data on winter DIP concentration, 16 stations had data only upto 1998. As it was the case with DIN, only station W-3 had sufficient data to analyze the mean concentration of the recent 3 years and trend. Decreasing trend was found with station W-3. The mean winter DIP concentration of the recent 3 years of station W-3 was 0.004 mg/L, which was below the reference value of 0.011 mg/L. Overall, the status/trend of winter DIP concentration in sub-area C was classified as 'LD'.

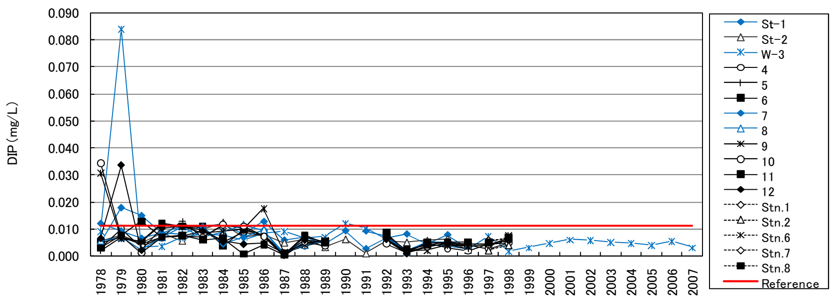

Fig. 4.39 Winter DIP concentration in sub-area C

(9) Winter DIN/DIP ratio

Only station W-3 had sufficient data to analyze the recent status and the trend of winter DIN/DIP ratio. No increasing or decreasing trend was identified at station W-3. The mean winter DIN/DIP ratio of the recent 3 years was 35, which exceeded the reference value of 16. Therefore, the status/trend of winter DIN/DIP ratio in sub-area C was classified as ‘HN’. However, since the winter DIN/DIP concentration at station W-3 was below the reference value, the classification of winter DIN/DIP ratio was not included in the assessment of category I.

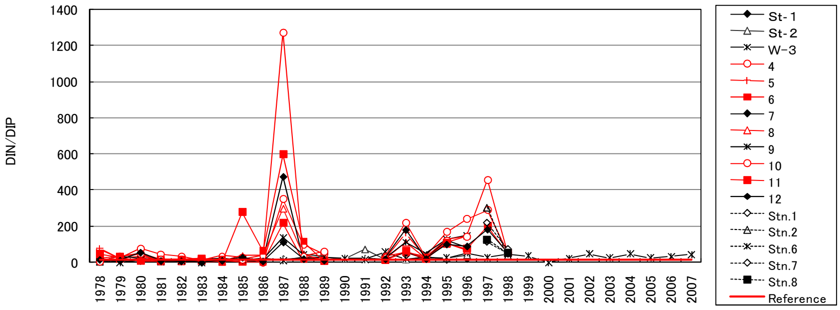

Fig. 4.40 Winter DIN/DIP ratio in sub-area C

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Data on annual maximum chlorophyll-*a* concentration were available at 18 stations. However, only station W-3 had long-term data (1981-2007) and data of the recent 3 years between 2003-2007. Annual maximum chlorophyll-*a* concentration at station W-3 showed no increasing or decreasing trend. The mean of the annual maximum chlorophyll-*a* concentration of the recent 3 years was 8.0 µg/l, which was below the reference value of 20 µg/l. Therefore, status/trend of annual maximum chlorophyll-*a* concentration in sub-area C was classified as ‘LN’.

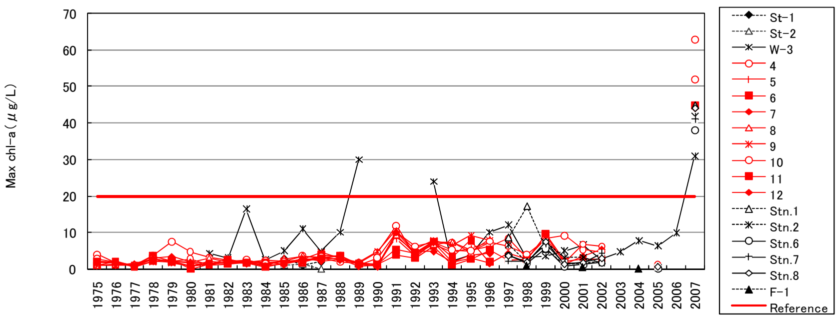

Fig. 4.41 Annual maximum chlorophyll-*a* concentration in sub-area C

(11) Annual mean chlorophyll-*a* concentration

Data on annual mean chlorophyll-*a* concentration were available at 18 stations. However, only station W-3 had long-term data (1981-2007) and data of the recent 3 years between 2003-2007. Annual mean chlorophyll-*a* concentration at station W-3 showed no increasing or decreasing trend. The mean of the annual mean chlorophyll-*a* concentration of the recent 3 years was 2.4 μg/l, which was below the reference value of 5 μg/l. Therefore, the status/trend of annual mean chlorophyll-*a* concentration in sub-area C was classified as 'LN'.

