A Case Study Report

on Assessment of Eutrophication Status

in Changjiang (Yangtze) River Estuary and its

Adjacent Area, China

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Contents

1 Scope of Assessment

1.1 Selection of assessment area

The Changjiang River Estuary is the largest estuary in China. The length of it from Xuliujing to the mouth is about 110 km and the width of estuary mouth is about 90 km. It is a mesotidal, partially mixed estuary characterized by semidiural tides, with a mean tidal amplitude of 2.8 m (Shi, 2004) and tidal currents of 1.0 - 2.0 m s^{-1}.

The Changjiang River's basin is characterized by many industrial and urban centers, especially along its lower reaches and the estuary. With the influence of the dense population, the extensive use of chemical fertilizers and domestic waste, the Changjiang River Estuary is facing the challenge of environmental deterioration. In recent decades, the Changjiang River Estuary has received a high loading of anthropogenic nutrients from more and more activities in agriculture, sewage due to massive economic growth and urban development. Investigations revealed that concentrations of nitrogen and phosphorus increased both inshore and offshore from the 1960s to 2004. Nitrate concentrations inshore increased nearly 9-fold since the early 1960s. Nitrate concentrations inshore demonstrated a fast ascending trend from 1960s to 1980s, which plateaued by the 1990s, and since then, the nitrate concentration has increased slowly. Also, SRP concentrations have increased about 3- to 4-fold since the 1960s.

According to Bulletin of Marine Environmental Quality of China, pollution conditions in coastal area of China in 2006~2009 are presented in Fig. 1.1 (State Oceanic Administration, 2006~2009). It can be concluded that pollution in the Changjiang River estuary is the most serious in coastal area of China. It should be noted that the main pollutants in this estuary are inorganic nitrogen, soluble reactive phosphorus and petroleum and the pollution is more serious inshore than offshore.

