A Case Study Report

on Assessment of Eutrophication Status

in the North Kyushu Sea Area, Japan

Northwest Pacific Region

Environmental Cooperation Center

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1. Scope of the assessment

1.1 Objective of the assessment

The North 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 induced by nutrient inputs from anthropogenic sources. Domestically, the area is also one of the most sensitive areas to environmental changes in the East China Sea and the 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 the North Kyushu sea area was implemented to objectively assess its eutrophication status with the NOWPAP Common Procedures for eutrophication assessment, and at the same time, to evaluate the validity of the NOWPAP Common Procedures. 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 areas

For the case study of the North 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). The boundary of the North Kyushu sea area was set as approximately 40 km offshore from the shoreline between east of the Kanmon Bridge (eastern boundary) and the 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 North Kyushu sea area is located next to the coastal side of the eastern channel of the 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 the Kanmon Strait. The North Kyushu sea area receives nutrients from rivers (there are in total 34 rivers (e.g. the 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 the Onga River predominates.

Fig. 1.1 Case study area of the North Kyushu sea area

1.3 Collection of relevant information

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

Table 1.1 Information collected for the eutrophication assessment of the North 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, Transparency, etc.	1-25/year
	Environmental Bureau, Kitakyushu City	Survey of Kitakyushu City Institute of Environmental Sciences	Monitoring of hypoxic water	DO: 1994-2000, 2004, 2006-2010 TN and TP (direct input from plants): 1998, 2004-2010	TN and TP, direct input from plants	1-14 / year
	Environmental Bureau, Fukuoka City	Measures and survey results of Hakata Bay	Water quality conservation of Hakata Bay	2002-2010	DO	6-25 / 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*, transparency	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 the North 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 North 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 North 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 North Kyushu sea area case study

Category		Assessment parameter
I	Degree of nutrient enrichment	(1) Riverine input: TN and TP
		(2) Input from direct discharge: TN and TP
		(3) TN and TP concentration
		(4) Winter DIN and DIP concentration
		(5) Winter DIN/DIP ratio
II	Direct effects of nutrient enrichment	(1) chlorophyll-*a* concentration (in-situ data)
		(2) Red tide (diatom sp.)
		(3) Red tide (dinoflagellate sp.)
III	Indirect effects of nutrient enrichment	(1) DO
		(2) Fish kill incidents
		(3) COD
		(4) Transparency
IV	Other possible effects of nutrient enrichment	(1) Red tide (*Noctiluca* sp.)
		(2) Shellfish poisoning incidents

1.5 Setting of sub-areas

The North Kyushu sea area was divided into sub-areas using the results of the preliminary eutrophication assessment, which was conducted with satellite data (see Fig. 1.2 for the results). The North Kyushu sea area is connected to the Seto Inland Sea through the Kanmon Strait. Small bays such as Dokai Bay, Hakata Bay, and Karatsu Bay are located adjacent to 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 the Kanmon Strait.

According to the monitoring results by remote sensing from 1997 to 2009, chlorophyll-*a* concentration was high (>5 μg/L) in the sea areas around Hakata Bay and Dokai Bay, and showed an increasing trend in some sea 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) (see Fig. 1.3). Fig. 1.4 shows the boundary of each sub-area. The Kanmon Strait was included into the intermediate area (sub-area C). Although the offshore waters of the 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 for that area.

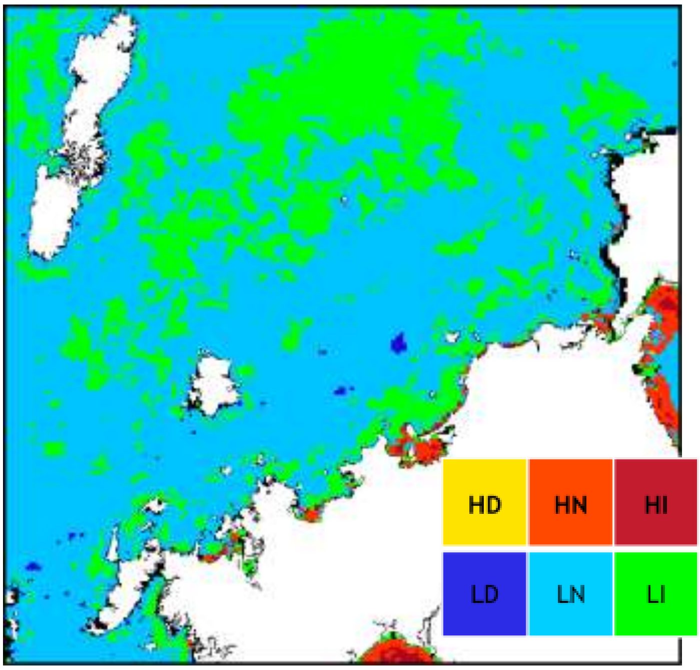

Fig. 1.2 Results of the preliminary eutrophication assessment of the North Kyushu sea area

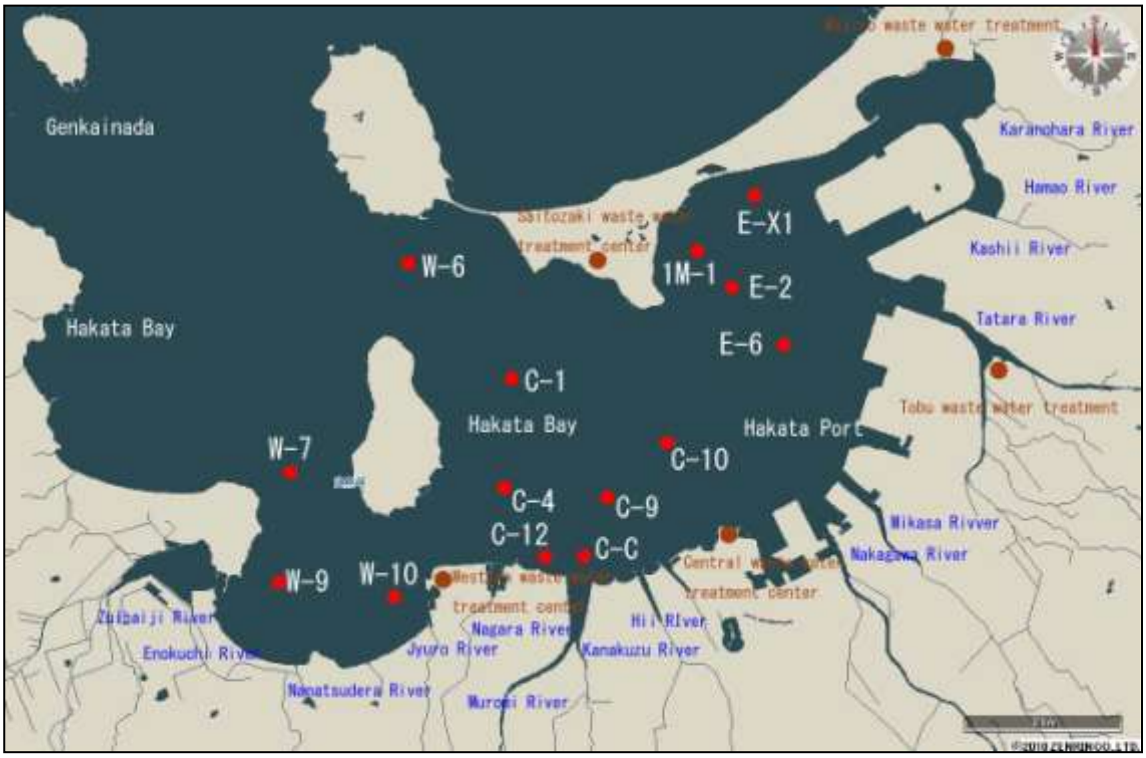

Fig. 1.3(1) Sub-area A of the North Kyushu sea area

Fig. 1.3(2) Sub-area B of the North Kyushu sea area

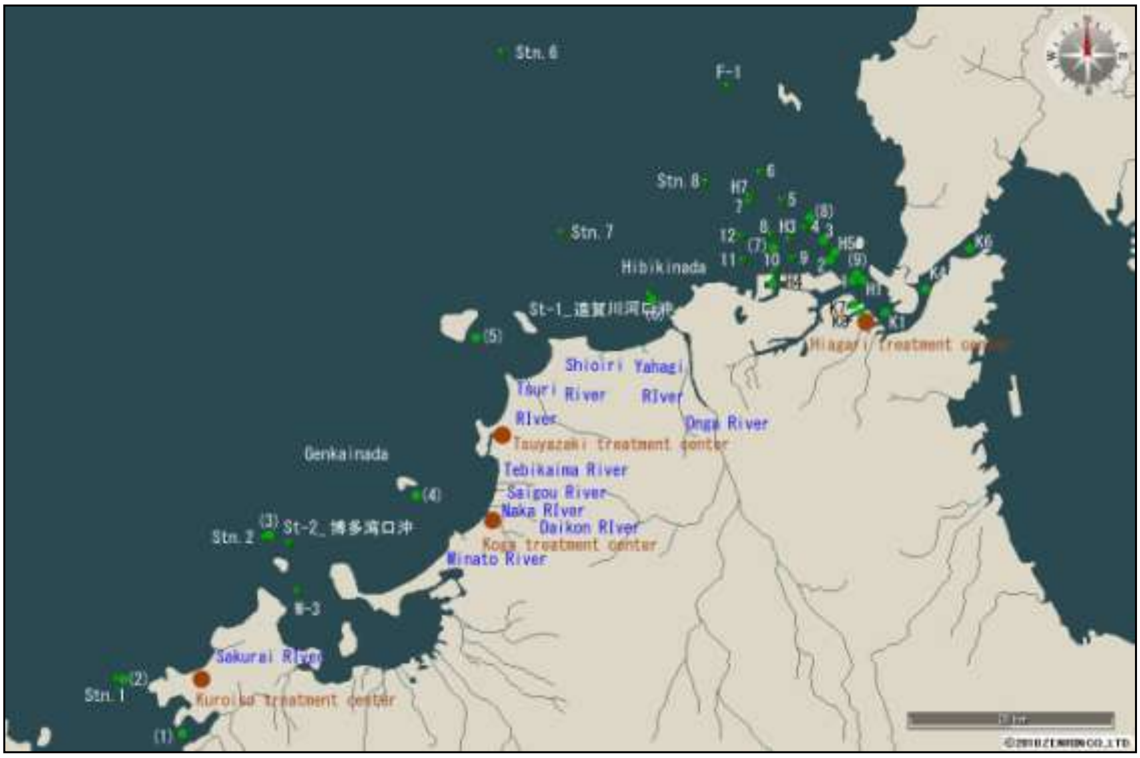

Fig. 1.3(3) Sub-area C of the North Kyushu sea area

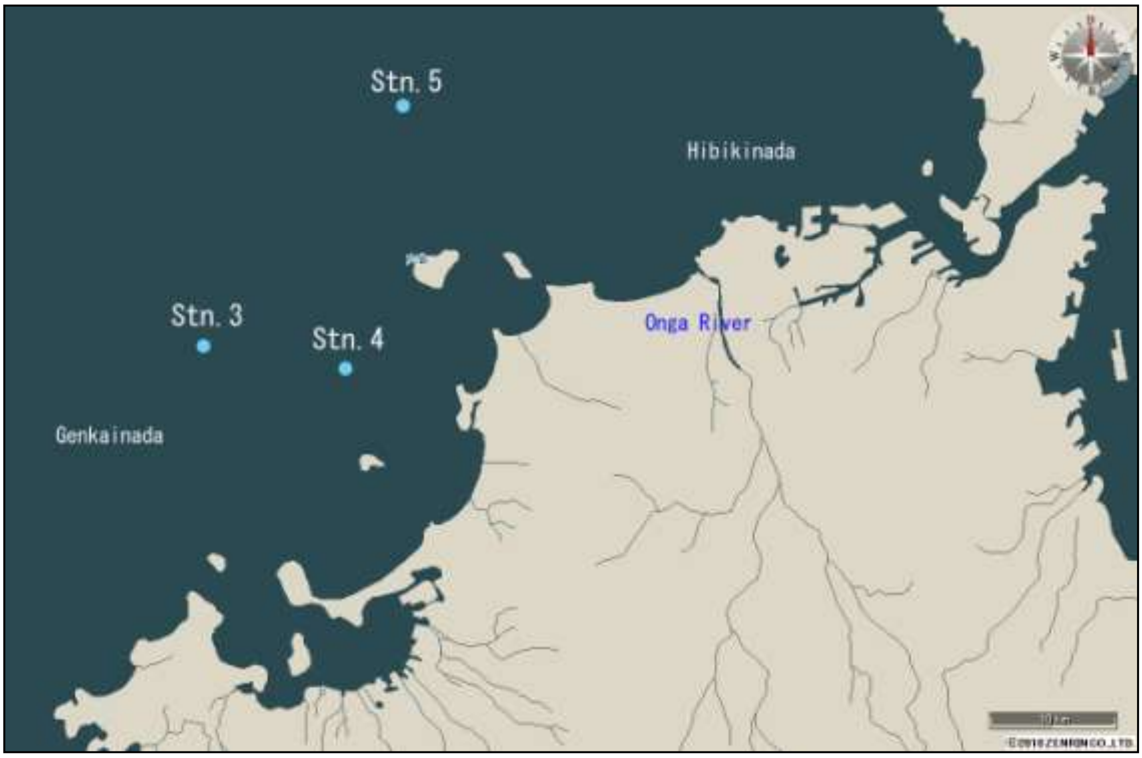

Fig. 1.3(4) Sub-area D of the North Kyushu sea area

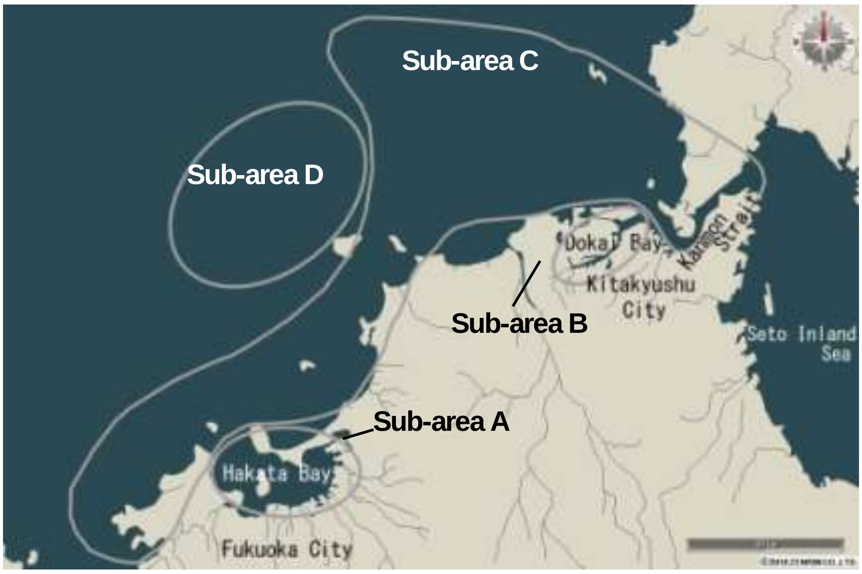

Fig. 1.4 Boundaries of the sub-areas of the North Kyushu sea area

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"	
	C-C	-	33˚36'03"	130˚21'36"	
	C-12	-	33˚36'05"	130˚21'08"	
	1M-1	-	33˚36'15"	130˚21'04"	
	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"	
	W-10	-	33˚35'30"	130˚18'02"	
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"	
	D2	40-604-01	33˚55'30"	130˚49'30"	
	St.1	-	-	-	Survey of Kitakyushu City Institute of Environmental Sciences
	St.2	-	-	-	
	St.3	-	-	-	
	St.4	-	-	-	
	St.5	-	-	-	
	St.5B	-	-	-	
	St.6	-	-	-	
	St.7	-	-	-	
C Intermediate area	H1	40-605-01	33˚56'25"	130˚51'51"	Water quality survey of public waters
	H3	40-605-52	33˚58'24"	130˚47'27"	
	H4	40-605-53	33°56'03"	130°46'21"	
	H5	40-605-02	33°57'54"	130°50'15"	
	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"	
	K7	40-602-01	33°55'16"	130°51'31"	
	K8	40-603-01	33°54'51"	130°51'51"	
	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"	
	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″	
	4	─	33˚59'00"	130˚48'30"	
	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"	
	(1)	─	33°32'00″	130°08'00″	
	(2)	─	33°35'00″	130°03'40″	
	(3)	─	33°42'56″	130°12'84″	
	(4)	─	33°44'00″	130°24'00″	
	(5)	─	33°52'50″	130°27'00″	
	(6)	─	33°55'15″	130°38'23″	

Sub-area	Station name	Station no.	Latitude	Longitude	Survey title
	(7)	—	33°57'54″	130°45'87″	
	(8)	—	33°59'17″	130°48'41″	
	(9)	—	33°56'19″	130°51'40″	
	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"	

N.B.: DO is measured at A Hakata Bay C-12, C-C, 1M-1, W-10, and B Dokai Bay St.1-St.7, St.5B.

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			
	D2			
C Intermediate area	K7	IV (1.0 mg/L)	IV (0.09 mg/L)	
	K8			
	H1	II (0.3 mg/L)	II (0.03 mg/L)	
	H3			
	H4			
	H5			
	K1			
	K4			
	K6			
	H7			
	W-3			
	St-1 Offshore of Onga rivermouth			
	St-2 Offshore of mouth of Hakata Bay			
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	Stn.1			
	Stn.2			
	Stn.6			
	Stn.7			
	Stn.8			
	(1)			
	(2)			
	(3)			
	(4)			
	(5)			
	(6)			
	(7)			
	(8)			
	(9)			
	F-1			
D Offshore area	Stn.3	II (0.3 mg/L)	II (0.03 mg/L)	
	Stn.4			
	Stn.5			

N.B.: DO is measured at A Hakata Bay C-12, C-C, 1M-1, W-10, and B Dokai Bay St.1-St.7, St.5B, so the standard is not listed here.

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; Environmental Bureau, Kitakyushu City; 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 1.6 shows the data processing methodologies applied for each assessment parameter. Table 1.7 shows the laboratory analysis method of chemical assessment parameters.