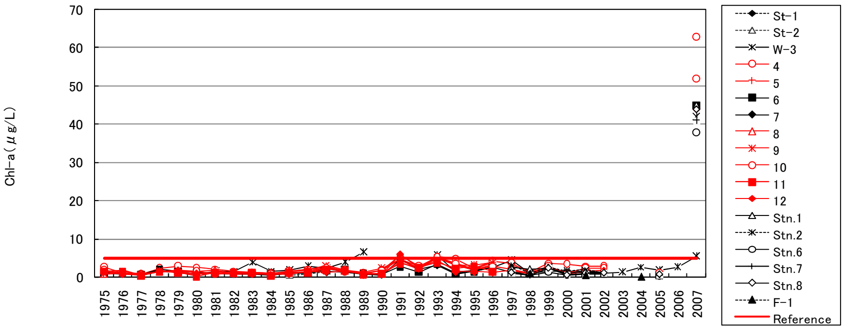

Fig. 4.42　Annual mean chlorophyll-*a* concentration in sub-area C

(12) Red tide (diatom sp.)

In sub-area C, diatom red tide occurred once in 2004. No increasing or decreasing trend was identified. Overall, the status/trend of diatom red tide in sub-area C was classified as 'LN'.

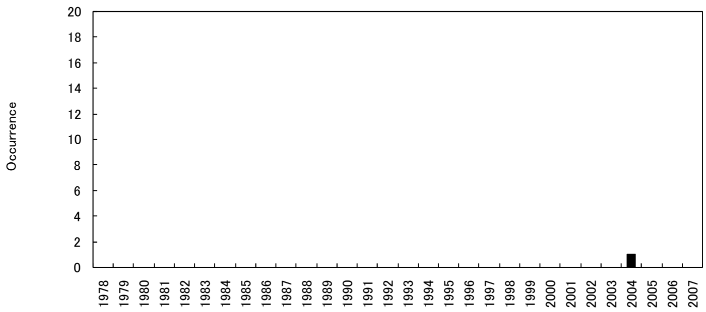

Fig. 4.43　Number of diatom red tide in sub-area C

(13) Red tide (dinoflagellate sp.)

In sub-area C, dinoflagellate red tide occurred 1-7 times per year. No increasing or decreasing trend was identified. In the recent 3 years, dinoflagellate red tide occurred once and twice in 2005 and 2006, respectively. Overall, the status/trend of dinoflagellate red tide in sub-area C was classified as 'HN'.

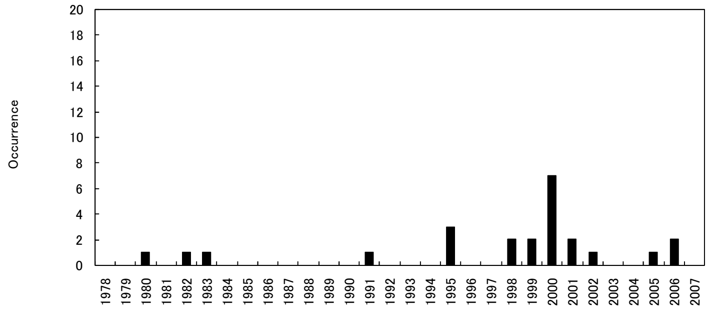

Fig. 4.44 Number of dinoflagellate red tide in sub-area C

Assessment results of category III parameters

(14) Dissolved oxygen (DO)

Within the 22 survey stations, annual minimum DO concentration showed a decreasing trend at 6 stations (4, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8); and no increasing or decreasing trend at the remaining 16 stations. Mean DO concentration of the recent 3 years, ranged between 5.3-7.2 mg/l. Two stations (Stn.6 and Stn.7) were below the reference value (6.0 mg/l); and 15 stations satisfied the reference value. Five stations (5, 7, 8, 9 and 11) were not assessed due to lack of recent data. Overall, the status/trend of DO in sub-area C was classified as 'LN'.

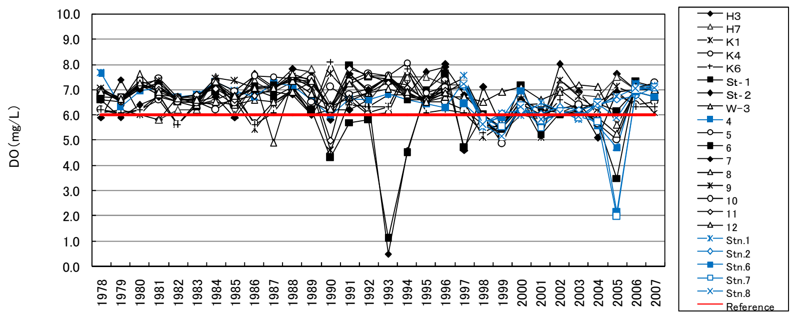

Fig. 4.45 DO concentration in sub-area C

(15) Abnormal fish kill

Incidents of abnormal fish kill were not confirmed. Therefore, its status/trend was classified as 'LN'.