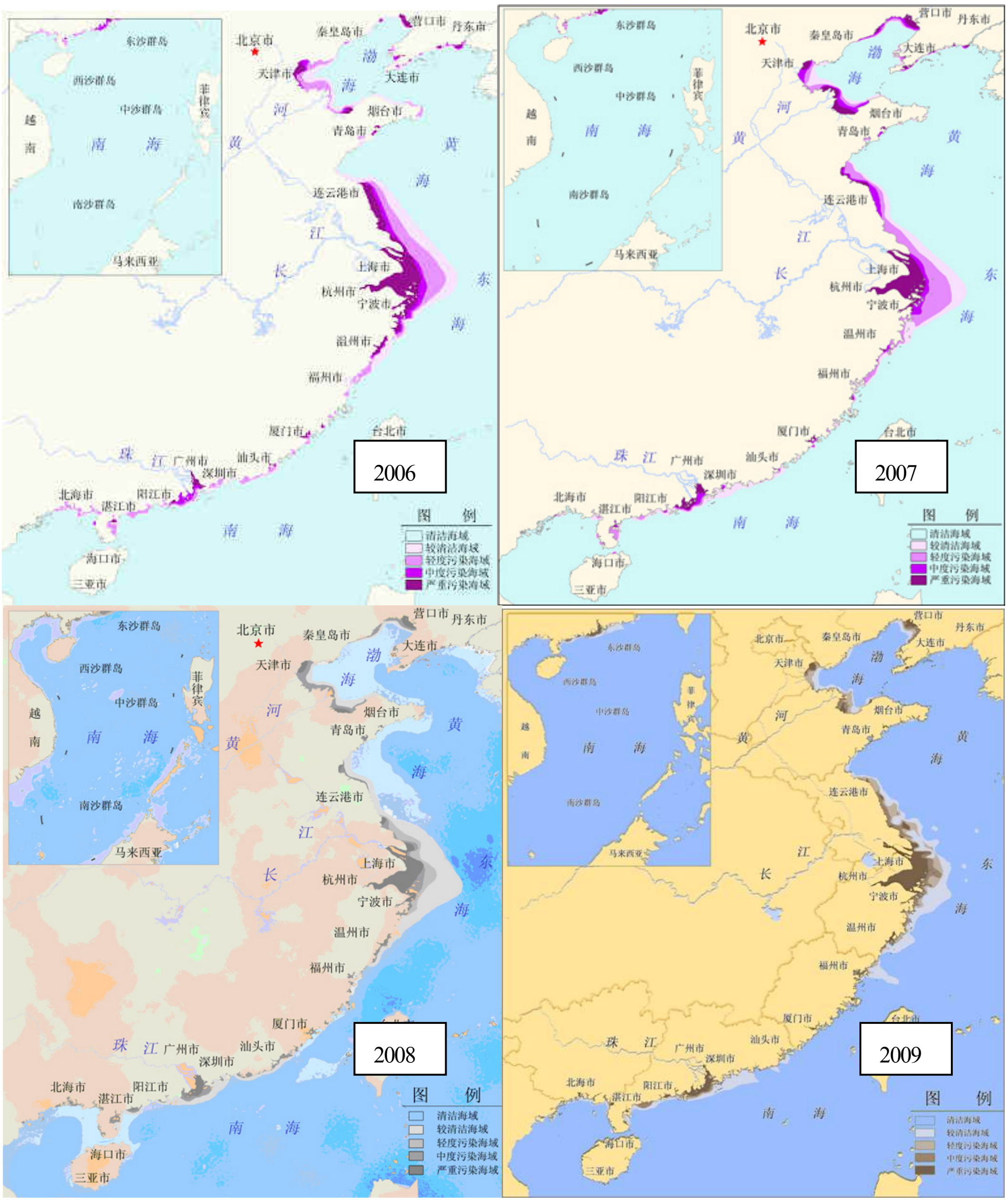

Fig. 1.1 Pollution condition in coastal area of China

With the pollution, the mean of DIN and SRP was 60~100 μM and 1~1.5 μM respectively in the upper estuary in November 2002~2006 (Fig. 1.2).

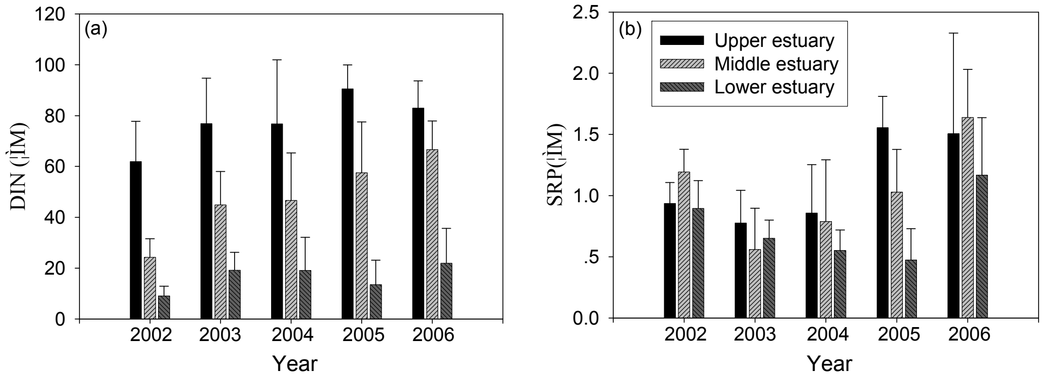

Fig. 1.2 DIN and SRP in November 2002~2006

In additon, noxious algal blooms have been of more frequent occurrence in the Changjiang River estuary. In 2009, the most algal blooms happened in this estuary (Fig. 1.3, State Oceanic Administration, 2009).

Fig. 1.3 Algal blooms in 2009 in coastal area of China

Therefore, the eutrophication in the Changjiang River Estuary is caused wide public concern over the recent years, and so many environmental monitoring projects are ongoing and much reference data can be consulted.

In order to assess eutrophication of the Changjiang River estuary, various methods were applied. Eutrophication index and Trophic quality indices (Zou et al., 1983) were applied to evaluate eutrophication in the Changjiang River estuary (Ye et al., 2000; Zhang et al., 2003; Zhu et al., 2005) and consistent results indicated that eutrophication grade decreased from coastal to offshore area in this estuary.

In addition, methods of fuzzy synthesis evaluation and artificial neural network were also applied and additional assessment parameters (Chl a and DO in surface water) were included (Chen et al., 2007; Su et al., 2008). Similar with eutrophication index, the results of both methods showed that the area west of 122.5°E was eutrophic and the area east of

122.5°E was oligotrophic.