Table 1.6(1) Data processing methodologies applied for the North Kyushu sea area case study (category I)

	Assessment parameter	Data processing methodology
I	(1) Riverine input of TN	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 2010.
	(2) Riverine input of TP	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 2010.
	(3) Input from direct discharge of TN	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 2010.
	(4) Input from direct discharge of TP	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 statistics. 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 2010.
	(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 (2008-2010) was compared with the reference value. The trend of the annual mean value from 1978 to 2010 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 (2008-2010) was compared with the reference value. The trend of the annual mean value from 1978 to 2010 was also analyzed.
	(7) Winter DIN concentration	Winter mean value was calculated by averaging the monthly data of three winter months (Jan.-Mar.), chosen because of the limited reproduction of phytoplankton which can show the average potential DIN amount before spring algal blooms. Data was acquired from the ‘water quality survey of public waters’ and ‘fixed-line survey of shallow waters’. The reference value was set based on the relationship between TN and DIN. The mean value of the recent three years (2008-2010) was compared with the reference value. The trend of the winter mean value from 1978 to 2010 was also analyzed.
	(8) Winter DIP concentration	Winter mean value was calculated by averaging the monthly data of three winter months (Jan.-Mar.), chosen because of the limited reproduction of phytoplankton which can show the average potential DIN amount before spring algal blooms. Data was acquired from the ‘water quality survey of public waters’ and ‘fixed-line survey of shallow waters’. The reference value was set based on the relationship between TP and DIP. The mean value of the recent three years (2008-2010) was compared with the reference value. The trend of the winter mean value from 1978 to 2010 was also analyzed.
	(9) Winter DIN/DIP ratio	Calculated from the winter DIN and DIP concentrations. The mean value of the recent three years (2008-2010) was compared with the reference value. The trend of the winter mean value from 1978 to 2010 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 1.6(2) Data processing methodologies applied for the North Kyushu sea area case study (categories II-IV)

	Assessment parameter	Data processing methodology
II	(10) Annual maximum chlorophyll-*a* concentration	The annual maximum value was determined by selecting the maximum value from one year's worth of 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 (2008-2010) was compared with the reference value. The trend of the annual maximum value from 1975 to 2010 was also analyzed.
	(11) Annual mean chlorophyll-*a* concentration	The 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 (2008-2010) was compared with the reference value. The trend of the annual mean value from 1975 to 2010 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 (2008-2010) was compared with the reference value. The trend of diatom red tide was analyzed from 1978 to 2010.
	(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 (2008-2010) was compared with the reference value. The trend of dinoflagellate red tide was analyzed from 1978 to 2010. *Noctiluca* sp. was not included.
III	(14) Annual minimum DO concentration at bottom layer	The annual minimum value was determined by selecting the minimum value from one year's worth of 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 (2008-2010) was compared with the reference value. The trend of the annual minimum value from 1978 to 2010 was also analyzed.
	(15) Fish kill incidents	The number of fish kill incidents caused by both anthropogenic and natural water quality changes was counted by referring to the data collected by Fukuoka Prefecture. The total number of abnormal fish kill incidents in the recent three years (2008-2010) was compared with the reference value. The trend of fish kill incidents was analyzed from the 1970s to 2010.
	(16) COD	The annual mean value was calculated by averaging one year's worth of 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 (2008-2010) was compared with the reference value. The trend of the annual mean value from 1978 to 2010 was also analyzed.
	(17) Transparency	The annual mean value was calculated by averaging one year's worth of 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 (2008-2010) was compared with the reference value. The trend of the annual mean value from 1978 to 2010 was also analyzed.
IV	(18) 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 (2008-2010) was compared with the reference value. The trend of *Noctiluca* red tide was analyzed from 1978 to 2010.
	(19) Shellfish poisoning incidents	The number of shellfish poisoning incidents was counted by referring to the data collected by Fukuoka City. The total number of shellfish poisoning in the recent three years (2008-2010) was compared with the reference value. The trend of shellfish poisoning incidents was analyzed from the 1970s to 2010.

Table 1.7 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 standards

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 1.8).

For the case study of the North Kyushu sea area, reference values were set for each assessment parameter by referring to the above water quality standards (see Table 1.9). For total nitrogen (TN) and total phosphorus (TP), the pre-designated 'Environmental water quality standard' was applied for the survey stations of the 'Water quality survey of public water' shown in Table 1.5. The 'Environmental water quality standard' for Type II water use was applied for the survey stations of other surveys. In Subarea A and B, the concentration of DO was referred to the level at which normal concentration distribution of seabed benthos is compromised. And in Subarea C and D, the concentration of DO was referred to the level of which the minimum summer bottom layer of the inner bay fishing must be maintained, according to the 'Fisheries water quality standard'. 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 North 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 Figures 1.5 and 1.6). 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 1.10).

Table 1.8 Standards of the 'Environmental water quality standard' and 'Fisheries water quality standard'

Category	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	Fishery Type 1[4]
		0.3 mg/l	Type II	0.6 mg/l	Fishery Type 2
		0.6 mg/l	Type III	1.0 mg/l	Fishery Type 3
		1.0 mg/l	Type IV		
	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	Annual maximum Chlorophyll-*a* concentration	None		None	
	Annual average Chlorophyll-*a* concentration	None		None	
III	Annual minimum DO	7.5 mg/l	Type A[3]		
		5 mg/l	Type B	6 mg/l	General
		2 mg/l	Type C	4.3 mg/l	Inner bay fishing ground
	COD[1]	2 mg/l	Type A		
		3 mg/l	Type B	1 mg/l	General
		8 mg/l	Type C	2 mg/l	Laver farm or enclosed bay

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

2) Type I: Conservation of natural environment

Type II: Fishery class 1, bathing

Type III: Fishery class 2

Type IV: Fishery class 3, industrial water, conservation of habitable environment for marine biota

3) Type A: Fishery class 1, bathing, conservation of natural environment

Type B: Fishery class 2, industrial water

Type C: Conservation of environment

4) Fishery Type 1: Stable and well-balanced catch of various fishery species including benthic fish/shellfish

Fishery Type 2: Large catch of fishery species, except certain benthic fish/shellfish

Fishery Type 3: Catch of fishery species tolerant to pollution

Table 1.9 Reference values applied for the eutrophication assessment of the North Kyushu sea area case study

	Assessment parameter	Reference value	Remarks
I	(1) Riverine input of TN	-	
	(2) Riverine input of TP	-	
	(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	0.170 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	0.010 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) Annual minimum DO at bottom layer	4.3 mg/l	Fisheries water quality standard
		3.6 mg/l	5)
	(15) Fish kill incidents	1 event/3 year	
	(16) COD	3.0 mg/l	Environmental water quality standard Type B
	(17) Transparency	-	
IV	(18) Red tide (*Noctiluca* sp.)	3 events/3 year	
	(19) Shellfish poisoning incidents	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)

5) The level that normal concentration distribution of seabed benthos is compromised based on Yanagi (1989)

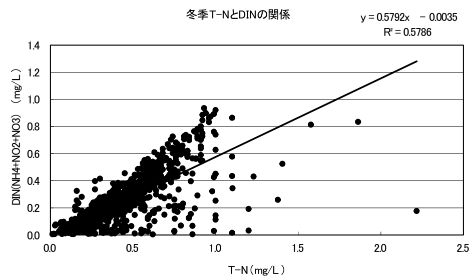

Fig. 1.5 Relationship between winter TN and DIN in the North Kyushu sea area

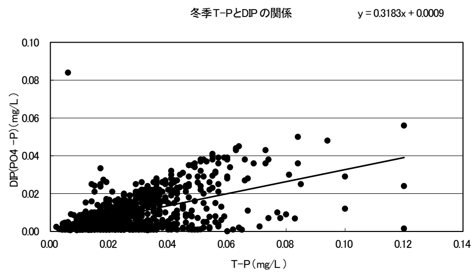

Fig. 1.6 Relationship between winter TP and DIP in the North Kyushu sea area

Table 1.10 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 (2008-2010) was compared with the reference value listed in Table 1.9. However, assessment was not conducted when data availability was limited to less than three years within the five-year period from 2006 to 2010. 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) fish kill incidents' and '(18) shellfish poisoning incidents'. 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 tides 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, trend respectively. Trend analysis was not conducted with survey stations that had less than five years of data; in such cases 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, according to the three trends of increasing trend, no change, and decreasing trend. Since a healthy marine environment is usually associated with high DO concentration and transparency, an increasing trend is shown by a blue line and an decreasing trend is shown by a red line.

Table 1.11 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. 1.7). 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. 1.8).

The status of each assessment category was determined by selecting the classifications that occurred more frequently with the 'comparison/occurrence' tools (H or L) and by selecting the classifications that occurred most frequently with the 'trend' tool (I, N or D). In case the above frequency was equivalent, the status of the category was classified with a range.

Table 1.11 The identification tools applied for the assessment parameters of the North Kyushu sea area case study

Category	Assessment parameter	Assessment value	Identification tool			Remarks
			Comparison	Occurrence	Trend	
I	(1) Riverine input of TN	Annual mean			✓	
	(2) Riverine input of TP	Annual mean			✓	
	(3) Input from direct discharge of TN	Annual mean				
	(4) Input from direct discharge of TP	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 at bottom layer	Annual min.	✓		✓	
	(15) Fish kill incidents	Annual mean		✓	✓	
	(16) COD	Annual no. of incidents	✓		✓	
	(17) Transparency		✓		✓	
IV	(18) Red tide (*Noctiluca* sp.)	Annual no. of events		✓	✓	
	(19) Shellfish poisoning incidents	Annual no. of incidents		✓	✓	

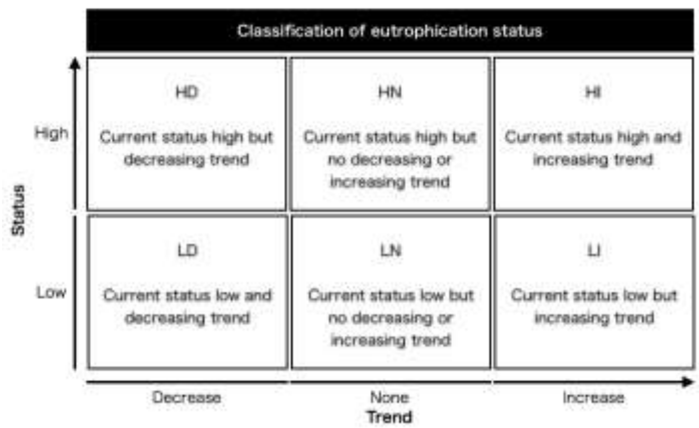

Fig. 1.7 The six classification categories stipulated in the Common Procedures (for 'status' and 'trend')

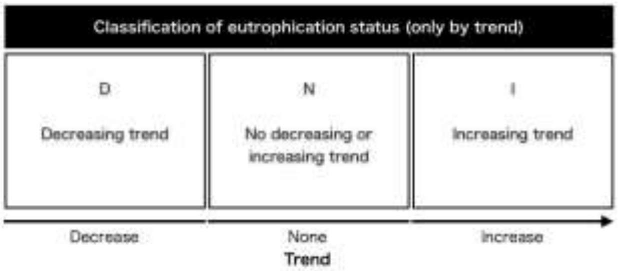

Fig. 1.8 The three classification categories stipulated in the Common Procedures (for 'trend' only)

4. Results

4.1 Sub-area A (Hakata Bay)

Assessment results of category I parameters

(1) Riverine input of TN

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 in 1993 to 1,642 ton/year in 2010. Within the thirteen rivers, inputs from the Mikasa River and the Tatara River contributed to 57-83% of the sum of TN input. Throughout the period from 1985 to 2010, within the thirteen rivers, TN input from twelve rivers showed a decreasing trend. No trend was identified with the Tatara 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'. Throughout the past ten-year period from 2001 to 2010, of the thirteen rivers, even though TN input from ten rivers showed no trend, TN input from all rivers showed a decreasing trend.

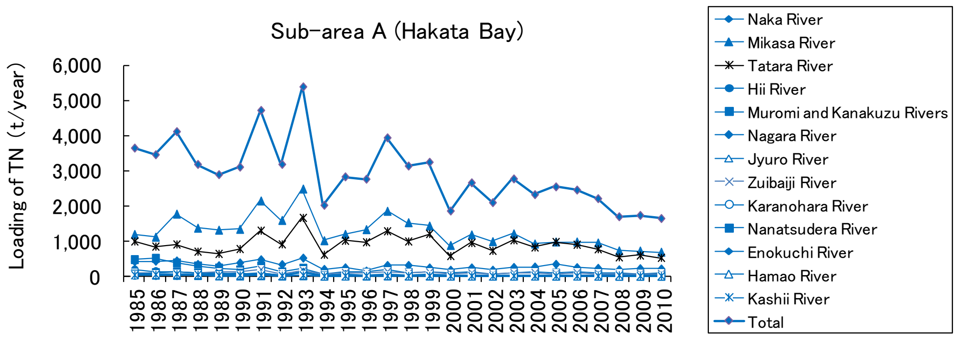

Fig. 1.9 TN input from the rivers of sub-area A

(2) Riverine input of TP

The sum of TP input from all the rivers of sub-area A has decreased from 375 tons/year in 1993 to 139 tons/year in 2010. As was the case with TN, inputs from the Mikasa River and the Tatara River dominated, contributing to 58-79% of the total TP input. Throughout the period from 1985 to 2010, TP input from twelve out of the thirteen rivers showed a decreasing trend. No trend was identified with the 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'. Throughout the past ten-year period from 2001 to 2010, TP input from eleven out of the thirteen rivers showed no trend. Overall, TP input from the total of all rivers showed no trend.

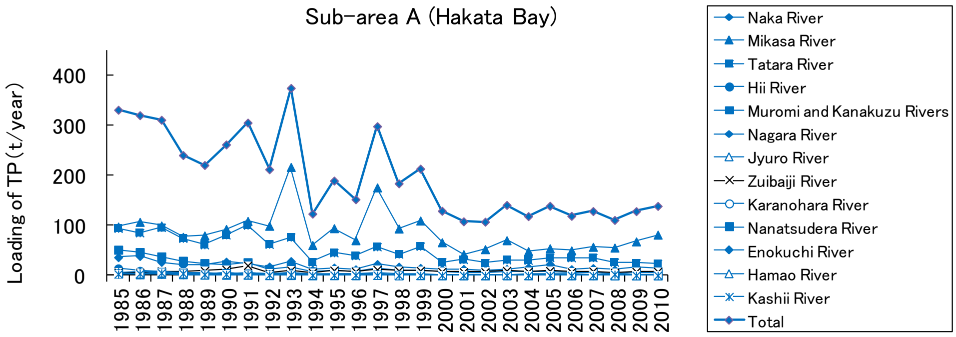

Fig. 1.10 TP input from the rivers of sub-area A

(3) Input from direct discharge of TN

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. Throughout the period from 1995 to 2010, 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 no trend, the trend of TN input from the sewage treatment plants of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, TN inputs from the Wajiro wastewater treatment center and the Western wastewater treatment center showed an decreasing trend., while no trend was identified with the other three plants. The sum of TN input from the five plants showed no trend.

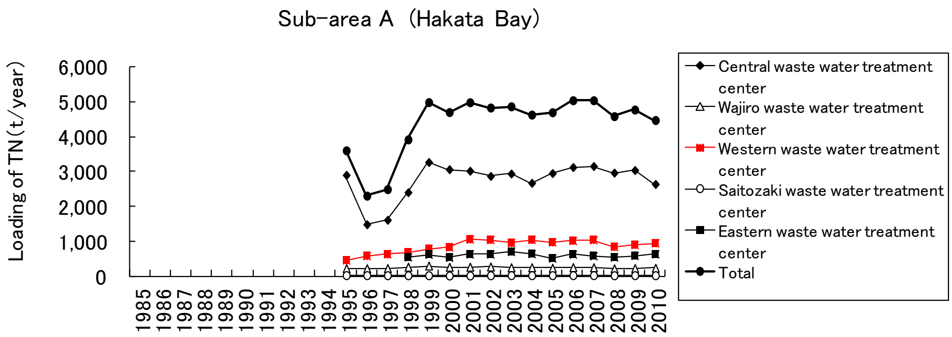

Fig. 1.11 Input from direct discharge of TN of sub-area A

(4) Input from direct discharge of TP

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 43-74% of the sum of TP input. Throughout the period of 1995 and 2010, TP input from the Central wastewater treatment center showed a decreasing trend. No trend was identified with the other four 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 and stayed at a certain level from 2005. Throughout the past ten-year period from 2001 to 2010, TP input from all wastewater treatment centers showed no trend and the sum of TP input from five plants showed no trend.

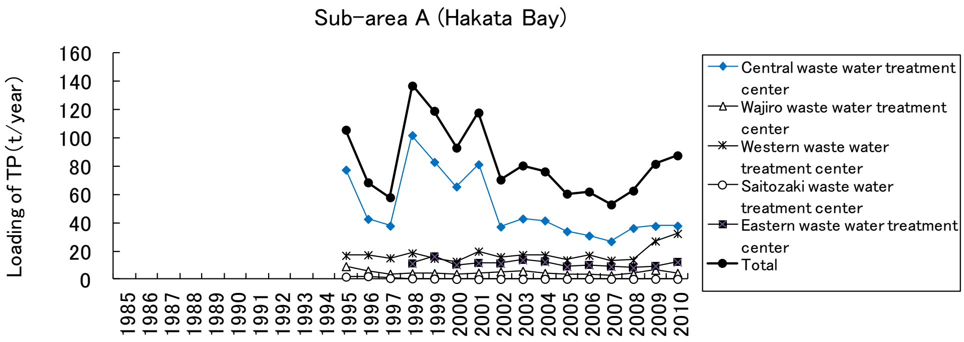

Fig. 1.12 Input from direct discharge of TP of sub-area A

(5) TN concentration

In sub-area A, there are ten survey stations, and data were available for the past thirty-three years from 1978 to 2010. Within the ten stations, annual mean TN concentrations showed increasing trends with eight stations (C-1, C-4, C-10, E-2, E-6, W-6, W-7 and W-9), and no trends with two stations (C-9 and E-X1). Since most of the stations showed an increasing trend, the trend of TN concentration of sub-area A was classified as ‘Increasing trend’. Throughout the past ten-year period from 2001 to 2010, all stations showed no trend.

The TN concentrations of the recent three years of east (E-2, E-6 and E-X1) and central (C-1, C-4, C-9 and C-10) sea areas were compared with their respective reference values of 0.6 mg/L (Reference III). The TN concentrations of west (W-6, W-7 and W-9) sea areas were compared with the reference value 0.3 mg/L (Reference II). Four stations (E-X1, W-6, W-7 and W-9) were above and six 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’.

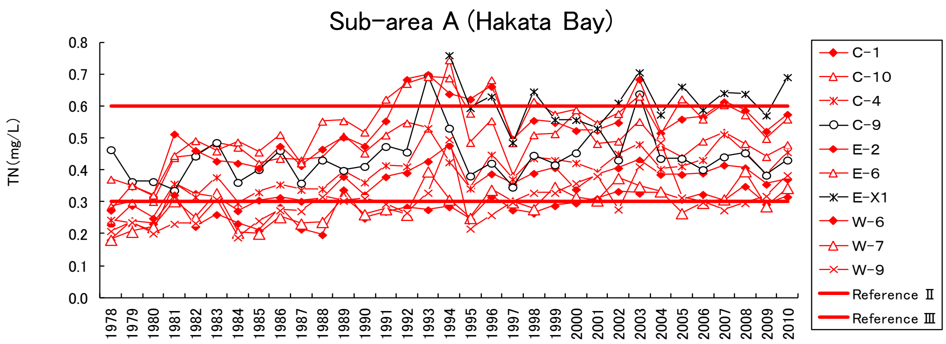

Fig. 1.13 TN concentration in sub-area A

(6) TP concentration

Throughout the period from 1978 to 2010, within the ten stations, nine stations (C-1, C-4, C-9, C-10, E-2, E-6, E-X1, W-6, and W-7) showed decreasing trends in annual mean TP concentrations. One station (W-9) showed no trend. Since most of the stations showed decreasing trend, the trend of TP concentration of sub-area A was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, all stations showed no trend.

Mean TP concentrations of the recent three years of east (E-2, E-6 and E-X1) and central (C-1, C-4, C-9 and C-10) sea areas were compared with their respective reference values 0.05 mg/L. Mean TP concentration of west (W-6, W-7 and W-9) sea areas was compared with the reference value 0.03 mg/L. 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 Decreasing trend'.