(16) Chemical oxygen demand (COD)

Within the 22 stations, 1 station (W-3) showed increasing trend in annual mean COD; 10 stations (St-1, 4, 5, 7, 8, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) showed decreasing trend; and the remaining 11 stations (H3, H7, St-2, 6, 9, 10, 11 and 12) showed no increasing or decreasing trend. Mean COD concentration of the recent 3 years ranged between 0.5-1.8 mg/l; hence all stations were below the reference value of 3.0 mg/l. Overall, the status/trend of COD in sub-area C was classified as 'LN'.

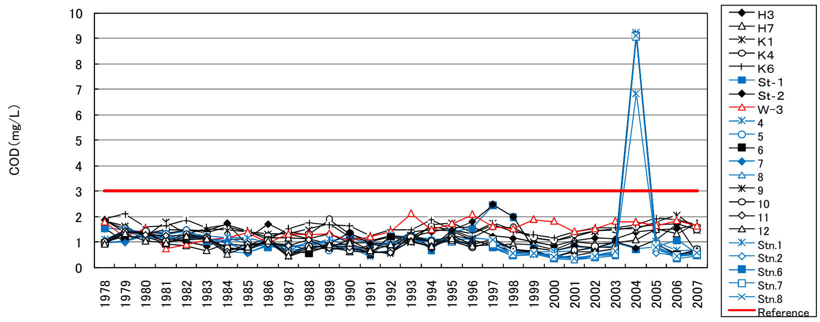

Fig. 4.46 COD concentration in sub-area C

Assessment results of category IV parameters

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

In sub-area C, *Noctiluca* red tide occurred 0-4 times per year. No increasing or decreasing trend was identified. In the recent 3 years, *Noctiluca* red tide occurred 0-4 times per year. Within the recent 3 years, *Noctiluca* red tide occurred 1-4 times per year. Overall, the status/trend of *Noctiluca* red tide in sub-area C was classified as 'HN'.

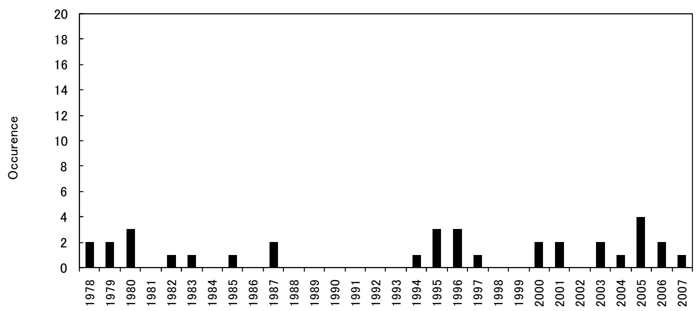

Fig. 4.47 Number of *Noctiluca* red tide in sub-area C

(18) Shellfish poisoning

No shellfish poisoning was confirmed. Therefore, its status/trend was classified as 'LN'.

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

※⑦冬季DIN濃度および⑧冬季DIP濃度が低いことから、カテゴリⅠの評価結果には反映していない。

Assessment results for sub-area C (intermediate area)

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

Category I (degree of nutrient enrichment) parameters: TN and TP inputs from the rivers showed no increasing or decreasing trend. TN input from the 2 sewage treatment plants showed decreasing trend. TP input from the sewage treatment plants showed increasing trend. TN and TP inputs from Hiagari treatment center, which discharges into Kanmon Strait, was predominant. TN and TP concentration in Kanmon Strait was below the reference value, and there was no increasing or decreasing trend.

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

Category III (indirect effects of nutrient enrichment) parameters: DO was below the reference value at one station. While COD exceeded the reference value at 3 stations, most stations were below the reference value. Furthermore, COD levels have decreased at stations that had high levels in the past; hence improvement in water quality was confirmed.

Category IV (other possible effects of nutrient enrichment) parameters: *Noctiluca* red tide occurred 7 times during the recent 3 years. No shellfish poisoning incidents were confirmed.