However, inshore area was considered as not sensitive to nutrient enrichment due to high turbidity, short residence time and strong tidal mixing (Chai et al., 2006). All of these factors constrained phytoplankton growth and signs of eutrophication (e.g. algal bloom and hypoxia) were not obvious. On the contrary, in spite that nutrients in offshore area were not so high as inshore area, better light, longer residence time, smaller tidal range resulted in more sensitivity to eutrophication in offshore area. Hence, eutrophication evaluation in the Changjiang River estuary should not only include water quality parameters, but also specific signs of eutrophication.

1.2 Collection of relevant information

1.2.1 Information on the assessment area that is necessary and relevant to eutrophication assessment

Information on the assessment area that is necessary and relevant to eutrophication assessment were mainly collected from following sources:

(1) Environmental monitoring/survey data:

The nuisance and toxic blooms was referenced to Bulletin of Marine Environmental Quality of Shanghai, Bulletin of Marine Environmental Quality of China, Bulletin of Marine disaster of China, Report on the state of the fishery eco-environmental in China, Report on water resource of Changjiang River basin, Changjiang sediment bulletin.

The nutrients, Chla, DO, etc. were referenced to published references and data, results from related research projects.

(2) Pollutant sources:

Pollutant sources (e.g. municipal, industrial, agricultural, marine aquaculture, atmospheric deposition) were referenced to published references and data and results from related research projects.

(3) Supplementary information:

The supplementary information (e.g. oceanography, meteorology, catchment area population, wastewater management, fishery status) were referenced to published references and data.

(4) Information on methods of field measurement and chemical analysis:

Four cruises were carried out annually in February, May, August and November during 2003~2007 in the Changjiang River Estuary and in the adjacent East China Sea, where 40 sampling stations were located. The four surveys, covering periods from low (November-April) to high (May-October) water discharge, were conducted from the estuary to the East China Sea, covering a salinity range from 0.1 to 35 psu. T, salinity, pH, DO, COD, nutrients, etc. in the estuary were monitored during 2003~2007 (Table 1.1). Chla was monitored during 2003~2006, 2009 (Table 1.1). Other data of nutrients were from literature.

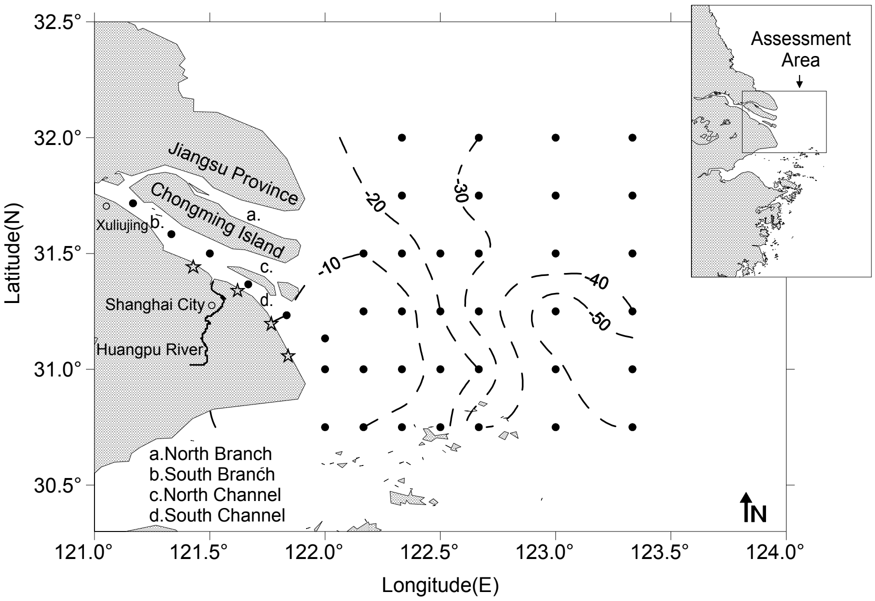

Fig.1.4 Map of the Changjiang River estuary and adjacent sea

1.2.2 Eutrophication related information/data from organizations:

(1) Organizations that monitor water quality:

Organizations that monitor water quality for environmental conservation purposes includes: State Oceanic Administration, Shanghai Oceanic Administration, Ministry of Agriculture, Ministry of Environmental Protection, Chinese Academy of Sciences. The data were reported annually, and survey frequency was not reported.

(2) Organizations that monitor harmful algal blooms:

Organizations that monitor water quality for protection of fishery resources includes: State Oceanic Administration, Shanghai Oceanic Administration. The data were reported annually, and survey frequency was not reported.