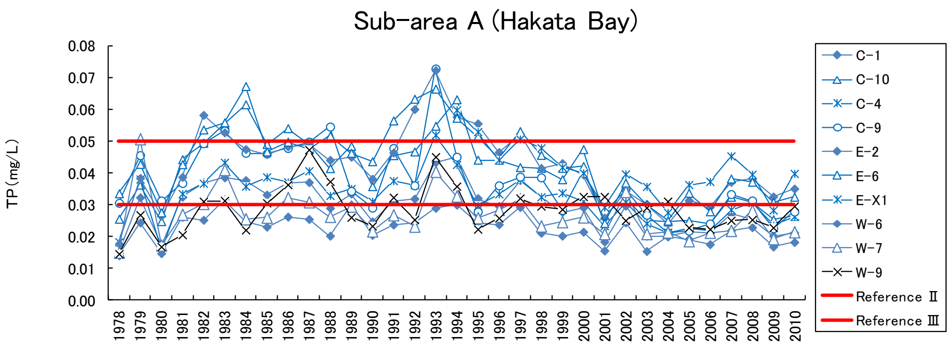

Fig. 1.14 TP concentration in sub-area A

(7) Winter DIN concentration

Throughout the period from 1978 to 2010, within the ten stations, eight stations showed increasing trends in winter DIN concentrations. The other two stations (W-7 and W-9) showed no trends. Since most of the stations showed increasing trend, the trend of winter DIN concentration of sub-area A was classified as 'Increasing trend'. Throughout the past ten-year period from 2001 to 2010, all stations showed no trend.

Mean winter DIN concentrations of the recent three years of east (E-2, E-6 and E-X1) and central (C-1, C-10, C-9 and C-4) sea areas were compared with their respective reference values of 0.340 mg/L (24.3 µM). The mean winter DIN concentrations of west (W-6, W-7 and W-9) sea areas were compared with the reference value of 0.170 mg/L (12.1 µM). Within the ten stations, eight stations (C-9, C-10, E-2, E-6, E-X1, W-6, W-7 and W-9) were above the reference values and two stations were below 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'.

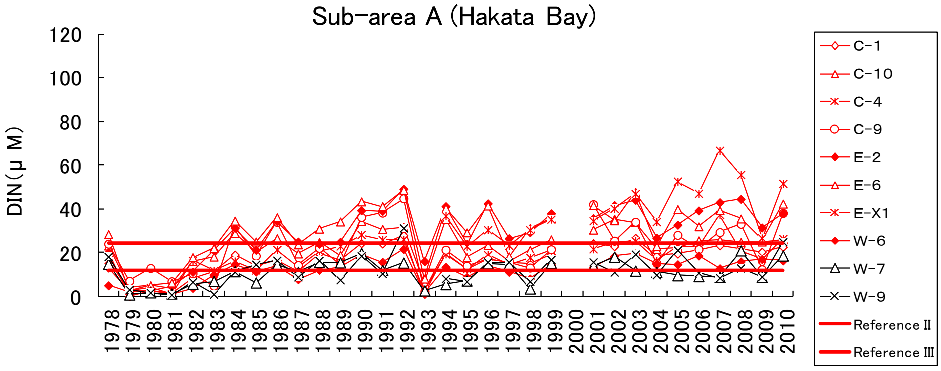

Fig. 1.15 Winter DIN concentration in sub-area A

(8) Winter DIP concentration

Throughout the period from 1978 to 2010, within the ten stations, eight stations showed no trends in winter DIP concentrations. The other two stations (C-4 and C-10) showed decreasing trends. Since most of the stations showed no trend, the trend of winter DIP concentration of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, within the ten stations, eight stations showed no trends in winter DIP concentrations. The other two stations (C-1 and W-6) showed decreasing trends. Therefore, most of the stations showed no trends.

Mean winter DIP concentrations of the recent three years of east (E-2, E-6 and E-X1) and central (C-1, C-4, C-9 and C-10) sea areas were compared with their respective reference values of 0.017 mg/L (0.55 μM). Mean winter DIP concentrations of west (W-6, W-7 and W-9) sea areas were compared with the reference value of 0.010 mg/L (0.36 μM). All the ten stations were below the reference values.

Overall, the status and trend of winter DIP concentration in sub-area A was classified as 'Low eutrophication status and No trend'.

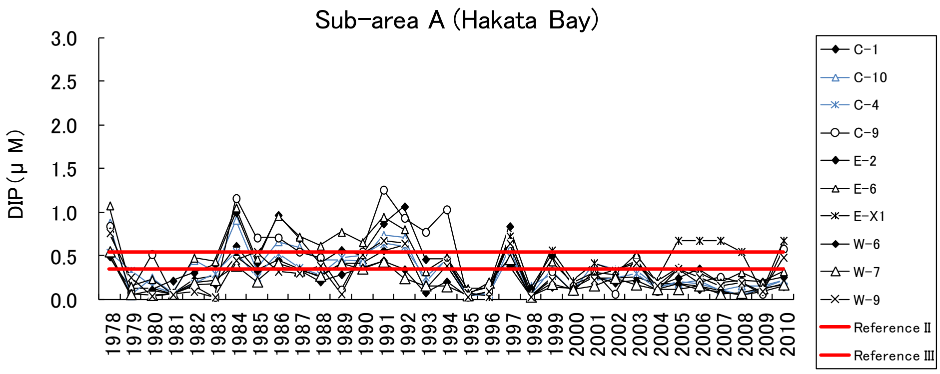

Fig. 1.16 Winter DIP concentration in sub-area A

(9) Winter DIN/DIP ratio

Throughout the period from 1978 to 2010, within the ten stations, nine stations showed increasing trends in winter DIN/DIP ratio. One station (E-X1) showed no trend. Since most of the stations showed increasing trends, the trend of winter DIN/DIP ratio of sub-area A was classified as 'Increasing trend'. Throughout the past ten-year period from 2001 to 2010, within the ten stations, six stations showed no trends in winter DIN/DIP ratio. The other four stations (C-1, C-4, C-10 and W-6) showed increasing trends. Therefore, most of the stations showed no trends.

Mean winter DIN/DIP ratio of the recent three years ranged from 70 to 232. 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'.

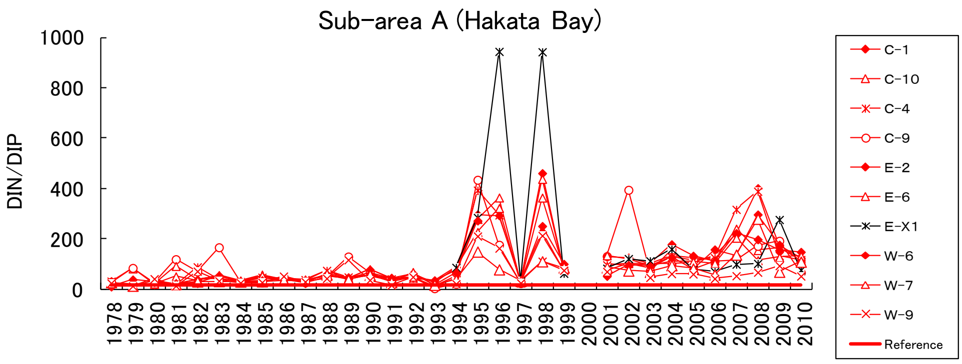

Fig. 1.17 Winter DIN/DIP ratio in sub-area A

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Throughout the period from 1981 to 2010, within the ten stations, eight stations showed no trends in annual maximum chlorophyll-*a* concentrations. The other two stations (C-10 and E-6) showed decreasing trends. Since most of the stations showed no trend, the trend of annual maximum chlorophyll-*a* concentrations of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, all stations showed no trends in annual maximum chlorophyll-*a* concentrations. In addition, E-2 had data of nine years from 2001 to 2010.

The mean of the annual maximum chlorophyll-*a* concentrations of the recent three years ranged between 31-69 µg/L. All stations were above the reference value (20 µg/L).

Overall, the status and trend of annual maximum chlorophyll-*a* concentration in sub-area A was classified as 'High eutrophication status and No trend'.

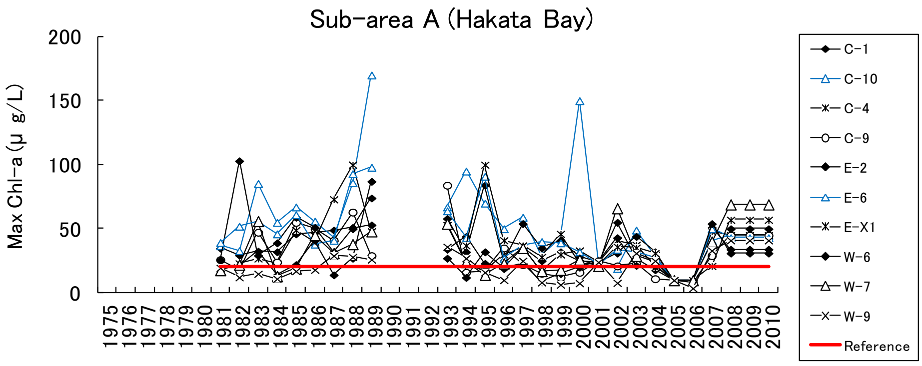

Fig. 1.18 Annual maximum chlorophyll-*a* concentration in sub-area A

(11) Annual mean chlorophyll-*a* concentration

Throughout the period from 1981 to 2010, within the ten stations, seven stations showed no trends in annual mean chlorophyll-*a* concentrations. The other three stations (C-1, C-10 and E-6) showed decreasing trends. Since most of the stations showed no trend, the trend of annual mean chlorophyll-*a* concentrations of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, all stations showed no trends in annual mean chlorophyll-*a* concentrations. In addition, E-2 had data of nine years from 2001 to 2010.

The mean of the annual mean chlorophyll-*a* concentration of the recent three years ranged between 9.1-23.7 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 No trend'.

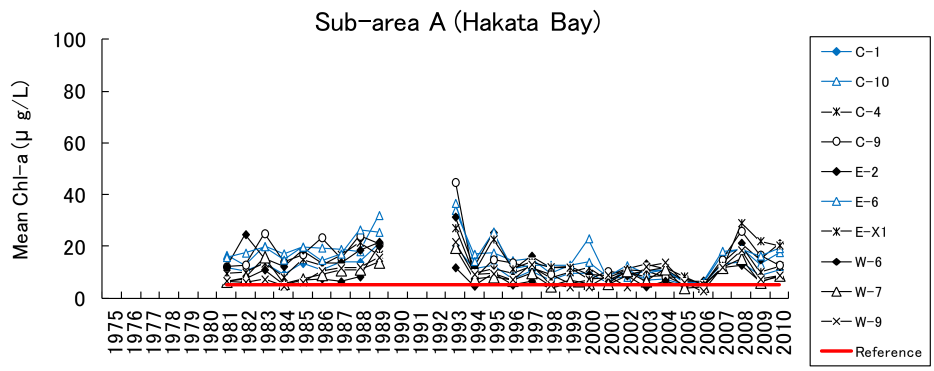

Fig. 1.19 Annual mean chlorophyll-*a* concentration in sub-area A

(12) Red tide (diatom sp.)

Throughout the period from 1978 to 2010, except 1989, the number of diatom red tide in sub-area A ranged between 1-18 events/year. Since no trend was identified, the trend of diatom red tide of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, the number of diatom red tide in sub-area A ranged between 1-10 events/year. Therefore, it showed no trends in the number of diatom red tide.

Within the recent three years, the number of diatom red tide ranged between 2-4 events/year.

Overall, the status and trend of diatom red tide in sub-area A was classified as 'High eutrophication status and No trend'.

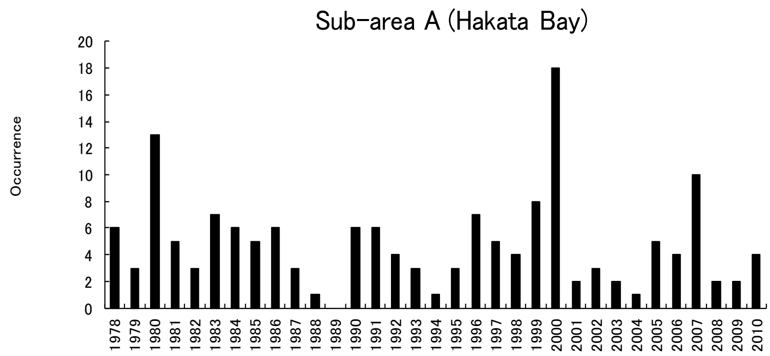

Fig. 1.20 Number of diatom red tide in sub-area A

(13) Red tide (dinoflagellate sp.)

Throughout the period from 1978 to 2010, except 1998, the number of dinoflagellate red tide in sub-area A ranged between 1-10 events/year. Since no trend was identified, the trend of dinoflagellate red tide of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, the number of dinoflagellate red tide in sub-area A ranged between 1-7 events/year. Therefore, it showed no trends in the number of dinoflagellate red tide.

Within the recent three years, the number of dinoflagellate red tide ranged between 1-3 events/year.

Overall, the status and trend of dinoflagellate red tide in sub-area A was classified as 'High eutrophication status and No trend'.

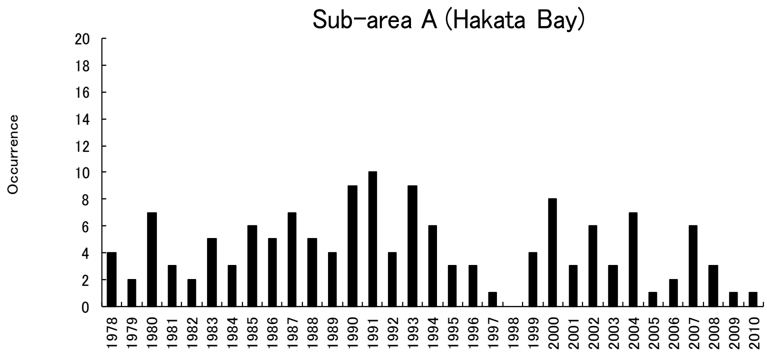

Fig. 1.21 Number of dinoflagellate red tide in sub-area A

Assessment results of category III parameters

(14) Dissolved oxygen (DO) at bottom layer

Throughout the period from 1978 to 2010, within the fourteen stations, eight stations (C-1, C-9, C-10, E-6, W-6, W-9, W-10 and 1M-1) showed no trends in annual minimum DO concentrations. Two stations (C-4 and W-7) showed increasing trends. The other two stations (E-2 and E-X1) showed decreasing trends. But because the data was insufficient, it was difficult to determine the trends. Since most of the stations showed no trend, the trend of annual minimum DO concentrations of sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, within the fourteen stations, ten stations showed no trend, and one station (W-9) showed increasing trend, and another station (E-X1) showed decreasing trend. Because the data of two stations was insufficient, it was difficult to determine the trend. Therefore, most of the stations showed no trend.

The mean DO concentrations of the recent three years ranged between 0.8-8.5 mg/L. Even though two stations did not satisfy the reference value of 3.6 mg/L, the ratio of stations that satisfied the reference values was dominant. And, the assessment method of DO was based on the method in section '3.2'. The determination was reverse to the other parameters.

Overall, the status and trend of DO in sub-area A was classified as 'Low eutrophication status and No trend'.

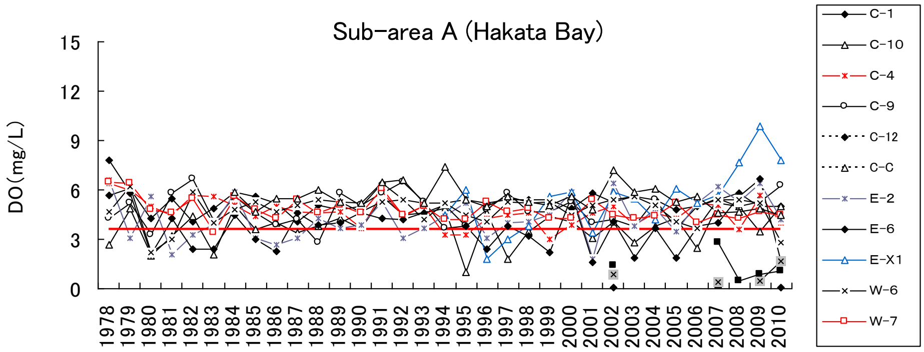

Fig. 1.22 DO concentration in sub-area A

(15) Fish kill incidents

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)

Throughout the period from 1978 to 2010, all the stations showed no trends in annual mean of COD, therefore, the trend of COD in sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, within the ten stations, five stations showed no trends and the other five stations (C-1, C-10, W-6, W-7 and W-9) showed decreasing trends in annual mean COD. The number of stations showed no trends and the number of stations showed decreasing trends were the same.

The mean COD of the recent three years ranged between 1.6-3.2 mg/L. One station (E-X1) was above the reference value (3.0 mg/L) and nine stations were below the reference value. The ratio of stations that were below the reference value was dominant.

Overall, the status and trend of COD in sub-area A was classified as 'Low eutrophication status and No trend'.

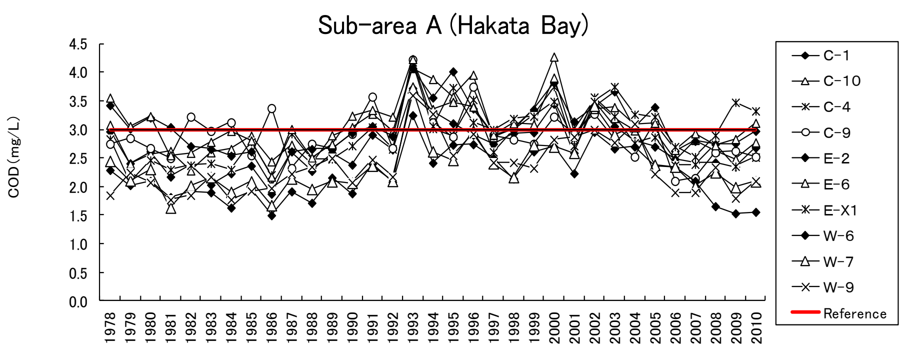

Fig. 1.23 COD concentration in sub-area A

(17) Transparency

Throughout the period from 1978 to 2010, within the ten stations, six stations (C-1, E-2, E-X1, W-6, W-7 and W-9) showed no trends and four stations (C-4, C-9, C-10 and E-6) showed increasing trends in the annual mean transparency. Since most of the stations showed no trends, the trend of the annual mean transparency in sub-area A was classified as 'No trend'.

The annual mean transparency of the recent three years ranged between 2.2-3.6 m.

Throughout the past ten-year period from 2001 to 2010, all the stations showed no trends.

Overall, the status and trend of transparency in sub-area A was classified as 'No trend'.

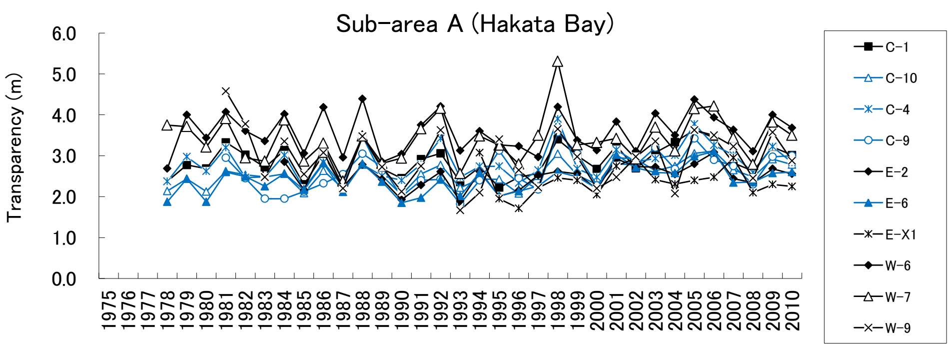

Fig. 1.24 Transparency in sub-area A

Assessment results of category IV parameters

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

Throughout the period from 1978 to 2010, *Noctiluca* red tide occurred at a frequency of 1-2 times per year in six years. Since no trend was identified, trend of *Noctiluca* red tide in sub-area A was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, since *Noctiluca* red tide occurred at a frequency of 0-1 times per year, no trend was identified in *Noctiluca* red tide.