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

Table 4.6 Reasons behind the classification of each assessment category (sub-area C)

Category	Reason	Classification
I Degree of nutrient enrichment	- TN and TP inputs from river: No increasing or decreasing trend - TN input from sewage treatment plant: Decreasing trend - TP input from sewage treatment plant: Increasing trend - TN and TP concentration: Low concentration and no increasing or decreasing trend - Winter DIN: Low concentration and no increasing or decreasing trend - Winter DIP: Low concentration and decreasing trend - Winter DIN/DIP ratio: High ratio but low concentration	LN
II Direct effects of nutrient enrichment	- Annual max./mean of chlorophyll-*a*: high concentration in 2007 but other year were below reference value. No increasing or decreasing trend. - Diatom red tide: No increasing or decreasing trend. No occurrences in recent 3 years. - Dinoflagellate red tide: No increasing or decreasing trend. 0-2 occurrences in recent 3 years.	LN
III Indirect effects of nutrient enrichment	- DO: Most stations satisfied the reference value. Most stations had no increasing or decreasing trend - Abnormal fish kill: None - COD: All stations satisfied the reference value. Most stations had no increasing or decreasing trend	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: No increasing or decreasing trend but occurred in total 7 times in recent 3 years - Shellfish poisoning: None	HN

4.4 Sub-area D (offshore area)

Assessment results of category I parameters

(1) TN input from river

Sub-area D is located in the offshore area of Northwest Kyhushu sea area, hence no input from river.

(2) TP input from river

Sub-area D is located in the offshore area of Northwest Kyhushu sea area, hence no input from river.

(3) TN input from sewage treatment plant

Sub-area D is located in the offshore area of Northwest Kyhushu sea area, hence no direct input from sewage treatment plant.

(4) TP input from sewage treatment plant

Sub-area D is located in the offshore area of Northwest Kyhushu sea area, hence no direct input from sewage treatment plant.

(5) TN concentration

In sub-area D, there were only 3 stations that surveyed TN, and data were available only for 1997. Therefore, the trend and the concentration of the recent 3 years could not be assessed.

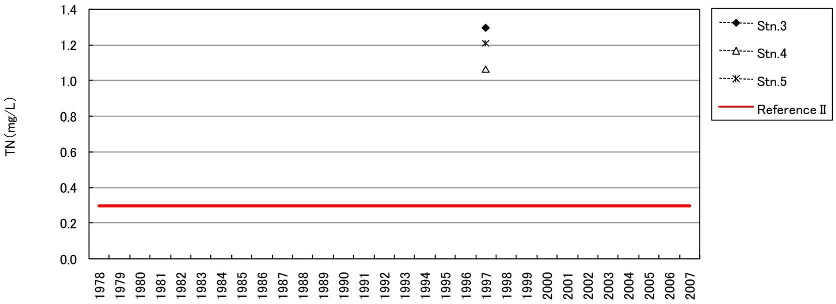

Fig. 4.48 TN concentration in sub-area D

(6) TP concentration

In sub-area D, there were only 3 stations that surveyed TP, and data were available only for 1997. Therefore, the trend and the concentration of the recent 3 years could not be assessed.

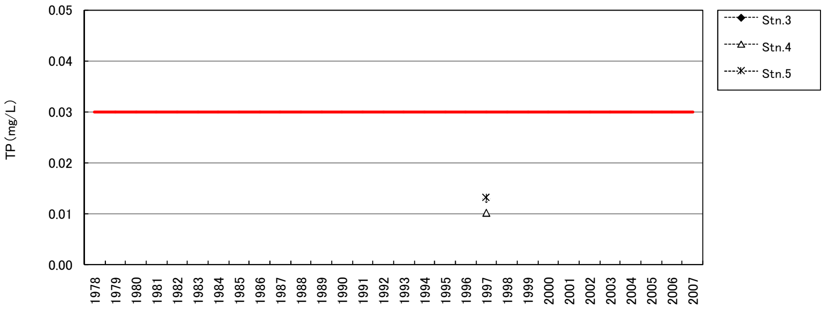

Fig. 4.49 TP concentration in sub-area D

(7) Winter DIN concentration

In sub-area D, there were only 3 stations that surveyed winter DIN concentration, and data were available only for 1997 and 1998. Therefore, the trend and the concentration of the recent 3 years could not be assessed.

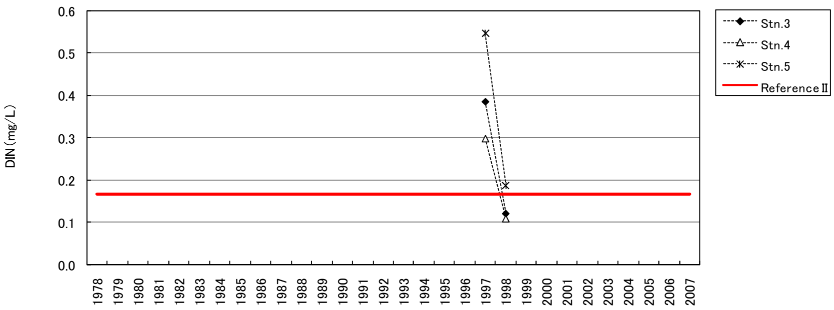

Fig. 4.50 Winter DIN concentration in sub-area D

(8) Winter DIP concentration

In sub-area D, there were only 3 stations that surveyed winter DIP concentration, and data were available only for 1997 and 1998. Therefore, the trend and the concentration of the recent 3 years could not be assessed.