(3) Organizations that have supporting environmental information:

Organizations that have supporting environmental information (e.g. oceanographic (physical, biogeochemical etc.) data, meteorological data) includes: State Oceanic Administration, Ministry of Water Resources. The data were reported annually, and survey frequency was not reported.

The collected environmental monitoring/survey information were in Table1.1.

1.3 Selection of assessment parameters

1.3.1 Categorization of monitored parameters

From the selected environmental monitoring programs, all eutrophication related parameters that are monitored within the assessment area were categorized into one of the following 3 assessment categories (Table 1.2):

(1) Category I Parameters that indicate degree of nutrient enrichment

(2) Category II Parameters that indicate direct effects of nutrient enrichment

(3) Category III Parameters that indicate indirect effects of nutrient enrichment

1.3.2 Selection of assessment parameters of each assessment category

Considering assessment parameters that are applicable for the assessment procedure on the basis of their data reliability and continuity, assessment parameters were set as following (Table 1.2):

(1) Category I: Riverine input of TN, TP in 2006~2010 provided by Chinese National Environmental Monitoring Center was presented in Fig 1.5~1.6. In recent years, there was no obvious change of TN and TP at Chaoyang Farm section of Changjiang river. Since longterm monitoring parameters of riverine input of TN, TP can not be colletced, riverine inputs of DIN, DIP were used in this study (data from Changjiang River Statistical Almanac Committee, 1992-2004; Li et al, 2007). Parameters that indicate degree of nutrient enrichment, including DIN, DIP and DIN/DIP ratio.

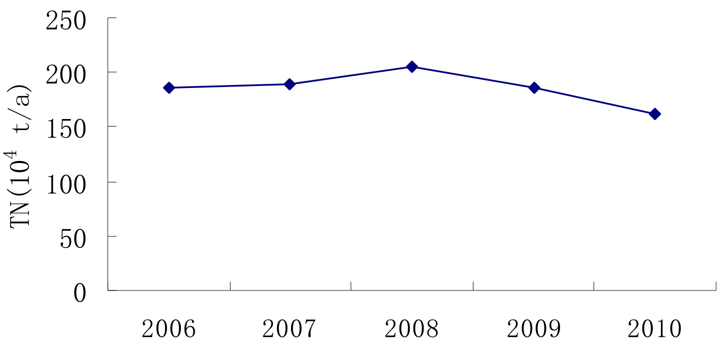

Fig. 1.5 Change of riverine input of TN

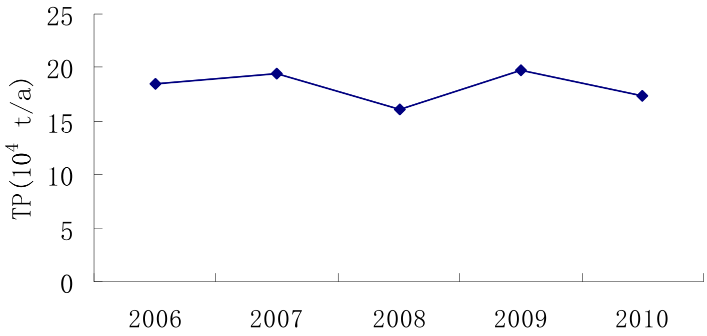

Fig. 1.6 Change of riverine input of TP

(2) Category II: Parameters that indicate direct effects of nutrient enrichment (including maximum of Chlorophyll a, mean of Chlorophyll a and red tide events)

(3) Category III: Parameters that indicate indirect effects of nutrient enrichment (including DO in bottom layer and COD)