Within the recent three years, no *Noctiluca* red tide was confirmed.

Overall, the status and trend of *Noctiluca* red tide in sub-area A was classified as 'Low eutrophication status and No trend'.

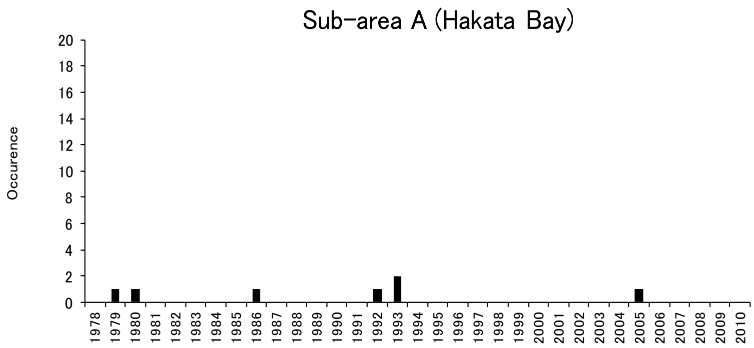

Fig. 1.25 Number of *Noctiluca* red tide in sub-area A

(19) Shellfish poisoning incidents

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

Assessment results of each assessment category

Table 1.12 shows assessment results of each assessment category in sub-area A.

Table 1.12 Assessment results of each assessment category (sub-area A, Hakata Bay)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Class identification
I	Riverine input of TN	X	X	D	D	LD-LI
	Riverine input of TP	X	X	D	D	
	Input from direct discharge of TN	X	X	N	N	
	Input from direct discharge of TP	X	X	N	N	
	TN concentration	L	X	I	LI	
	TP concentration	L	X	D	LD	
	Winter DIN concentration	H	X	I	HI	
	Winter DIP concentration	L	X	N	LN	
	Winter DIN/DIP ratio	H	X	I	HI	
II	Annual maximum of chlorophyll-*a*	H	X	N	HN	HN
	Annual mean of chlorophyll-*a*	H	X	N	HN	
	Red tide events (diatom sp.)	X	H	N	HN	
	Red tide events (dinoflagellate sp.)	X	H	N	HN	
III	Dissolved oxygen (DO) at bottom layer	L	X	N	LN	LN
	Fish kill incidents	X	L	N	LN	
	Chemical oxygen demand (COD)	L	X	N	LN	
	Transparency	X	X	N	N	
IV	Red tide events (*Noctiluca* sp.)	X	L	N	LN	LN
	Shellfish poisoning incidents	X	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 and TP input from the sewage treatment plants showed no trend. TN concentration satisfied the reference value but showed increasing trends at many stations. TP concentration satisfied the reference value and showed decreasing trends at all stations. Winter DIN concentration was above the reference value and showed increasing trends at many stations. On the other hand, winter DIP concentrations were below the reference value at all stations. Consequently, the winter DIN/DIP ratio was higher than the Redfield ratio.

Category II (direct effects of nutrient enrichment) parameters, annual maximum and mean of chlorophyll-*a* concentrations, showed no trend, despite that they were above the reference values at all stations. Diatom and dinoflagellate red tides were also confirmed.

Category III (indirect effects of nutrient enrichment) parameter, DO, of 2 stations did not satisfy the reference value, but the ratio of stations that satisfied the reference values was dominant. While COD at some stations, all the stations showed no trend in COD level. Transparency showed no trends.

Category IV (other possible effects of nutrient enrichment) parameter, *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 1.13 Reasons behind the classification of each assessment category (sub-area A, Hakata Bay)

Category	Reason	Classification
I Degree of nutrient enrichment	- TN and TP inputs from river: Decreasing trend - TN and TP inputs from sewage treatment plant: No trend - TN concentration: Majority of stations below reference value but increasing trend - TP concentration: Below reference value and decreasing trend - Winter DIN concentration: Majority of stations above reference value and no trend - Winter DIP concentration: Majority of stations below reference value and no trend - Winter DIN/DIP ratio: Majority of stations above reference value and increasing trend	LD-LI
II Direct effects of nutrient enrichment	- Annual max./mean of chlorophyll-*a*: Majority of stations above reference value and no trend. High concentration in 2007. - Diatom and dinoflagellate red tides: No trend but high frequency of both red tides.	HN
III Indirect effects of nutrient enrichment	- DO at bottom layer: Majority of stations above reference value and no trend - Fish kill incidents: None - COD: Majority of stations below reference value and no trend - Transparency: Stations showing no trend were dominant	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: Low frequency throughout the period - Shellfish poisoning incidents: None	LN

4.2 Sub-area B (Dokai Bay)

Assessment results of category I parameters

(1) Riverine input of TN

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 in 1991 to 223 ton/year in 2010. Within the four rivers, inputs from Shinshinhori River contributed to 16-78% of the sum of TN input and the inputs from Egawa River and Murasaki River have increased since 2008. Throughout the period from 1987 to 2010, within the four rivers, TN inputs from two rivers (Shinshinhori River and Kanate River) showed decreasing trends, while other rivers showed no trends. Since the sum of TN inputs from the rivers showed a decreasing trend, the trend of TN input from the rivers of sub-area B was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, within the four rivers, TN inputs from three rivers showed no trends, so TN inputs from all the rivers of sub-area showed no trends.

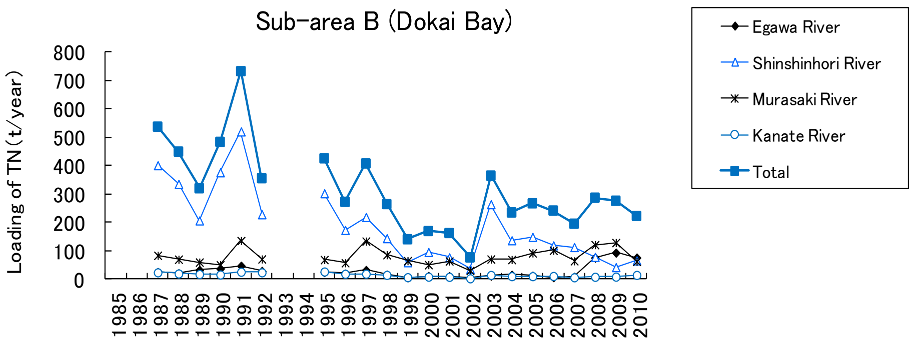

Fig. 1.26 TN input from the rivers of sub-area B

(2) Riverine input of TP

The sum of TP input from the rivers of sub-area B has decreased from 29 ton/year in 1987 to 13 ton/year in 2010. As it was the case with TN, inputs from Shinshinhori River dominated, contributing to 13-74% of the sum of TP input. TP inputs from Egawa River and Murasaki River have showed increasing trends since 2008. Throughout the period from 1987 to 2010, TP inputs from Shinshinhori River and Kanate River showed decreasing trends, while other rivers showed no trends. 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'. Throughout the past ten-year period from 2001 to 2010, within the four rivers, TP inputs from three rivers showed no trends, so TP inputs from the rivers of sub-area showed no trends.

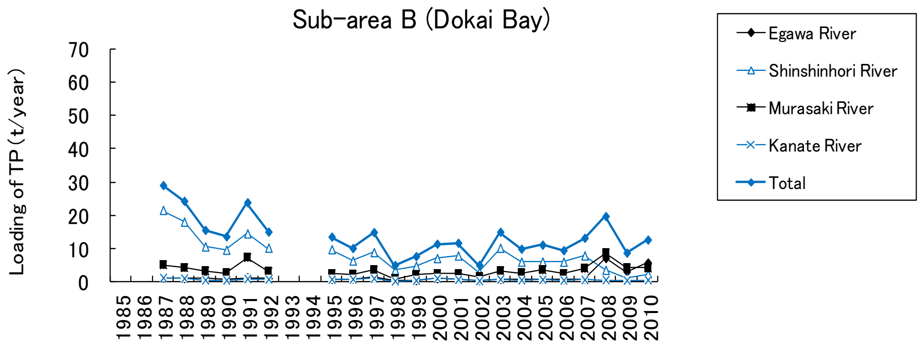

Fig. 1.27　TP input from the rivers of sub-area B

(3) Input from direct discharge of TN

Direct inputs that discharge directly into sub-area B included those from two sewage treatment plants, namely Kougasaki treatment center and Kitaminato treatment center, and those from plants. The sum of inputs from direct discharge of TN has decreased from 4,290 ton/year in 1998 to 1,716 ton/year in 2010. Throughout the period from 1995 to 2010, TN inputs from plants and from the Kitaminato treatment center showed decreasing trends, while no trend was identified with Kougasaki treatment center. Since the sum of TN input showed decreasing trends, the trend of TN input from the sewage treatment plants of sub-area B was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, TN inputs directly discharged from plants and from the Kitaminato treatment center showed decreasing trends, while no trend was identified with Kougasaki treatment center. Overall TN inputs showed no trend.

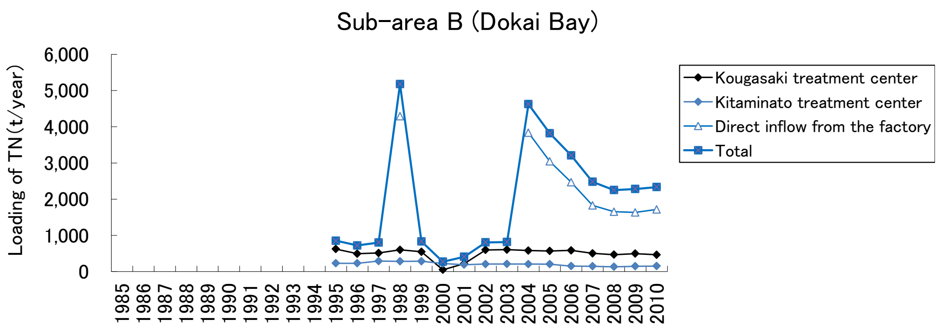

Fig. 1.28　Input from direct discharge of TN of sub-area B

(4) Input from direct discharge of TP

TP inputs that discharge directly into sub-area B has decreased from 201 ton/year in 1998 to 39 ton/year in 2010. As it was the case with TN, throughout the period from 1995 to 2010, even though TP inputs from plants, etc. dominated, TP inputs directly from plants and from the Kougasaki treatment center and the Kitaminato treatment center showed decreasing trends. Since the sum of TP input showed a decreasing trend, the trend of TP input from the sewage treatment plants of sub-area B was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, TP inputs directly from plants and from the Kougasaki treatment center showed decreasing trends, while no trend was identified with Kitaminato treatment center. Overall TP inputs showed decreasing trends.

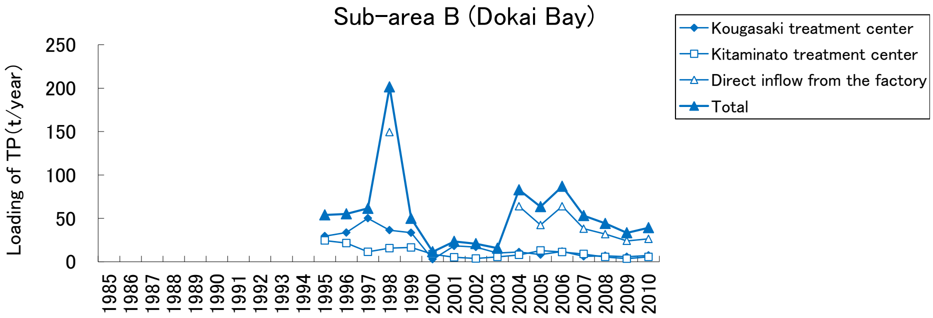

Fig. 1.29 Input from direct discharge of TP of sub-area B

(5) TN concentration

In sub-area B, there are four survey stations, and data were available for the past thirty-three years from 1978 to 2010. Throughout the period from 1978 to 2010, annual mean TN concentration showed decreasing trends with all the stations (D2, D3, D6, and D7). Therefore, the trend of TN in sub-area B was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, annual mean TN concentration showed decreasing trends with all the stations (D2, D3, D6, and D7).

The mean TN concentrations of the recent three years of two stations (D6 and D7) within the four stations were above the reference value of 1.0 mg/L.

Overall, the status and trend of TN in sub-area B was classified as 'Low eutrophication status and decreasing trend'.

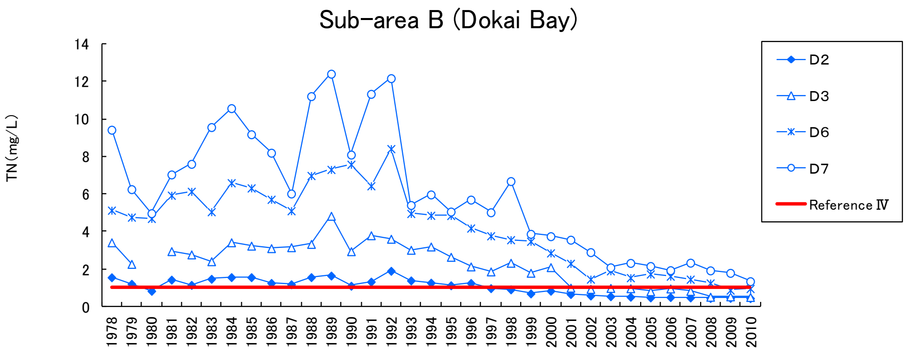

Fig. 1.30 TN concentration in sub-area B

(6) TP concentration

Throughout the period from 1978 to 2010, annual mean TP concentration showed decreasing trends with all the stations (D2, D3, D6, and D7). Therefore, the trend of TP in sub-area B was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, since annual mean TP concentration showed decreasing trends with three stations and it showed no trends with 1 station (D2), it showed decreasing trends with most of the stations.

The mean TP concentrations of the recent three years of all 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'.

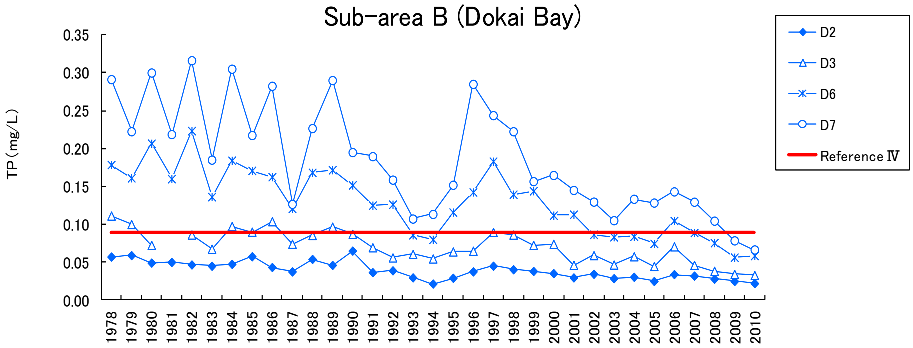

Fig. 1.31 TP concentration in sub-area B

(7) Winter DIN concentration

There was no station that monitored winter DIN concentration. Therefore, the trend and winter DIN of the recent three years in sub-area B was not classified.

(8) Winter DIP concentration

There was no station that monitored winter DIP concentration. Therefore, the trend and winter DIP of the recent three years in sub-area B was not classified.

(9) Winter DIN/DIP ratio

There was no station that monitored winter DIN and DIP concentration. Therefore, the trend and winter DIN/DIP ratio of the recent three years in sub-area B was not classified.

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Two stations (D2 and D6) had data up to 2010, and one station (D7) had no recent data. Throughout the period from 1986 to 2010, since all stations showed no trend, the trend of annual maximum chlorophyll-*a* concentration in sub-area B was classified as 'No trend'. Station D7 had data only for one year, so its trend was not identified. Two stations, which had data up to 2010, showed no trend throughout the past ten-year period from 2001 to 2010. In addition, the two stations had only data of 9 years.

The annual maximum chlorophyll-*a* concentration of the recent three years of two stations (D2 and D6) ranged between 24-66 µg/L. All stations 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'.

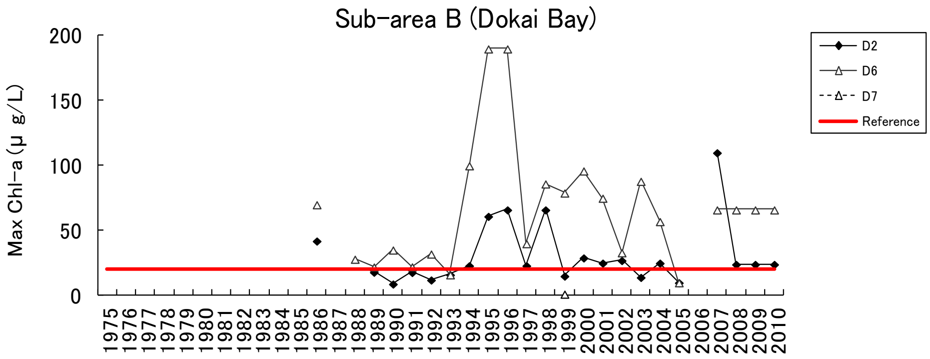

Fig. 1.32 Annual maximum chlorophyll-*a* concentration in sub-area B

(11) Annual mean chlorophyll-*a* concentration

Two stations (D2 and D6) had data up to 2010, and one station (D7) had no recent data. Throughout the period from 1986 to 2010, since all stations showed no trend, trend of annual mean chlorophyll-*a* concentration in sub-area B was classified as 'No trend'. Station D7 had data only for one year, so its trend was not identified. Two stations, which had data up to 2010, showed no trend throughout the past ten-year period from 2001 to 2010. In addition, the two stations had only data of 9 years.

The annual mean chlorophyll-*a* concentration of the recent three years of four stations (D2 and D6) ranged between 5.3-12.5 μg/L. All stations 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'.

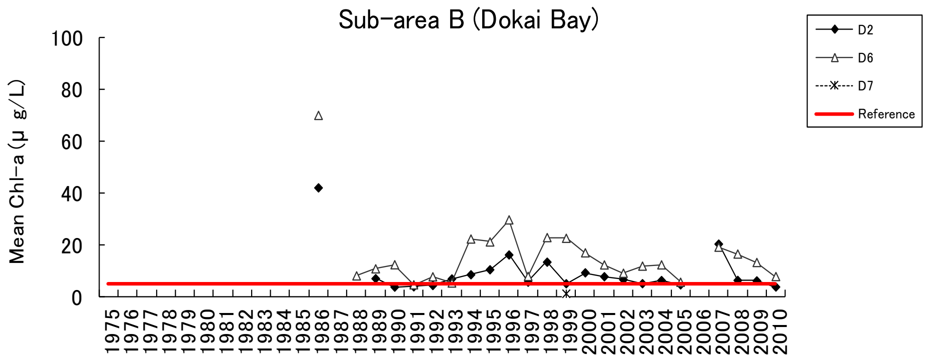

Fig. 1.33 Annual mean chlorophyll-*a* concentration in sub-area B

(12) Red tide (diatom sp.)