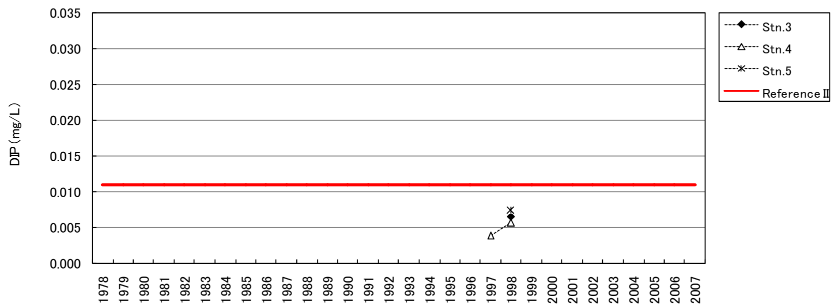

Fig. 4.51 Winter DIP concentration in sub-area D

(9) Winter DIN/DIP ratio

In sub-area D, there were only 3 stations that surveyed winter DIN/DIP ratio, and data were available only for 1997 and 1998. Therefore, the trend and the concentration of the recent 3 years could not be assessed.

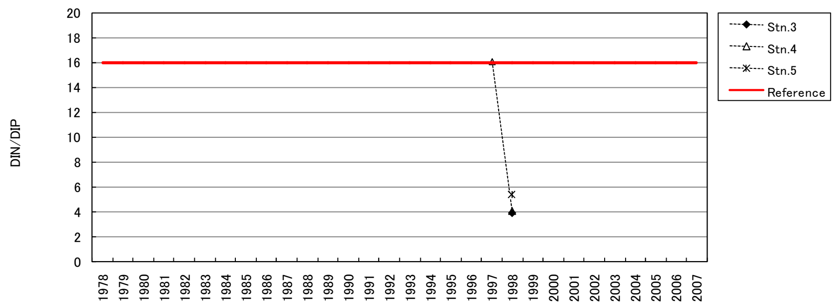

Fig. 4.52 Winter DIN/DIP ratio in sub-area D

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Data on annual maximum chlorophyll-*a* concentration were available at 3 stations for the period 1997-2007. No increasing or decreasing trend was identified. The mean of the annual maximum chlorophyll-*a* concentration of the recent 3 years was not compared with the reference value as data was limited to 2 years between the period from 2003-2007. Therefore, trend of annual maximum chlorophyll-*a* concentration in sub-area D was classified as 'N'.

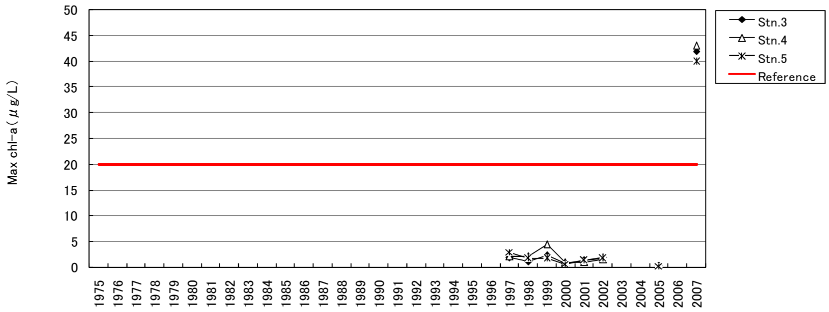

Fig. 4.53 Annual maximum chlorophyll-*a* concentration in sub-area D

(11) Annual mean chlorophyll-*a* concentration

Data on annual mean chlorophyll-*a* concentration were available at 3 stations for the period 1997-2007. However, the data of 2007 was excluded as it was limited to a single data collected in summer. No increasing or decreasing trend in annual mean chlorophyll-*a* concentration was identified with all the stations during 1997-2005. The annual mean chlorophyll-*a* concentration of the recent 3 years was not compared with the reference value as valid data was available for only 2005. Therefore, trend of annual mean chlorophyll-*a* concentration in sub-area D was classified as 'N'.

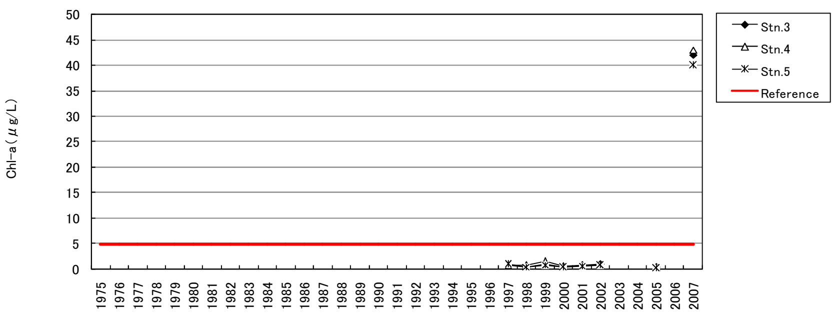

Fig. 4.54 Annual mean chlorophyll-*a* concentration in sub-area D

(12) Red tide (diatom sp.)

In sub-area D, diatom red tide occurred once in 2004. No increasing or decreasing trend was identified. No diatom red tide occurred in the recent 3 years. Overall, the status/trend of diatom red tide in sub-area D was classified as ‘LN’.

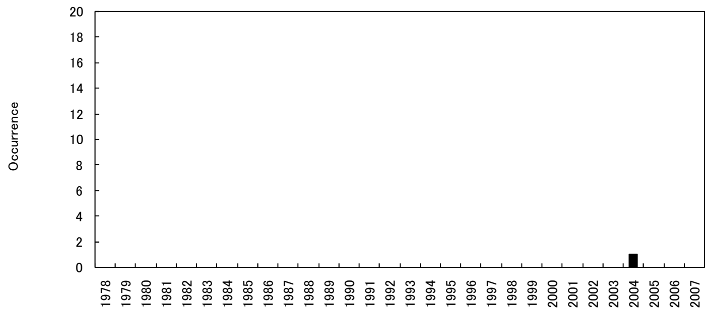

Fig. 4.55 Number of diatom red tide in sub-area D

(13) Red tide (dinoflagellate sp.)

In sub-area D, dinoflagellate red tide occurred once in 1980. No increasing or decreasing trend was identified. No dinoflagellate red tide occurred in the recent 3 years. Overall, the status/trend of dinoflagellate red tide in sub-area D was classified as ‘LN’.

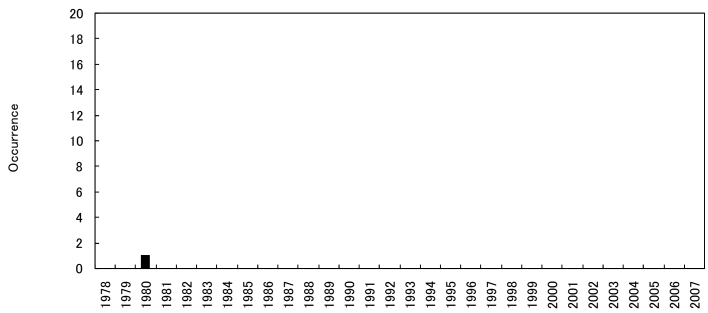

Fig. 4.56 Number of dinoflagellate red tide in sub-area D

Assessment results of category III parameters

(14) Dissolved oxygen (DO)

The annual minimum DO showed no increasing or decreasing trend at all the stations. DO concentration was particularly low at Stations 4 and 5 in 2005. The mean DO concentration of the recent 3 years ranged between 5.3-7.0 mg/l. Within the 3 stations, 2 stations were below the reference value of 6.0 mg/l. Overall, the status/trend of DO in sub-area D was classified as 'HN'.

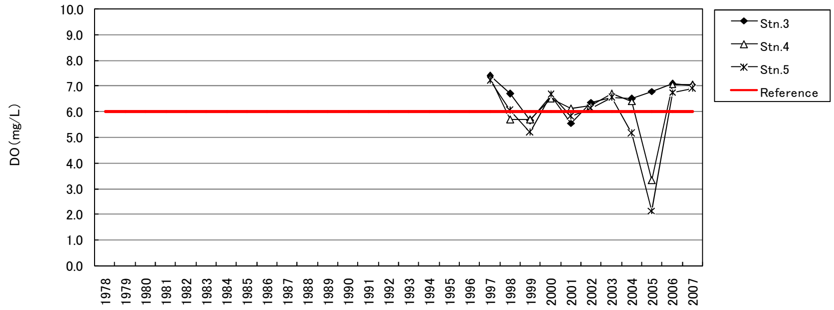

Fig. 4.57　DO concentration in sub-area D

(15) Abnormal fish kill

Incidents of abnormal fish kill were not confirmed. Therefore, its status/trend was classified as 'LN'.