From 1978 to 2010, diatom red tide occurred 1 time per year in 2009. No trend was identified. Therefore the trend of diatom red tide in sub-area B was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, the number of diatom red tide in sub-area B ranged between 0-1 event/year. It showed no trends in the number of diatom red tide.

Within the recent three years, the number of diatom red tide ranged between 0-1 event/year.

Overall, the status and trend of diatom red tide in sub-area B was classified as 'High eutrophication status and No trend'.

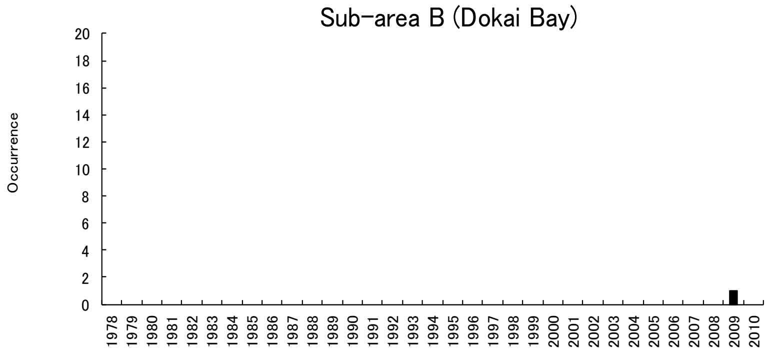

Fig. 1.34 Number of diatom red tide in sub-area B

(13) Red tide (dinoflagellate sp.)

From 1978 to 2010, dinoflagellate red tide did not occur. 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'.

Assessment results of category III parameters

(14) Dissolved oxygen (DO) at bottom layer

Seven stations (St.1, St.2, St.3, St.4, St.5, St.6 and St.7) had data from 1994 to 2010, and one station (St.5B) had data only from 2006 and 2007. Since all stations showed no trend, throughout the period from 1978 to 2010, the trend of DO in sub-area B was classified as 'No trend'. Station St.5B had data only of two years, so its trend was not identified. Of seven stations, which had data up to 2010, five stations showed no trend and two stations (St.1 and St.3) showed decreasing trends, throughout the past ten-year period from 2001 to 2010. So the stations that showed no trend were dominant.

For seven stations, the mean DO concentrations of the recent three years ranged between 1.6-6.7 mg/L. Within the seven stations, four stations (St.1, St.2, St.3 and St.4) satisfied the reference value of 3.6 mg/L, and three stations did not satisfy the reference value. So the ratio of stations that satisfied the reference value was dominant. And, the assessment method of DO was based on the method in section '3.2'. The determination was reverse to the other parameters.

Overall, the status and trend of DO in sub-area B was classified as 'Low eutrophication status and No trend'.

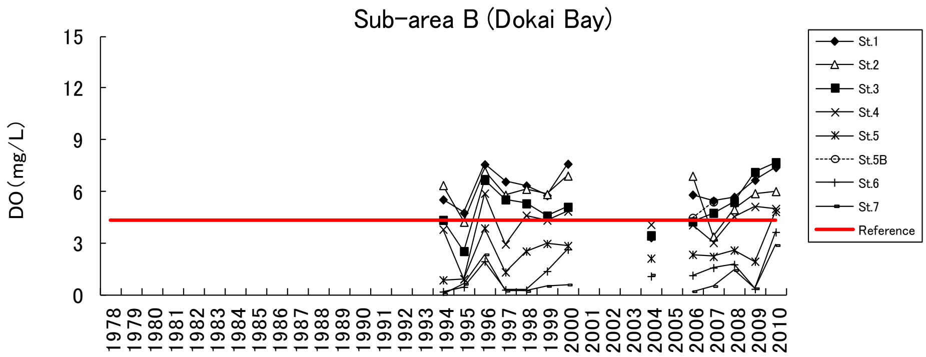

Fig. 1.35 DO concentration in sub-area B

(15) Fish kill incidents

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)

Throughout the period from 1978 to 2010, within the four stations (D2, D3, D6, and D7), three stations (D3, D6, and D7) showed decreasing trends and one station (D2) showed no trends in annual mean COD. Since stations that showed decreasing trends were dominant, the trend of COD in sub-area B was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, all the four stations (D2, D3, D6, and D7) showed no trends in annual mean COD.

The mean COD of the recent three years ranged between 1.8-3.6 mg/L. Within the four stations, one station (D7) was above the reference value (3.0 mg/L), and three stations were below the reference value. The ratio of stations that were below the reference value was dominant.

Overall, the status and trend of COD in sub-area B was classified as 'Low eutrophication status and Decreasing trend'.

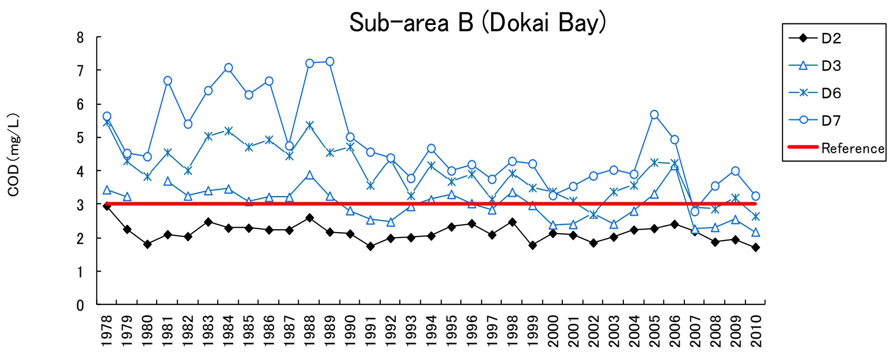

Fig. 1.36 COD concentration in sub-area B

(17) Transparency

Throughout the period from 1978 to 2010, within the four stations, three stations (D2, D3 and D7) showed increasing trends and one station (D6) showed no trend in the annual mean transparency. Since the stations that showed increasing trends were dominant, the trend of the annual mean transparency in sub-area B was classified as ‘Decreasing trend’. Throughout the past ten-year period from 2001 to 2010, one station had no data of the recent ten years, and three stations showed no trend in the annual mean transparency.

The annual mean transparency of the recent three years ranged between 1.9-3.3 m.

The assessment method of transparency was based on the method in section ‘3.2’. The determination was reverse to the other parameters. Overall, the status and trend of transparency in sub-area B was classified as ‘Decreasing trend’.

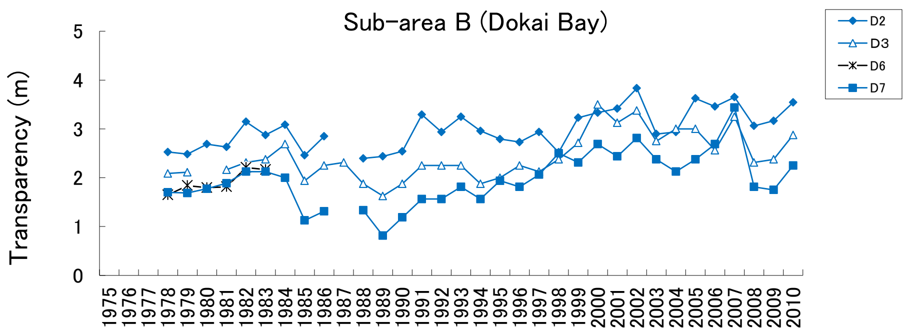

Fig. 1.37 Transparency in sub-area B

Assessment results of category IV parameters

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

In sub-area B, *Noctiluca* red tide did not occur from 1978 to 2010. Overall, the status and trend of *Noctiluca* red tide in sub-area B was classified as ‘Low eutrophication status and No trend’.

(19) Shellfish poisoning incidents

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

Assessment results of each assessment category

Table 1.14 shows assessment results of each assessment category in sub-area B.

Table 1.14 Assessment results of each assessment category (sub-area B, Dokai Bay)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Class identification
I	Riverine input of TN	X	X	D	D	LD
	Riverine input of TP	X	X	D	D	
	Input from direct discharge of TN	X	X	D	D	
	Input from direct discharge of TP	X	X	D	D	
	TN concentration	L	X	D	LD	
	TP concentration	L	X	D	LD	
	Winter DIN concentration	X	X	X	-	
	Winter DIP concentration	X	X	X	-	
	Winter DIN/DIP ratio	X	X	X	-	
II	Annual maximum of chlorophyll-*a*	H	X	N	HN	HN
	Annual mean of chlorophyll-*a*	H	X	N	HN	
	Red tide events (diatom sp.)	X	H	N	HN	
	Red tide events (dinoflagellate sp.)	X	L	N	LN	
III	Dissolved oxygen (DO) at bottom layer	L	X	N	LN	LD-LN
	Fish kill incidents	X	L	N	LN	
	Chemical oxygen demand (COD)	L	X	D	LD	
	Transparency	X	X	D	D	
IV	Red tide events (*Noctiluca* sp.)	X	L	N	LN	LN
	Shellfish poisoning incidents	X	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).

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

Category II (direct effects of nutrient enrichment) parameters: Annual maximum and mean of chlorophyll-*a* concentrations exceeded the reference values at all stations. Occurrences of diatom red tides were confirmed also. Dinoflagellate red tide was not confirmed.

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

Category IV (other possible effects of nutrient enrichment) parameters: *Noctiluca* red tide did not occur. 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 COD concentration decreased between the 1970s and 1990s, but has remained stable in the recent ten years.

Table 1.15 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 and TP inputs from sewage treatment plant: Decreasing trend - TN concentration: Stations that were below the reference values and stations that showed decreasing trends dominated - TP concentration: Stations that were below the reference values and that showed decreasing trends dominated	LD
II Direct effects of nutrient enrichment	- Annual max./mean of chlorophyll-*a*: Stations that were above the reference values and that showed no trends dominated - Diatom and dinoflagellate red tides: Diatom red tides have low occurrences and dinoflagellate red tides did not occur throughout the period. No trends showed.	HN
III Indirect effects of nutrient enrichment	- DO at bottom layer: Most stations satisfied the reference value and had no trend - Fish kill incidents: None - COD: Stations that were below the reference values and that showed decreasing trends dominated - Transparency: Improvement confirmed	LN-LD
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: No occurrence throughout the period. - Shellfish poisoning incidents: None	LN

4.3 Sub-area C (intermediate sea area)

Assessment results of category I parameters

(1) Riverine input of TN

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 in 1985 to 2,456 ton/year in 2010, no trend was identified. Within the thirteen rivers, inputs from Onga River contributed to 62-90% of the sum of TN input. Throughout the period from 1985 to 2010, within the thirteen rivers, eight rivers showed no trends, and three rivers (Yahagi River, Naka River and Tebikaima River) showed increasing trends, and two rivers (Bachi River and Wariko River) showed decreasing trends. Since the sum of TN input from all the rivers showed no trend, the trend of TN input from the rivers of sub-area C was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, within the thirteen rivers, eleven rivers showed no trends, and all rivers showed no trends.

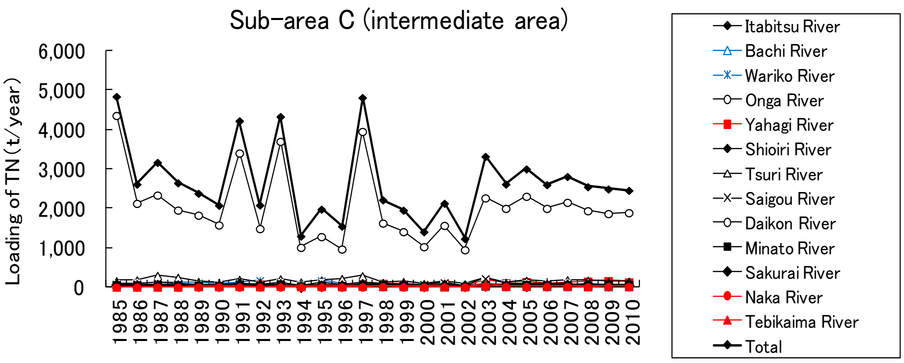

Fig. 1.38 TN input from the rivers of sub-area C

(2) Riverine input of TP

The sum of TP input from the rivers of sub-area C has decreased from 412 ton/year in 1985 to 127 ton/year in 2010. As it was the case with TN, TP inputs from Onga River was dominant and contributed to 44-87% of the total TP input. Throughout the period from 1985 to 2010, within the thirteen rivers, TN inputs from eight rivers showed no trends; Wariko River, Daikon River and Minato River showed decreasing trends; Naka River and Tebikaima River showed increasing trends. Since the sum of TP input from all the rivers showed no trend, the trend of TP input from the rivers of sub-area C was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, within the thirteen rivers, nine rivers showed no trends, and all rivers showed no trends.

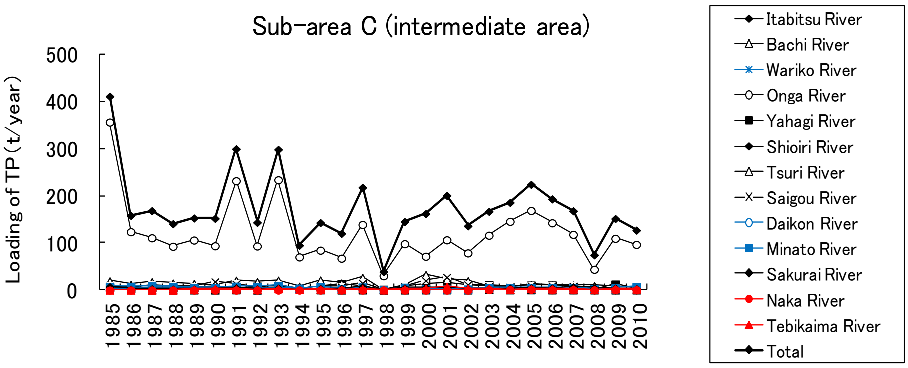

Fig. 1.39 TP input from the rivers of sub-area C

(3) Input from direct discharge of TN

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 in 1995 to 923 ton/year in 2010. Within the four sewage treatment plants, Hiagari treatment center contributed to 88-95 % of the sum of TN input. Throughout the period from 1995 to 2010, although TN inputs from Koga treatment center and Kuroiso treatment center showed increasing trends, their contributions to the sum of TN input were 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'. Throughout the ten-year period from 2001 to 2010, while TN input from the Tsuyazaki and Kuroiso treatment centers showed no trends, and Hiagari treatment center showed decreasing trends, and Koga treatment center showed increasing trends, the sum of TN input from the four sewage treatment plants showed increasing trends. In addition, Tsuyazaki treatment center had data of nine years from 2001 to 2010.

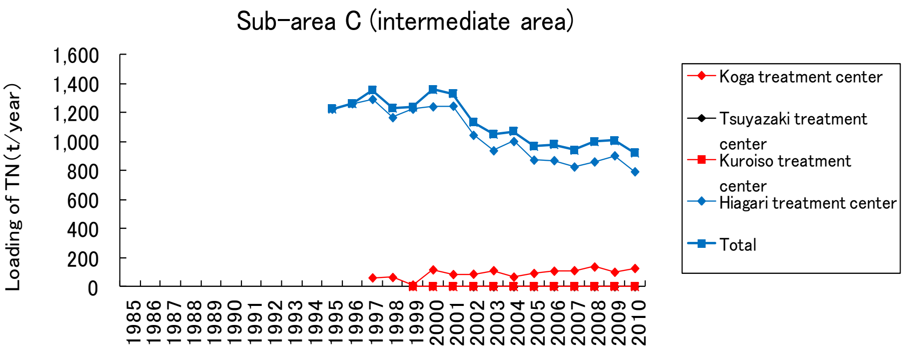

Fig. 1.40 Input from direct discharge of TN of sub-area C

(4) Input from direct discharge of TP

The sum of TP input from the sewage treatment plants of sub-area C has increased from 51 ton/year in 1995 to 90 ton/year in 2010. Within the four sewage treatment plants, Hiagari treatment center contributed to 96-100 % of the sum of TP input. Throughout the period from 1995 to 2010, while TP inputs 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'. Throughout the ten-year period from 2001 to 2010, while TP inputs from the Tsuyazaki and Kuroiso treatment centers showed increasing trends, and Koga and Hiagari treatment centers showed no trends, the sum of TP input from the four sewage treatment plants showed no trends.

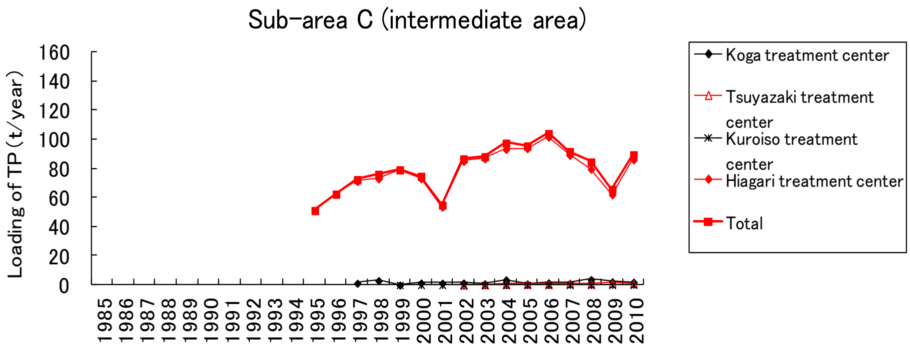

Fig. 1.41 Input from direct discharge of TP of sub-area C

(5) TN concentration

In sub-area C, there are twenty-four survey stations. Thirteen stations had data for the past thirty-three years from 1978 to 2010. However, data were limited to the period from 1995 to 1997 at eleven stations. Throughout the period from 1978 to 2010, within the thirteen stations, seven stations (H3, H4, H7, K8, St-1, St-2 and W-3) showed no trends, and six stations (H1, H5, K1, K4, K6 and K7) showed decreasing trends. Since stations that showed no trends were dominant, the trend of TN in sub-area C was classified as 'No trend'. Trend analysis was not conducted for these eleven stations (1, 4, 6, 8, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) as data was limited to less than three years. Throughout the past ten-year period from 2001 to 2010, within the thirteen stations, eleven stations showed no trends, and one station (St-2) showed an increasing trend, and one station (K8) showed a decreasing trend. Stations that showed no trends were dominant.

The mean TN concentrations of the recent three years of two stations (K7 and K8) were compared with the reference value of 1.0 mg/L (Reference IV), and those of eleven stations (H1, H3, H4, H5, H7, K1, K4, K6, St-1, St-2 and W-3) were compared with the reference value of 0.3 mg/L (Reference II). The mean TN concentrations of the recent three years ranged between 0.13-0.52 mg/L; hence all stations were below the reference values.

Overall, the status and trend of TN in sub-area C was classified as 'Low eutrophication status and No trend'.