(16) Chemical oxygen demand (COD)

The annual mean COD showed no increasing or decreasing trend at all the stations. The mean COD of the recent 3 years ranged between 0.5-0.6 mg/l; hence all stations were below the reference value of 3.0 mg/l. Overall, the status/trend of COD in sub-area D was classified as 'LN'.

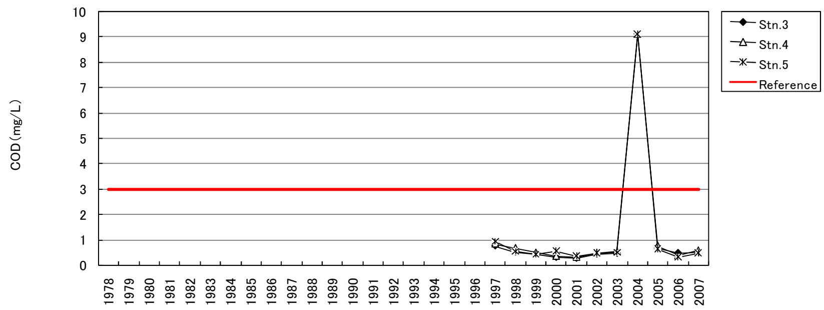

Fig. 4.58　COD concentration in sub-area D

Assessment results of category IV parameters

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

In sub-area D, *Noctiluca* red tide occurred once each in 1988, 2001, 2003 and 2005. No increasing or decreasing trend was identified. In the recent 3 years, *Noctiluca* red tide occurred once in 2005, which is below the reference value of 3 events/3 years. Overall, the status/trend of *Noctiluca* red tide in sub-area D was classified as 'LN'.

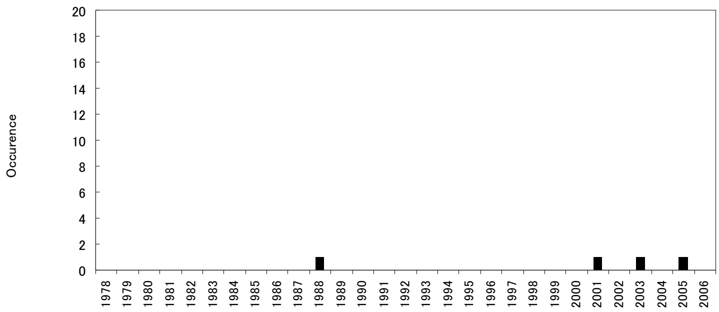

Fig. 4.59 Number of *Noctiluca* red tide in sub-area D

(18) Shellfish poisoning

Incidents of shellfish poisoning was not confirmed. Therefore, its status/trend was classified as 'LN'.

Assessment results of each assessment category

Table 4.7 Assessment results of each assessment category (sub-area D)

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

Assessment results of sub-area D (offshore area)

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

Category I (degree of nutrient enrichment) parameters: There are no rivers or sewage treatment plants that discharge directly into sub-area D. Trend analysis was not possible as TN and TP data were limited to 1997 and 1998.

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

Category III (indirect effects of nutrient enrichment) parameters: DO did not satisfy the reference value at some stations. However, no fish kill was confirmed. COD was below the reference value, and no increasing or decreasing trend was identified.

Category IV (other possible effects of nutrient enrichment) parameters: *Noctiluca* red tide occurred only once within the recent 3 years. No shellfish poisoning incidents was confirmed.

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

Table 4.8 Reasons behind the classification of each assessment category (sub-area D)

Category	Reason	Classification
I Degree of nutrient enrichment	Category I was not classified due to the following reasons: - Since sub-area D is an offshore area, there are no data on TN and TP inputs from land-based sources; - Data on TN, TP and winter DIN/DIP concentration was scarce.	—
II Direct effects of nutrient enrichment	- The mean of the annual max./mean chlorophyll-*a* concentration of the recent 3 years was not assessed as data of 2007 was limited to a single data in summer. Both annual max. and mean chlorophyll-*a* concentration showed no increasing or decreasing trend. - Diatom and dinoflagellate red tides: no increasing or decreasing trend. No occurrences in the recent 3 years.	LN
III Indirect effects of nutrient enrichment	- DO: No increasing or decreasing trend. However, DO concentration at some stations did not satisfy the reference value, in particular due to the low concentration in 2005. - Abnormal fish kill: None - COD: No increasing or decreasing trend. Concentration of the recent 3 years was low.	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: Only occurred occasionally, and when it did, it occurred at a frequency of one event per year. - Shellfish poisoning: None	LN

4.5 Comprehensive assessment of Northwest Kyushu sea area

Table 4.9 shows the assessment results of sub-areas A-D by each assessment category. Following are the main findings of each assessment category:

Category I (degree of nutrient enrichment)

The status of nutrient enrichment in sub-areas A, B and C was low. However, there was an increasing trend in sub-area A. Sub-area B had a decreasing trend. Sub-area C had no increasing or decreasing trend.

Category II (direct effects of nutrient enrichment)

The status of chlorophyll-*a* in sub-area A was high, but the trend was decreasing. The status of red tide in sub-area A was high, but there was no increasing or decreasing trend. The status of chlorophyll-*a* in sub-area B was high, but there was no increasing or decreasing trend. The status of red tide in sub-area B was low, but there was no increasing or decreasing trend. The status of sub-areas C and D was low, and there were no increasing or decreasing trend.

Category III (indirect effects of nutrient enrichment)

The status was low at all the sub-areas. All the sub-areas also had no increasing or decreasing trend.

Category IV (other possible effects of nutrient enrichment)

The status was high at sub-area C, but there was no increasing or decreasing trend. The other sub-areas had low status and no increasing or decreasing trend.

Following are the main findings of each sub-area:

Sub-area A

There was an increase in nitrogen input from the sewage treatment plants. High levels of winter DIN and chlorophyll-*a* were confirmed. Diatom and dinoflagellate red tides were also recorded.

Sub-area B

There was a significant decrease in TN and TP levels due to the reduction of nitrogen and phosphorus. However, chlorophyll-*a* concentration was slightly high.

Sub-area C

There was no increasing or decreasing trend in TN and TP inputs from the rivers. TN and TP inputs from the sewage treatment plants showed decreasing and increasing trends respectively. Although nutrient input from the Hiagari treatment center, which discharges into Kanmon Strait, was highest among the sewage treatment plants in sub-area C, TN and TP levels in Kanmon Strait were below the reference value. Diatom and dinoflagellate red tides occurred at a relatively high frequency; hence it will be necessary to investigate the causes of these red tides.

Sub-area D

Apart from the low DO level in 2005, there was no indication of effects caused by eutrophication. However, it must be noted that the parameters that indicate degree of nutrient enrichment (TN, TP, DIN and DIP) was not measured in the area, and hence assessment was difficult. In order to conduct eutrophication assessment, it will be necessary to measure these parameters in the future.

Table 4.9 Assessment results of Northwest Kyushu sea area by assessment category and sub-area

Category	Sub-area				Comment on category classification
	A	B	C	D	
I	LI	LD	LN	-	Low status in sub-areas B and C. Increase trend in sub-area A. Decrease trend in sub-area B. No increase or decrease trend in sub-area C.
II	HD-HN	LN-HN	LN	LN	High status of red tide in sub-areas A and B. Low status of red tide in sub-areas C and D. Decrease trend in chlorophyll-*a* in sub-area A. No increase or decrease trend in other parameters.
III	LN	LN	LN	LN	Low status at all sub-areas. No increase or decrease trend in all sub-areas.
IV	LN	LN	HN	LN	High status in sub-area C. Other sub-areas had low status. No increase or decrease trend in all sub-areas.

5. Conclusion and recommendation

Hakata Bay

- Although TN and TP inputs from the rivers showed a decreasing trend, TN input from the sewage treatment plants showed an increasing trend.
- There was no increasing or decreasing trend in TP input from the sewage treatment plants.
- Although the long-term trend of COD showed an increase, a decreasing trend was identified from 2000 onwards.
- TN concentration showed an increasing trend.
- TP and winter DIP concentration decreased significantly from 1994-1995 onwards. However, winter DIN concentration tended to be high; and diatom and dinoflagellate red tides were also confirmed.
- In Hakata Bay, it is important to reduce the frequency of red tides by controlling discharges from nutrient sources.
- Phosphorus levels have been decreasing in Hakata Bay. However, this has resulted in low seaweed growth due to lack of phosphorus in water (Fuchigami 2009). Therefore, it is necessary to balance nitrogen and phosphorus levels in the sea by controlling discharges of nitrogen and phosphorus.

Dokai Bay

- TN and TP levels have been on a decreasing trend, and improvements have been confirmed regarding eutrophication. However, chlorophyll-*a* levels are still high.
- Water quality improvement projects have been actively implemented in the area, and should be continued.

Intermediate area

- There was no increasing or decreasing trend in TN/TP input from the rivers.
- Although there was an increasing trend in TP input from sewage treatment plants, TP concentration in the sea area was low.
- Dinoflagellate and *Noctiluca* red tides were confirmed. The causes behind these red tides should be investigated.

Offshore area

- Apart from DO, all parameters had low concentration levels, and no increasing or decreasing trend. There was no indication of eutrophication related problems. However, there were some uncertainties in the assessment due to lack of data (e.g. DIN and DIP). The low DO levels and high COD levels are also of concern. Further assessment will be necessary.

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