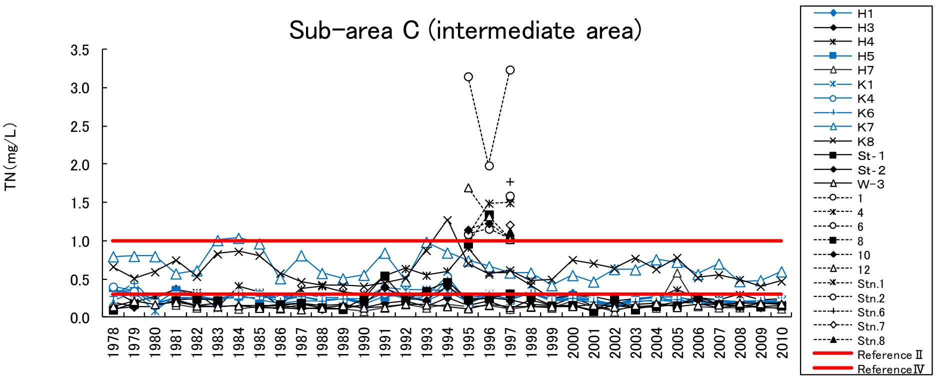

Fig. 1.42 TN concentration in sub-area C

(6) TP concentration

Throughout the period from 1978 to 2010, within the thirteen stations, nine stations (H1, H3, H5, H7, K6, K8, St-1 St-2 and W-3) showed no trends in annual mean TP concentrations, and three stations (K1, K4 and K7) showed decreasing trend, and one station (H4) showed increasing trend. Since stations that showed no trends were dominant, the trend of TP in sub-area C was classified as 'No trend'. Trend analysis was not conducted at these eleven stations (1, 4, 6, 8, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) as data were limited to less than three years. Throughout the past ten-year period from 2001 to 2010, within the thirteen stations, twelve stations showed no trends and one station (K4) showed a decreasing trend. Stations that showed no trends were dominant.

The mean TP concentrations of the recent three years of two stations (K7 and K8) were compared with the reference value of 0.09 mg/L (Reference IV) and those of eleven stations (H1, H3, H4, H5, H7, K1, K4, K6, St-1, St-2 and W-3) were compared with the reference value of 0.03 mg/L (Reference II). The mean TP concentrations of the recent three years ranged between 0.011-0.026 mg/L; hence all stations were below the reference values.

Overall, the status and trend of TP in sub-area C was classified as 'Low eutrophication status and No trend'.

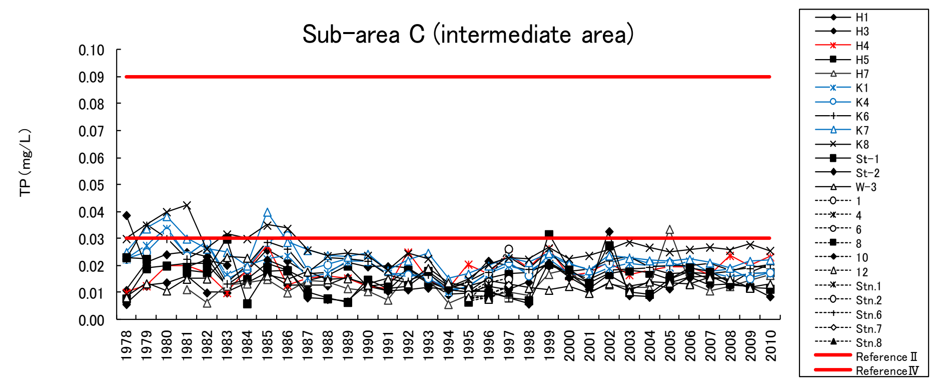

Fig. 1.43 TP concentration in sub-area C

(7) Winter DIN concentration

Although twenty-seven stations had data on winter DIN concentration, seventeen stations had data only from 1978 to 1996 or from 1999 to 2008. Also because nine stations started the survey from 2010, only one station (W-3) had sufficient data to analyze the mean of the recent 3 years and trend. Throughout the period from 1978 and 2010, no trend was identified with station W-3. The trend of winter DIN concentration was classified as ‘No trend’. Throughout the past ten-year period from 2001 and 2010, no trend was identified.

The mean winter DIN concentration of the recent 3 years was compared with reference value of 0.170 mg/L (12.1 µM). The mean winter DIN concentration of the recent 3 years of station W-3 was 0.091 mg/L, which was below the reference value.

Overall, the status and trend of winter DIN concentration in sub-area C was classified as ‘Low eutrophication status and No trend’.

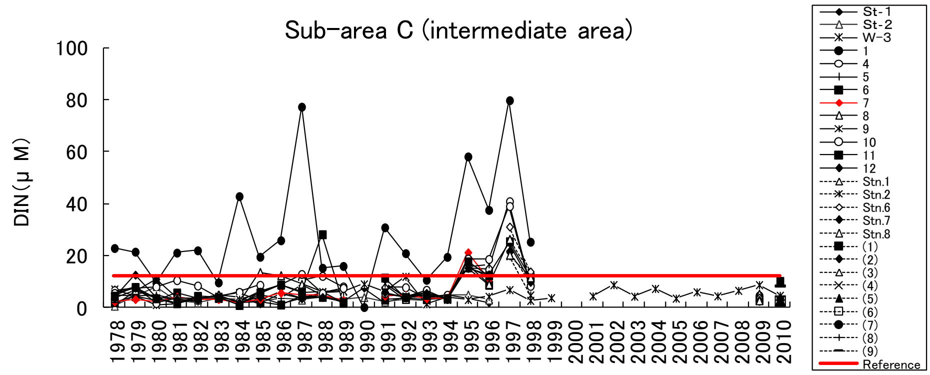

Fig. 1.44 Winter DIN concentration in sub-area C

(8) Winter DIP concentration

Although twenty-seven stations had data on winter DIP concentration, 17 stations had data only from 1978 to 1996 or from 1999 to 2008. Also because nine stations started the survey from 2010, 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. Throughout the period from 1978 to 2010, decreasing trend was identified with station W-3. The trend of winter DIP concentration was classified as ‘Decreasing trend’. Throughout the past ten-year period from 2001 to 2010, decreasing trend was identified.

The mean winter DIP concentration of the recent 3 years of station W-3 was 0.003 mg/L, which was below the reference value of 0.010 mg/L (0.36 µM).

Overall, the status and trend of winter DIP concentration in sub-area C was classified as ‘Low eutrophication status and Decreasing trend’.

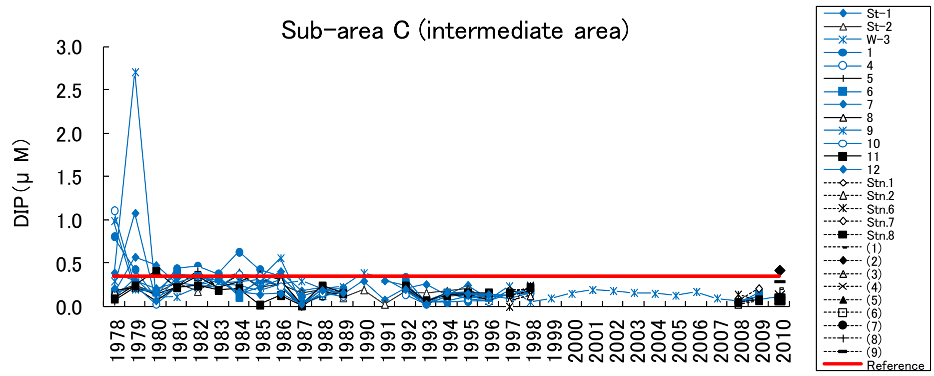

Fig. 1.45 Winter DIP concentration in sub-area C

(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. Throughout the period from 1978 to 2010, since increasing trend was identified with station W-3, the trend of winter DIN/DIP ratio was classified as 'Increasing trend'. Throughout the past ten-year period from 2001 to 2010, no trend was identified.

The mean winter DIN/DIP ratio of the recent 3 years at station W-3 was 84, which was above the reference value of 16.

Therefore, the status and trend of winter DIN/DIP ratio in sub-area C was classified as 'High eutrophication status and Increasing trend'. 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.

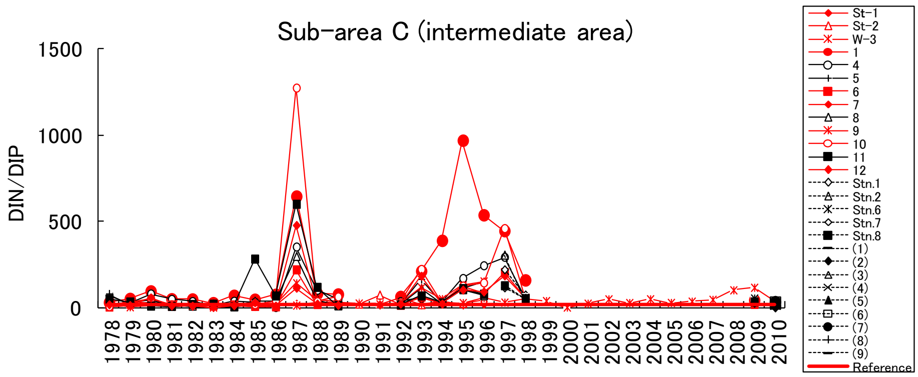

Fig. 1.46 Winter DIN/DIP ratio in sub-area C

Assessment results of category II parameters

(10) Annual maximum chlorophyll-*a* concentration

Data on annual maximum chlorophyll-*a* concentration were available at thirty-one stations. However, only twelve stations (W-3, 1, 4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7, Stn.8 and H5) had long-term data (2006-2010) and data of the recent 3 years. Throughout the period from 1975 to 2010, within the twelve stations, 8 stations (W-3, 12, Stn.1, Stn.2, Stn.6, Stn.7, Stn.8 and H5) showed no trends and four stations (1, 4, 6 and 10) showed increasing trends in annual maximum chlorophyll-*a* concentration. Since stations that showed no trends were dominant, the trend of annual maximum chlorophyll-a concentration was classified as 'No trend'. Throughout the past ten-year period from 2001 and 2010, no trend was identified at eleven stations, and increasing trend was identified at one station (W-3). Stations that showed no trends were dominant. In addition, within the twelve stations, ten stations (1, 4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) had data of six years and one station (H5) had data of nine years from 2001 to 2010.

The mean of the annual maximum chlorophyll-*a* concentration of the recent 3 years ranged between 5.7-39.5μg/L. Three stations (4, 10 and Sn.1) were above the reference value of 20μg/L and the other nine stations were below the reference value.

Therefore, the status and trend of annual maximum chlorophyll-*a* concentration in sub-area C was classified as 'Low eutrophication status and No trend'.

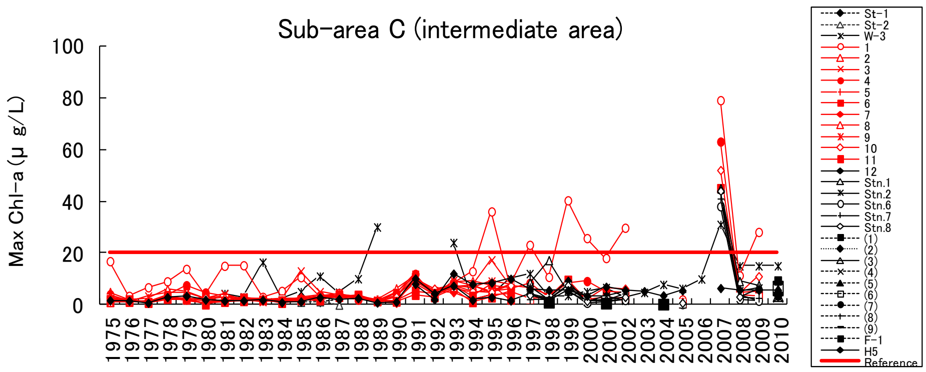

Fig. 1.47 Annual maximum chlorophyll-*a* concentration in sub-area C

(11) Annual mean chlorophyll-*a* concentration

As it was the case with annual maximum chlorophyll-a concentration, data on annual mean chlorophyll-*a* concentration were available at thirty-one stations. However, only twelve stations (W-3, 1, 4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7, Stn.8 and H5) had long-term data (2006-2010) and data of the recent 3 years. Throughout the period from 1975 to 2010, within the twelve stations, nine stations (W-3, 6, 12, Stn.1, Stn.2, Stn.6, Stn.7, Stn.8 and H5) showed no trend, and three stations (1, 4 and 10) showed increasing trends in annual mean chlorophyll-*a* concentration. Since stations that showed no trend were dominant, the trend of annual mean chlorophyll-a concentration was classified as ‘No trend’. Throughout the past ten-year period from 2001 and 2010, no trend was identified at eleven stations, and increasing trend was identified at one station (W-3). Stations that showed no trends were dominant. In addition, within the twelve stations, ten stations (1, 4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) had data of six years and one station (H5) had data of nine years from 2001 to 2010.

The mean of the annual mean chlorophyll-*a* concentration of the recent 3 years was 2.6-31.3 μg/L. Ten stations were above the reference value of 5 μg/L and the other two stations were below the reference value. Stations that were above the reference value were dominant.

Therefore, the status and trend of annual mean chlorophyll-*a* concentration in sub-area C was classified as ‘High eutrophication status and No trend’.

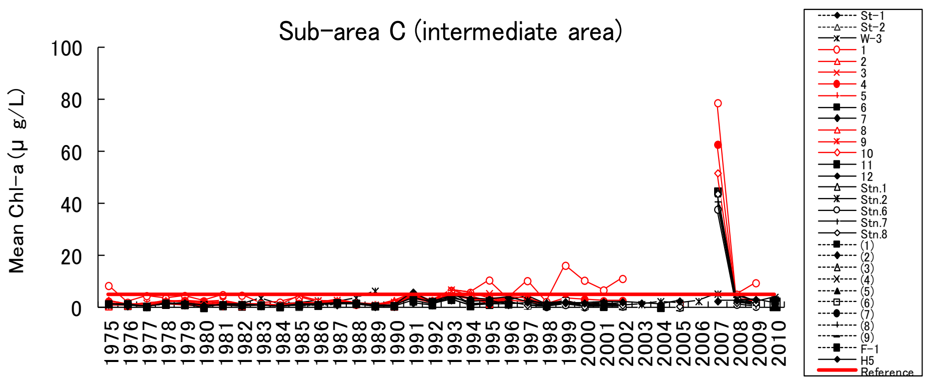

Fig. 1.48 Annual mean chlorophyll-*a* concentration in sub-area C

(12) Red tide (diatom sp.)

In sub-area C, diatom red tide occurred once in 2004. Throughout the period from 1978 to 2010, since no trend was identified, the trend of diatom red tide in sub-area C was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, no trend was identified.

Overall, the status and trend of diatom red tide in sub-area C was classified as 'Low eutrophication status and No trend'.

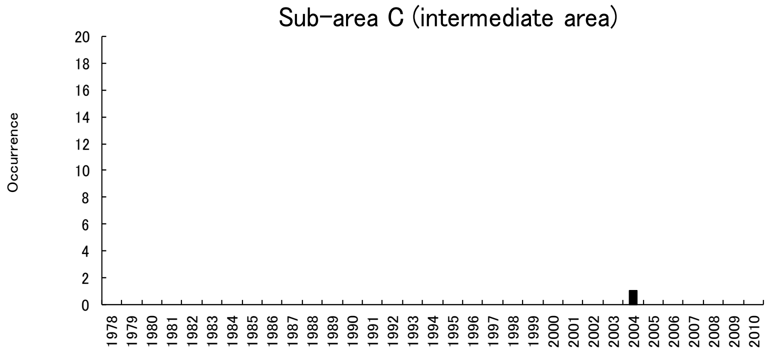

Fig. 1.49 Number of diatom red tide in sub-area C

(13) Red tide (dinoflagellate sp.)

Throughout the period from 1978 to 2010, in sub-area C, dinoflagellate red tide occurred 1-7 times per year. Since increasing trend was identified, the trend of dinoflagellate red tide in sub-area C was classified as 'Increasing trend'. Throughout the past ten-year period from 2001 to 2010, dinoflagellate red tide occurred 0-3 times per year. No trend was identified.

In the recent 3 years, dinoflagellate red tide occurred twice and three times in 2008 and 2009, respectively.

Overall, the status and trend of dinoflagellate red tide in sub-area C was classified as 'High eutrophication status and Increasing trend'.

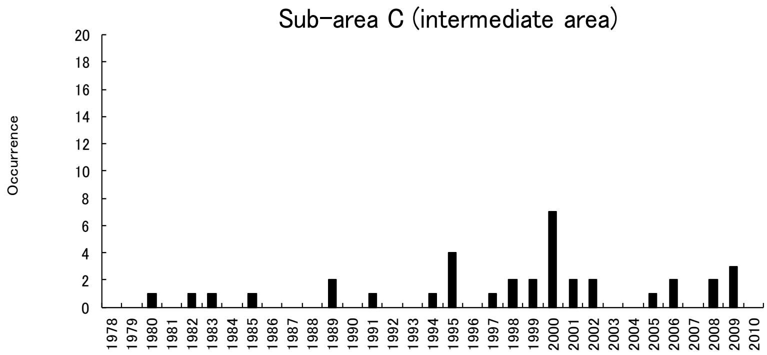

Fig. 1.50 Number of dinoflagellate red tide in sub-area C

Assessment results of category III parameters

(14) Dissolved oxygen (DO) at bottom layer

Data on annual minimum DO was available at twenty-seven stations. However, only eleven stations (W-3, 1, 4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) had long-term data (2006-2010) and data of the recent 3 years. Throughout the period from 1978 to 2010, within the eleven stations, one station (Stn.1) showed decreasing trend, and one station (6) showed increasing trend, and the other nine stations showed no trends in annual minimum DO. Since stations that showed no trends were dominant, the trend of annual minimum DO was classified as 'No trend'. Throughout the past ten-year period from 2001 and 2010, decreasing trend was identified at six stations, and no trend was identified at five stations (W-3, 1, Stn.6, Stn.7 and Stn.8). Stations that showed no trends were dominant. In addition, within the eleven stations, nine stations (4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) had data of nine years from 2001 and 2010.

The mean of DO of the recent 3 years ranged between 5.7-7.1 mg/L. All stations were above the reference value of 4.3 mg/L. And, the assessment method of DO was based on the method in section '3.2'. The determination was reverse to the other parameters.

Overall, the status and trend of DO in sub-area C was classified as 'Low eutrophication status and No trend'.

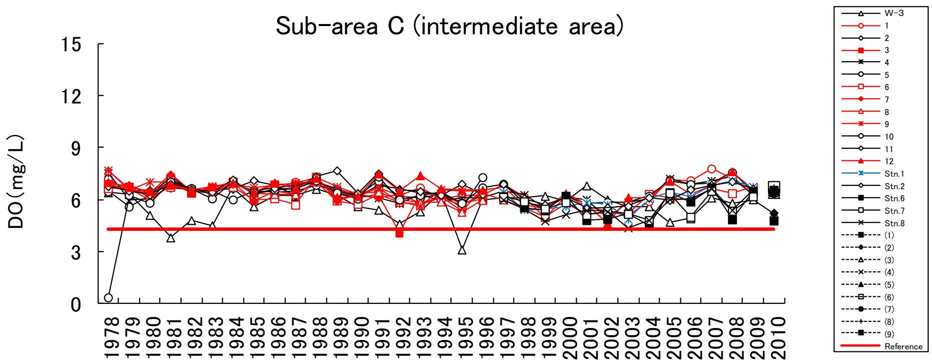

Fig. 1.51 DO concentration in sub-area C

(15) Fish kill incidents

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)

Data on annual mean COD was available at thirty-seven stations. However, only twenty-three stations (H1, H3, H4, H5, H7, K1, K4, K6, K7, K8, St-1, St-2, W-3, 1, 4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) had long-term data (2006-2010) and data of the recent 3 years. Throughout the period from 1978 to 2010, within the twenty-three stations, three stations (H4, H7 and W-3) showed increasing trends, and seven stations (St-1, St-2, 1, 4, 6, 10 and 12) showed decreasing trends, and the other thirteen stations showed no trends in annual mean COD. Since stations that showed no trends were dominant, the trend of COD was classified as 'No trend'. Throughout the past ten-year period from 2001 and 2010, all stations showed no trends. In addition, within the twenty-three stations, nine stations (4, 6, 10, 12, Stn.1, Stn.2, Stn.6, Stn.7 and Stn.8) had data of nine years from 2001 and 2010.

The mean of COD of the recent 3 years ranged between 0.4-1.6 mg/L. All stations were below the reference value of 3.0 mg/L.

Overall, the status and trend of COD in sub-area C was classified as ‘Low eutrophication status and No trend’.

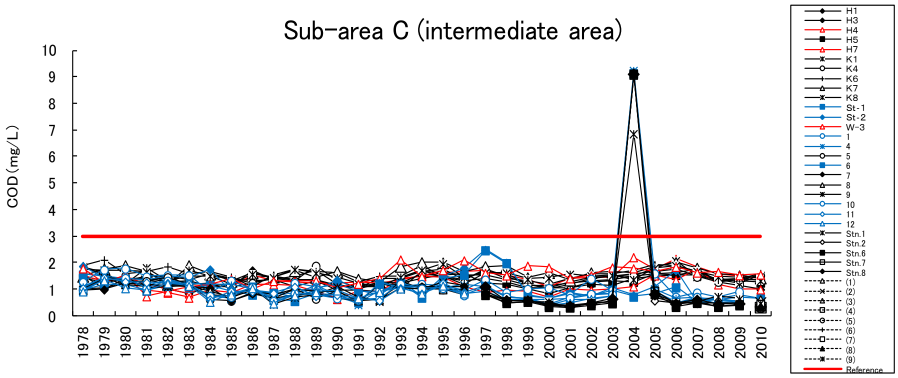

Fig. 1.52 COD concentration in sub-area C

(17) Transparency

Throughout the period from 1978 to 2010, within the twenty-seven stations, twenty-four stations showed no trends and three stations (H4, H7 and K7) showed decreasing trends in the annual mean transparency. Since the stations that showed no trends were dominant, the trend of the annual mean transparency in sub-area C was classified as ‘No trend’. Throughout the past ten-year period from 2001 to 2010, five stations had no data of recent ten years, and six stations had data up to 2009, and sixteen stations showed no trends in the annual mean transparency.

The annual mean transparency of the recent three years ranged between 2.9-17.2 m.

Overall, the status and trend of transparency in sub-area C was classified as ‘No trend’.

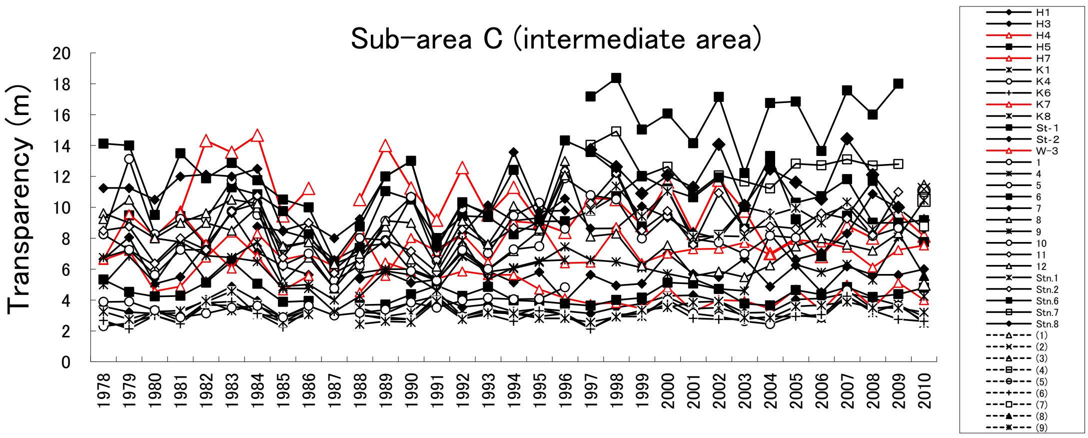

Fig. 1.53 Transparency in sub-area C

Assessment results of category IV parameters

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

Throughout the period from 1978 to 2010, in sub-area C, *Noctiluca* red tide occurred 0-4 times per year. Since no trend was identified, the trend of *Noctiluca* red tide was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, Noctiluca red tide occurred 0-4 times per year. No trend was identified.

In the recent 3 years, *Noctiluca* red tide occurred 0-1 times per year.

Overall, the status and trend of *Noctiluca* red tide in sub-area C was classified as 'Low eutrophication status and No trend'.

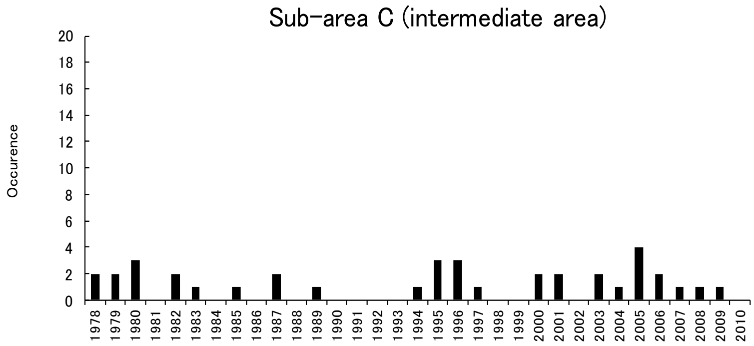

Fig. 1.54 Number of *Noctiluca* red tide in sub-area C

(19) Shellfish poisoning incidents

No shellfish poisoning incidents were confirmed. Therefore, its status/trend was classified as 'Low eutrophication status and No trend'.

Assessment results of each assessment category

Table 1.16 shows assessment results of each assessment category in sub-area C.

Table 1.16 Assessment results of each assessment category (sub-area C)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Class identification
I	Riverine input of TN	X	X	N	N	LN
	Riverine input of TP	X	X	N	N	
	Input from direct discharge of TN	X	X	D	D	
	Input from direct discharge of TP	X	X	I	I	
	TN concentration	L	X	N	LN	
	TP concentration	L	X	N	LN	
	Winter DIN concentration	L	X	N	LN	
	Winter DIP concentration	L	X	D	LD	
	Winter DIN/DIP ratio	H	X	I	HI	
II	Annual maximum of chlorophyll-*a*	L	X	N	LN	LN-HN
	Annual mean of chlorophyll-*a*	H	X	N	HN	
	Red tide events (diatom sp.)	X	L	N	LN	
	Red tide events (dinoflagellate sp.)	X	H	I	HI	
III	Dissolved oxygen (DO) at bottom layer	L	X	N	LN	LN
	Fish kill incidents	X	L	N	LN	
	Chemical oxygen demand (COD)	L	X	N	LN	
	Transparency	X	X	N	N	
IV	Red tide events (*Noctiluca* sp.)	X	L	N	LN	LN
	Shellfish poisoning incidents	X	L	N	LN	

Assessment results for sub-area C (intermediate sea 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 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 dominant. TN and TP concentrations in Kanmon Strait were below the reference value, and there was no increasing trend.

Category II (direct effects of nutrient enrichment) parameters: Annual max./mean of chlorophyll-*a* concentrations were above the reference value, and dinoflagellate red tide occurred in 2007.

Category III (indirect effects of nutrient enrichment) parameters: DO was below the reference value at all stations and COD was below the reference value at all stations. No trend was confirmed at most stations. No trend in transparency was confirmed.

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

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

Table 1.17 Reasons behind the classification of each assessment category (sub-area C, intermediate sea area)

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: Below the reference values and stations of no trend were dominant. - Winter DIN: Below the reference values and no increasing or decreasing trend - Winter DIP: Below the reference values and decreasing trend - Winter DIN/DIP ratio: Above the reference value but low concentration	LN
II Direct effects of nutrient enrichment	- Annual max./mean of chlorophyll-*a*: High concentration in 2007 but other years 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: Increasing trend. 2-3 occurrences in recent 3 years.	LN-HN
III Indirect effects of nutrient enrichment	- DO at bottom layer: All stations satisfied the reference value. Stations showing no increasing or decreasing trend were dominant - Fish kill incidents: None - COD: All stations satisfied the reference value. Stations showing no increasing or decreasing trend were dominant - Transparency: Stations showing no increasing or decreasing trend were dominant	LN
IV Other possible effects of nutrient enrichment	- *Noctiluca* red tide: No increasing or decreasing trend but occurred twice in recent 3 years - Shellfish poisoning incidents: None	LN

4.4 Sub-area D (offshore area)

Assessment results of category I parameters

(1) Riverine input of TN

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

(2) Riverine input of TP

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

(3) Input from direct discharge of TN

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

(4) Input from direct discharge of TP

Sub-area D is located in the offshore area of the North Kyushu 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.

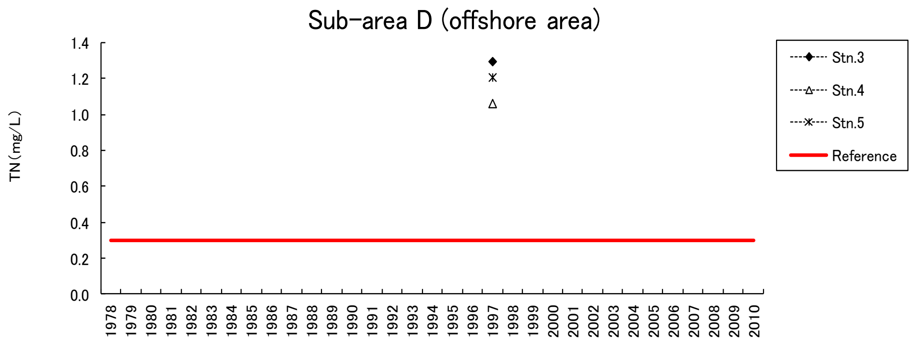

Fig. 1.55 TN concentration in sub-area D

(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.

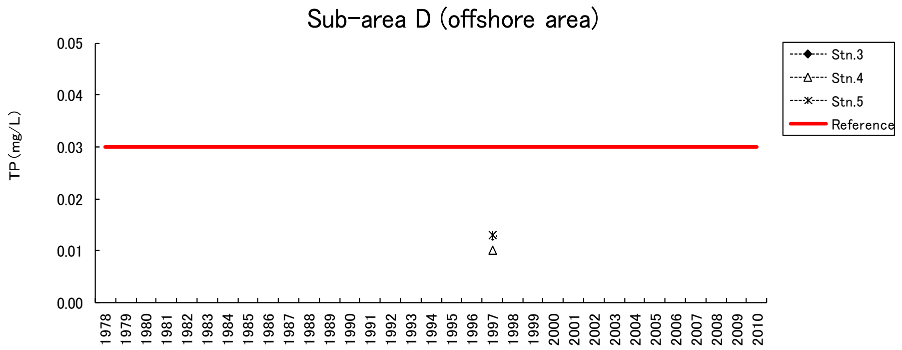

Fig. 1.56 TP concentration in sub-area D

(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.

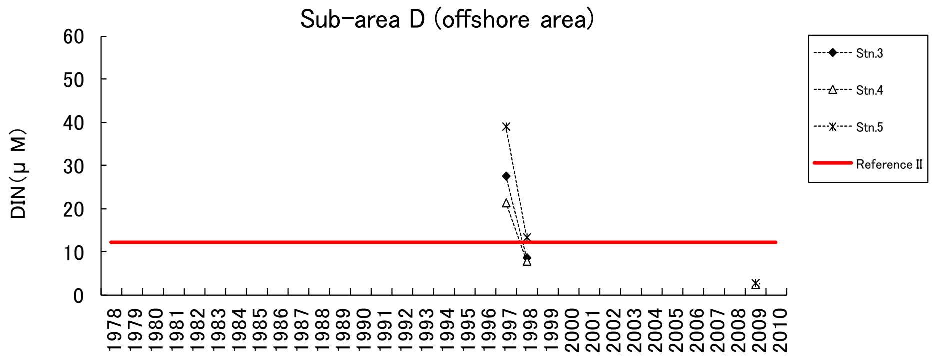

Fig. 1.57 Winter DIN concentration in sub-area D

(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.

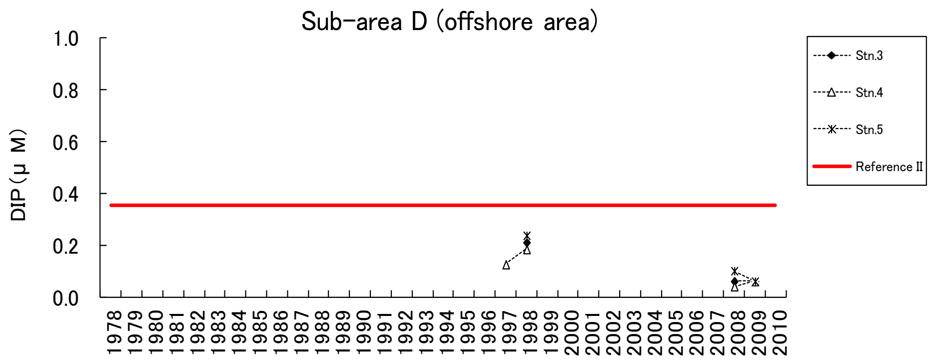

Fig. 1.58 Winter DIP concentration in sub-area D

(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.

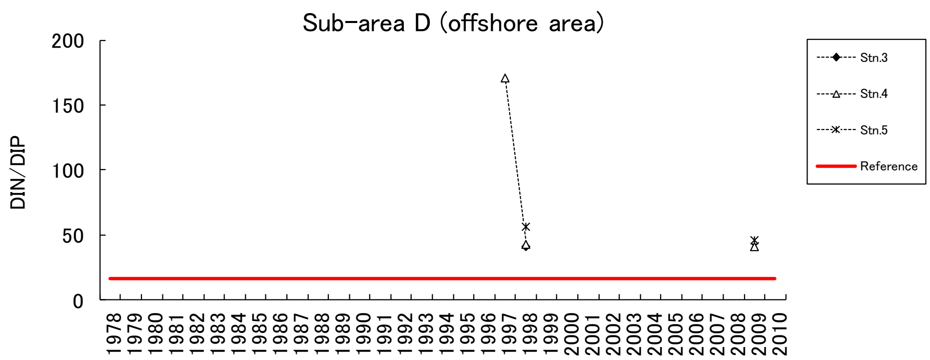

Fig. 1.59 Winter DIN/DIP ratio in sub-area D

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 1997-2009. Throughout the period from 1997 to 2009, since no increasing or decreasing trend was identified at all stations, the trend of annual maximum chlorophyll-a concentration was classified as 'No trend'. Throughout the nine-year period from 2001 to 2009, no increasing or decreasing trend was identified at all stations. In addition, three stations had data of six years from 2001 to 2009.

The mean of the annual maximum chlorophyll-*a* concentration of the recent 3 years ranged between 14.5-16.6 µg/L, which was below the reference value of 20 µg/L.

Therefore, the trend of annual maximum chlorophyll-*a* concentration in sub-area D was classified as 'Low eutrophication status and No trend'.

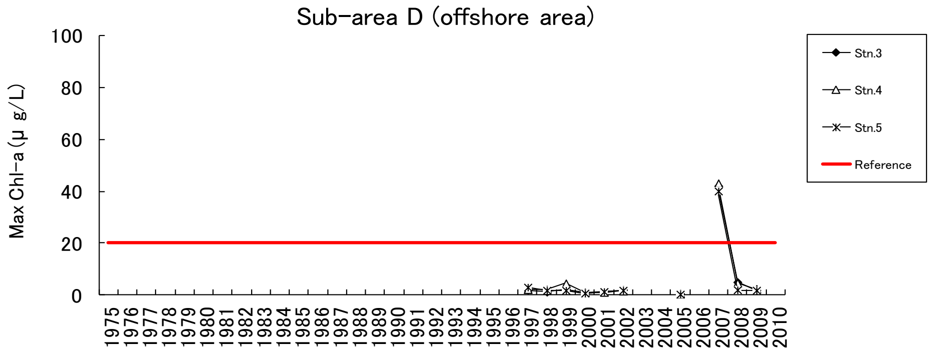

Fig. 1.60 Annual maximum chlorophyll-*a* concentration in sub-area D

(11) Annual mean chlorophyll-*a* concentration

Data on annual mean chlorophyll-*a* concentration were available at three stations for the period 1997-2009. However, the data of 2007 was excluded as it was a single data collected in summer. Throughout the period from 1997 to 2009, since no increasing or decreasing trend in annual mean chlorophyll-*a* concentration was identified with all the stations, the trend of annual mean chlorophyll-a concentration was classified as 'No trend'. Throughout the nine-year period from 2001 to 2009, no increasing or decreasing trend was identified at all stations. In addition, three stations had data of five years from 2001 to 2009.

The annual mean chlorophyll-*a* concentration was not compared with the reference value because there was no data available for the recent three years from 2006 to 2010 and the data of 2007 was a single data collected in summer. Therefore, the trend of annual mean chlorophyll-*a* concentration in sub-area D was classified as 'No trend'.

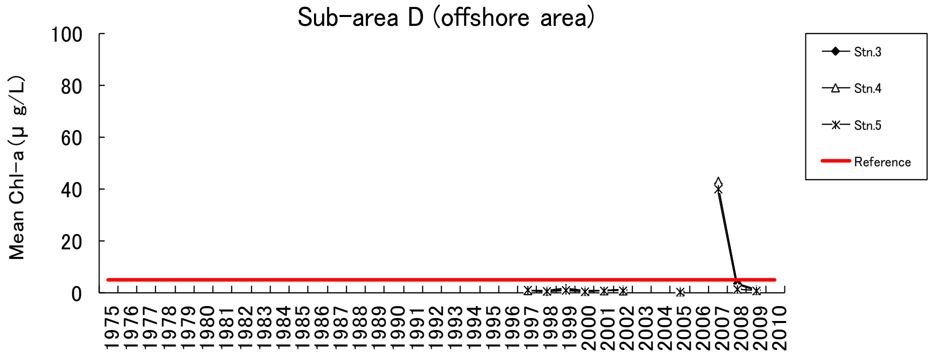

Fig. 1.61 Annual mean chlorophyll-*a* concentration in sub-area D

(12) Red tide (diatom sp.)

Throughout the period from 1978 to 2010, in sub-area D, diatom red tide occurred once in 2004. Since no trend was identified, the trend of diatom red tide was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, diatom red tide occurred 0-1 times per year. No trend was identified.

In the recent 3 years, diatom red tide did not occur.

Overall, the status and trend of diatom red tide in sub-area D was classified as 'Low eutrophication status and No trend'.

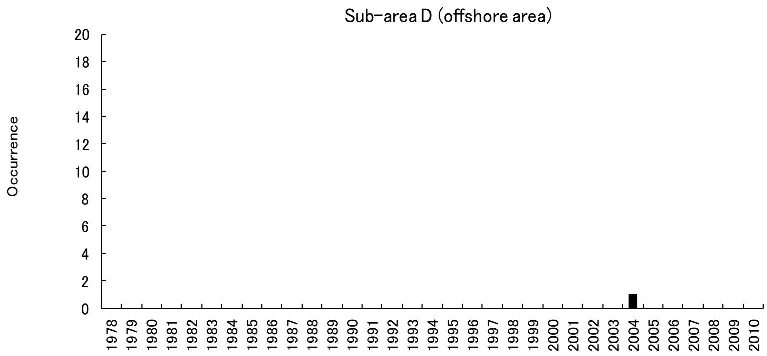

Fig. 1.62 Number of diatom red tide in sub-area D

(13) Red tide (dinoflagellate sp.)

Throughout the period from 1978 to 2010, in sub-area D, dinoflagellate red tide occurred once in 1980 and once in 2009 respectively. Since no increasing or decreasing trend was identified, the trend of dinoflagellate red tide was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, dinoflagellate red tide occurred 0-1 time/year, and no increasing or decreasing trend was identified.

In the recent 3 years, dinoflagellate red tide occurred once in 2009.

Overall, the status and trend of dinoflagellate red tide in sub-area D was classified as 'High eutrophication status and No trend'.

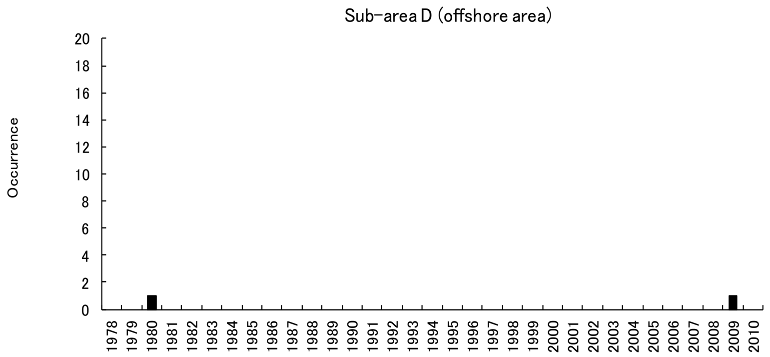

Fig. 1.63 Number of dinoflagellate red tide in sub-area D

Assessment results of category III parameters

(14) Dissolved oxygen (DO) at bottom layer

Throughout the period from 1997 to 2009, within three stations, two stations (Stn.3 and Stn.4) showed increasing trends and one station (Stn.5) showed no trend in annual minimum DO. Since stations that showed increasing trends were dominant, the trend of annual minimum DO for eutrophication in sub-area D was classified as 'Decreasing trend'. Throughout the past ten-year period from 2001 to 2010, two stations (Stn.3 and Stn.4) showed decreasing trends and one station (Stn.5) showed no trend. Stations that showed decreasing trends were dominant. In addition, three stations had data of nine years from 2001 and 2010.

The mean DO concentration of the recent 3 years ranged between 6.2-6.5 mg/L and satisfied the reference value 4.3 mg/L at all stations. And, the assessment method of DO was based on the method in section '3.2'. The determination was reverse to the other parameters.

Overall, the status and trend of DO in sub-area D was classified as 'Low eutrophication status and Decreasing trend'.

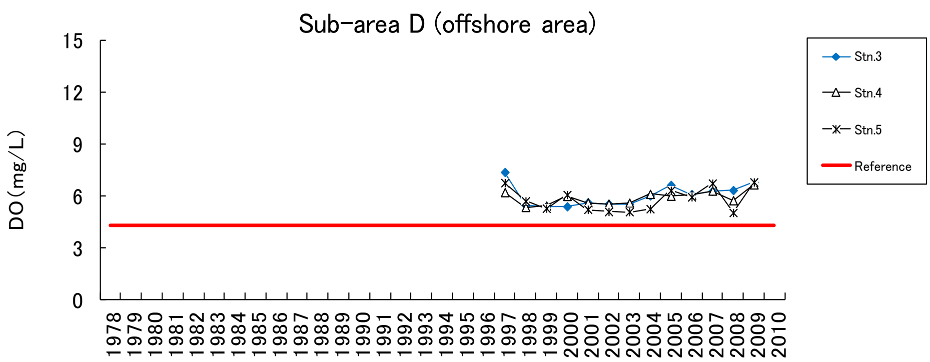

Fig. 1.64 DO concentration in sub-area D

(15) Fish kill incidents

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

(16) Chemical oxygen demand (COD)

Throughout the period from 1997 to 2009, since all stations showed no trends, the trend of annual mean of COD was classified as 'No trend'. Throughout the past ten-year period from 2001 and 2010, all stations showed no trends. In addition, three stations had data of nine years from 2001 and 2010.

The mean of COD of the recent 3 years ranged between 0.4-0.5 mg/L. All stations were below the reference value of 3.0 mg/L.

Overall, the status and trend of COD in sub-area D was classified as 'Low eutrophication status and No trend'.

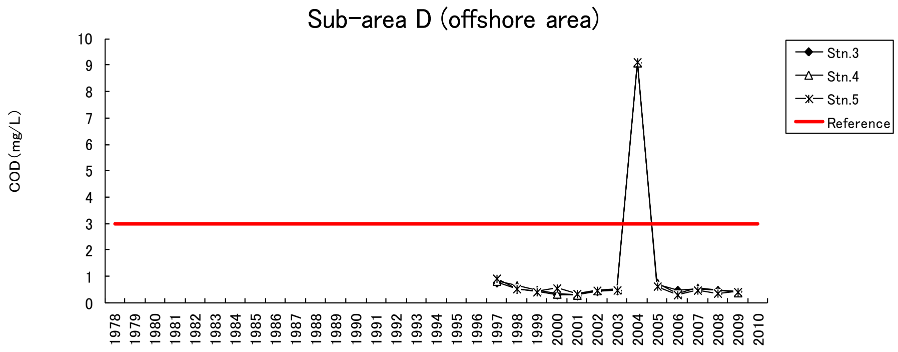

Fig. 1.65 COD concentration in sub-area D

(17) Transparency

Throughout the period from 1978 to 2009, within the three stations, two stations (Stn.4 and Stn.5) showed no trends and one station (Stn.3) showed decreasing trends in the annual mean transparency. Since the stations that showed no trends were dominant, the trend of the annual mean transparency was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, all stations, which had data up to 2009, showed no trends in the annual mean transparency.

The annual mean transparency of the recent three years ranged between 12-15 m.

Overall, the status and trend of transparency in sub-area D was classified as 'No trend'.

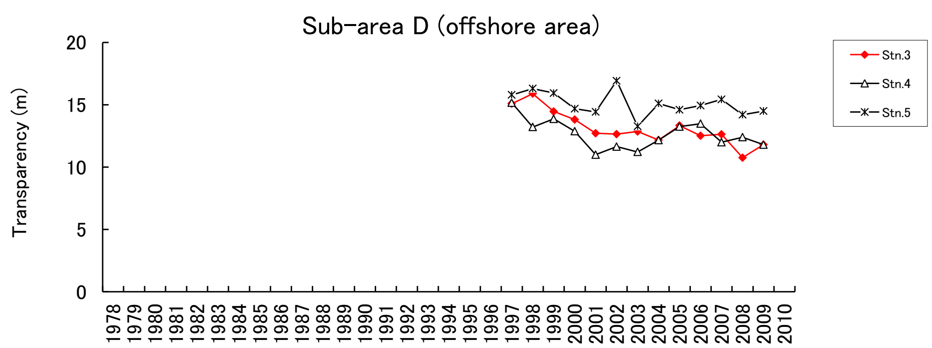

Fig. 1.66 Transparency in sub-area D

Assessment results of category IV parameters

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

In sub-area D, *Noctiluca* red tide occurred once each in 1988, 2001, 2003, 2005 and 2009. Throughout the period from 1978 to 2010, since no increasing or decreasing trend was identified, the trend of *Noctiluca* red tide was classified as 'No trend'. Throughout the past ten-year period from 2001 to 2010, *Noctiluca* red tide occurred 0-1 event/year. No increasing or decreasing trend was identified.

In the recent 3 years, *Noctiluca* red tide occurred once in 2009, which is below the reference value of 3 events/3 years.

Overall, the status and trend of *Noctiluca* red tide in sub-area D was classified as 'Low eutrophication status and No trend'.

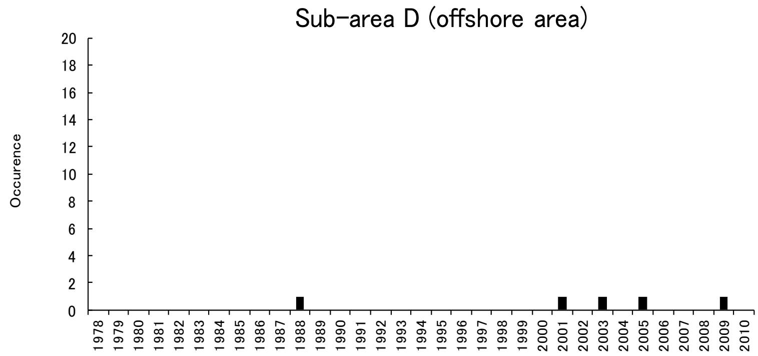

Fig. 1.67 Number of *Noctiluca* red tide in sub-area D

(19) Shellfish poisoning incidents

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

Assessment results of each assessment category

Table 1.18 shows assessment results of each assessment category in sub-area D.

Table 1.18 Assessment results of each assessment category (sub-area D)

Categories	Assessment parameters	Comparison	Occurrence	Trend	Parameter identification	Class identification
I	Riverine input of TN	X	X	X	-	-
	Riverine input of TP	X	X	X	-	
	Input from direct discharge of TN	X	X	X	-	
	Input from direct discharge of TP	X	X	X	-	
	TN concentration	X	X	X	-	
	TP concentration	X	X	X	-	
	Winter DIN concentration	X	X	X	-	
	Winter DIP concentration	X	X	X	-	
	Winter DIN/DIP ratio	X	X	X	-	
II	Annual maximum of chlorophyll-*a*	L	X	N	LN	LN
	Annual mean of chlorophyll-*a*	X	X	N	N	
	Red tide events (diatom sp.)	X	L	N	LN	
	Red tide events (dinoflagellate sp.)	X	H	N	HN	
III	Dissolved oxygen (DO) at bottom layer	L	X	D	LD	LN
	Fish kill incidents	X	L	N	LN	
	Chemical oxygen demand (COD)	L	X	N	LN	
	Transparency	X	X	N	N	
IV	Red tide events (*Noctiluca* sp.)	X	L	N	LN	LN
	Shellfish poisoning incidents	X	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: No trend in annual max./mean of chlorophyll-*a* concentration. Diatom and dinoflagellate red tide did occur at low frequency.

Category III (indirect effects of nutrient enrichment) parameters: DO satisfied the reference value and decreasing trends were identified at all stations. No fish kill was confirmed. COD was below the reference value, and no increasing or decreasing trend was identified. No increasing or decreasing trend was identified in transparency.

Category IV (other possible effects of nutrient enrichment) parameters: *Noctiluca* red tide occurred only once in 2009 in the recent 3 years. No shellfish poisoning incidents were confirmed.

Except for dinoflagellate red tide, all parameters were classified as either 'LN' or 'N'. Hence, eutrophication has not appeared to be a major issue in sub-area D.

Table 1.19 Reasons behind the classification of each assessment category (sub-area D, offshore area)

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: The annual maximum was below the reference values at all stations. The annual mean 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. Dinoflagellate red tide occurred once in 2009.	LN
III Indirect effects of nutrient enrichment	- DO at bottom layer: DO concentration was above the reference value. Decreasing trends were confirmed. - Fish kill incidents: None - COD: No increasing or decreasing trend. Concentration of the recent 3 years was low. - Transparency: Stations showing no trend were dominant.	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 incidents: None	LN

4.5 Comprehensive assessment of the North Kyushu sea area

Table 1.20 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. As of TN and DIN concentrations, there was an increasing trend in sub-area A, a decreasing trend in sub-area B, and no increasing or decreasing trend in sub-area C.

Category II (direct effects of nutrient enrichment)

The status of chlorophyll-*a* and red tide in sub-area A and B was high and in sub-area D was low. There was no increasing or decreasing trend in all areas.

Category III (indirect effects of nutrient enrichment)

The status was low in all areas. There were decreasing trends in COD and transparency in sub-area B and D, but no increasing or decreasing trend in other sub-areas.

Category IV (other possible effects of nutrient enrichment)

The status was low in all areas. There was no increasing or decreasing trend.

Following are the main findings of each sub-area:

Sub-area A

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. However, TN inputs from the sewage treatment plants showed decreasing trends and TP inputs showed increasing trends. Although nutrient input from the Hiagari treatment center, which discharges into Kanmon Strait, was high in sub-area C, TN and TP levels in Kanmon Strait were below the reference value. Dinoflagellate and *Noctiluca* 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 (TN, TP, DIN and DIP), which indicate degree of nutrient enrichment, were 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 1.20 Assessment results of the North Kyushu sea area by assessment category and sub-area

Category	Sub-area				Comment on category classification
	A	B	C	D	
I Degree of nutrient enrichment	LD-LI	LD	LN	-	Low status in sub-areas A, B and C. As of TN and DIN concentrations, increasing trend in sub-area A, decreasing trend in sub-area B, and no increasing or decreasing trend in sub-area C.
II Direct effects of nutrient enrichment	HN	HN	LN-HN	LN	As of chlorophyll-*a* and red tides, high status in sub-areas A and B, and low status in sub-areas D. No increasing or decreasing trend in all sub-areas.
III Indirect effects of nutrient enrichment	LN	LD-LN	LN	LN	Low status in all sub-areas. Decreasing trend in COD and transparency in sub-area B, and decreasing trend in DO in sub-area D. No increasing or decreasing trend in other sub-areas.
IV Other possible effects of nutrient enrichment	LN	LN	LN	LN	Low status in all sub-areas. No increasing or decreasing trend in all sub-areas.

4.6 Comparison of the comprehensive assessment with findings in the literature

In order to evaluate the comprehensive assessment results in the North Kyushu sea area, comparison was conducted with the findings in existing literature including environmental survey results.

Hakata Bay, located in the North Kyushu sea area waters, is adjacent to Fukuoka City, the biggest city in Kyushu. Since Hakata Bay is shallow in water depth and is a semi-enclosed bay, the water environment has deteriorated rapidly in the period of rapid economic growth. In order to understand the cause of deterioration, many existing surveys have been conducted in Hakata Bay and then in Dokai Bay. Therefore, comparison with the comprehensive assessment was carried out in Hakata Bay and Dokai Bay. Table 1.21 shows the literature that were used for comparison.

Table 1.21 Literature used for comparison

Comparison sub-area	Literature including environmental survey reports	Survey Organization	Sources	No.
Sub-area A	Measures and monitoring results for Hakata Bay environmental conservation in 2012	Water Depth Committee of Hakata Bay Environmental Conservation Plan	Fukuoka City(2012)	(1)
	Long-term changes on the water quality environment in Fukuoka Bay	Fukuoka Fisheries and Marine Technology Research Center	Research Report of Fukuoka Fisheries and Marine Technology Research Center, No. 19, March 2009	(2)
	Long-term changes on TN/TP inputs discharged to Fukuoka Bay	Fukuoka Fisheries and Marine Technology Research Center	Research Report of Fukuoka Fisheries and Marine Technology Research Center, No. 19, March 2009	(3)
	Changes on water temperature and water quality in Hakata Bay	Fukuoka City Institute for Hygiene and the Environment	Report of Fukuoka City Institute for Hygiene and the Environment, No. 34, 2008	(4)
	Generation and disappearance mechanisms of hypoxia in the head of Hakata Bay	Yanagi Tetsuo, Ishii Daisuke	Oceanography in Japan, 18(2), 169-176, 2009	(5)
Sub-area B	Occurrence characteristics of seaweeds and eutrophic level of Dokai Bay	Yamada Machiko, Ueda Naoko, Hanada Hirofumi	Journal of Environmental Laboratories Association, 30(4), 2005	(6)

The following are the main findings of each sub-areas:

<Sub-area A>

Riverine input of TN: Decreasing trend in the comprehensive assessment; large change not confirmed in the literature[(3)].

Riverine input of TP: Decreasing trend in the comprehensive assessment; decreasing trend in the literature [(3)].

Input from direct discharge of TN: No increasing or decreasing trend in the comprehensive assessment; increasing trend in the literature[(3)] (only included input from sewage plants).

Input from direct discharge of TP: No increasing or decreasing trend in the comprehensive assessment; decreasing trend in the literature[(3)] (only included input from sewage plants).

TN concentration: Increasing trend in the comprehensive assessment; increasing trend[(2)] or plateau[(1)(3)] in the literature.

TP concentration: Decreasing trend in the comprehensive assessment; decreasing trends in the literature[1)(2)(3)].

Winter DIN concentration: Increasing trend in the comprehensive assessment; increasing trend in the literature[(2)] for full year DIN.

Winter DIP concentration: No increasing or decreasing trend in the comprehensive assessment; decreasing trend in the literature[(2)] for full year DIP.

Chlorophyll-*a*: No increasing or decreasing trend in the comprehensive assessment; decreasing trend in the literature[(2)]. The same trend was confirmed in one paper[(4)] in which the same data of C-1 and W-3 were used for analysis.

COD: Nearly the same trend was confirmed in the literature[(1)(4)] in which the same data of C-1, C-4, C-10, E-2, E-6, W-3, W-6, and W-7 were used for analysis.

DO at bottom layer: No increasing or decreasing trend in this comprehensive assessment; large increasing or decreasing trend was not confirmed in the literature.

Overall, there were many common assessment parameters in this comprehensive assessment compared with the literature. With regards to parameters with different results, the assessment results (increasing trends, decreasing trends, or vice versus) were not very different from each other.

<Sub-area B>

According to the literature[(6)], Dokai Bay was divided into 5 classes (Oligotrophic area, Eutrophic area, weak over-affected area, over-nutrition area and oligosaprobic area) based on the nutrition classes, using COD concentrations as a proxy. COD concentrations used in this case study were compared with the determined COD level in each class in the literature. As a result, the COD concentration of D6 in this case study was lower than the COD level in the literature, but the COD concentrations of other stations in this case study were in the range of the classes in the literature. Overall, there was no significant difference between the results of this case study and that in the literature. (See Table 1.22)

Table 1.22 Comparison with literature

Literature[(6)]			COD (mg/L) in this case study	
Nutrition class	COD（mg/L）	Division in Dokai Bay	Station	Three-year mean
Oligotrophic area	<1	―	―	
Eutrophic area	1-3	Bay entrance	D2	1.8
Weak over-affected area	3-5	Wakato Bridge	D3	2.4
Over-nutrition area	3-10	Inner bay, Center bay, Yawata district	D7, D6	3.6, 2.9
Oligosaprobic area	>10	―	―	―

5. Conclusions and Recommendations

Hakata Bay

- Although TN and TP inputs from the rivers showed decreasing trends, 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 increasing trend, 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.
- With regards to TN and TP inputs, TN and TP concentrations, DIN, DIP, chlorophyll-*a* and COD in sub-area A, there were many common assessment parameters in this comprehensive assessment compared with the references. As of different parameters, the assessment results (increasing trends, decreasing trends, or vice versus) were not so different from each other. As of COD concentration in sub-area B of Dokai Bay, results in most stations in this case study were not so different from the results in references.
- The evaluation of DO and transparency has been added since the assessment in 2010. As a result, the reliability of the assessment of the indirect effects of the increase in nutrient of category III in each sub-area has been improved.

Dokai Bay

- Sub-areas have been changed since the assessment in 2010. As Dokai Bay and its surrounding areas were selected as target areas, assessments on parameters were limited the areas within Dokai Bay.
- As of TN and TP inputs, in addition to the inputs from the sewage treatment plants, inputs from the factories were also added, therefore the reliability of the assessment of the extent of the increase in nutrient of category I has been improved.
- As a result, 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 Dokai Bay sea areas, and should be continued.

Intermediate area

- There was no increasing or decreasing trend in TN and TP inputs 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 was identified. 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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