Table 1.1 The collected environmental monitoring/survey information

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Report frequency
China coastal water	State Oceanic Administration	Bulletin of Marine Environmental Quality of China	Survey and assessment of marine environmental quality	1990~2009	COD, nutrient, petroleum, heavy metals, PCB, BHC, DDT, diversity index, pollutant sources, red tides	Annually
China coastal water	State Oceanic Administration	Bulletin of Marine disaster of China	Survey and assessment of marine disaster	1990~2009	red tides	Annually
Changjiang River Estuary	Shanghai Oceanic Administration	Bulletin of Marine Environmental Quality of Shanghai	Survey and assessment of marine environmental quality	2001~2006	COD, nutrient, petroleum, heavy metals, PCB, BHC, DDT, diversity index, pollutant sources, red tides	Annually
Marine fishery waters and key inland fishery waters in China	Ministry of Agriculture, Ministry of Environmental Protection	Report on the state of the fishery eco-environmental in China	Survey and assessment of Marine fishery waters and key inland fishery waters	1900~2007	COD, nutrient, petroleum, heavy metals, Chla, phytoplankton density, zooplankton density,	Annually
Changjiang basin	Ministry of Water Resources	Report on water resource of Changjiang River basin	Survey of water resource	1999~2006	Precipitation, amount of water resources, waste water discharge	Annually
Changjiang River	Ministry of Water Resources	Changjiang sediment bulletin	Survey of water and sediment discharges	2000~2007	Water and sediment discharges	Annually
Changjiang River Estuary	Chinese Academy of Sciences	Project of eutrophication research	Survey and assessment of eutrophication	2003~2007	T, Salinity, pH, DO, COD, Nutrients	Quarterly(survey frequency)
Changjiang River Estuary	Chinese Academy of Sciences	Project of eutrophication research	Survey and assessment of eutrophication	2003~2006,2009	Chla	Quarterly(survey frequency)
Riverine input of DIN,	Changjiang River Statistical Almanac Committee	Almanac of the Yangtze River, , Research project	Survey of Riverine input of DIN	1963.1973~1997, 2001~2007	DIN flux	Annually
Riverine input of DIP	Changjiang River Statistical Almanac Committee	Almanac of the Yangtze River, Research project	Survey of Riverine input of DIP	1964~1984, 1987~1988,1996,2001~2007	DIP flux	Annually

Table 1.2 Assessment parameters used in the Changjiang River Estuary

Category	Assessment parameter
Category I	Riverine input of DIN
	Riverine input of DIP
	DIN
	DIP
	DIN/DIP ratio
Category II	maximum of Chlorophyll a
	mean of Chlorophyll a
	red tide events
Category III	DO in bottom layer
	COD

1.3.3 Setting the assessment values

Except maximum of Chlorophyll a and red tide events, all parameters are based on annual mean.

1.3.4 Setting subareas

Since some date were from literatures, which did not report data (such as COD, nutrients, etc.) in different areas of the Changjiang River estuary. Therefore, in order to compare and analyze data, subareas were not set in this study.

2 Data processing

Values of each assessment parameters were measured using commonly accepted methods. Since NO_3 was the only major nitrogen nutrient in DIN in the Changjiang River estuary, DIN concentration was based on NO_3 The evaluation concentrations used have been the annual mean for DIN, DIP, Chlorophyll a, DO(in bottom layer) and COD. And, annual maximum of Chlorophyll a was used. Furthermore, there was not enough data of red tide events in this estuary and most of red tides in East China Sea happened in this area. Therefore, the frequency of red tide events was based on the data of East China Sea.

3 Setting of assessment criteria

3.1 Setting of identification criteria of the assessment data

Eutrophication status based on each assessment parameter is assessed by identifying its current status and/or trend. Identification tools applied to each assessment parameter in the Changjiang River Estuary were as following (Table 3.1). The parameters of DIN, DIP, DIN/DIP ratio, COD, Chla and DO (in bottom layer) were identified by comparison and trend. The parameter of red tide events was identified by occurrence and trend.

Table 3.1 Identification tools applied to each assessment parameter in the Changjiang River Estuary

Category	Assessment parameter	Assessment value	Identification tools		
			Comparison	Occurrence	Trend
I	Riverine input of DIN				√
	Riverine input of DIP				√
	DIN	Annual mean	√		√
	DIP	Annual mean	√		√
	DIN/DIP ratio	Annual mean	√		√
II	maximum of Chlorophyll a	Annual maximum	√		√
	mean of Chlorophyll a	Annual mean	√		√
III	red tide events	Annual		√	√
	DO in bottom layer	Annual mean	√		√
	COD	Annual mean	√		√

3.2 Setting of classification criteria of the assessment parameters

According to USEPA (2001), thresholds of assessment parameters were set between the historical and present median. In spite of no distribution of historical data, the mean in this estuary was reported and it was assumed that median was equal to mean in this paper. DIN and DIP in 1960s were about 0.03~0.2, 0.006~0.012 mg l^{-1}, respectively (Gu 1980; Gu 1981; Gu et al., 1982). Annual average Chl a shared a similar trend with phytoplankton cell density, which in the early 1980s, was very close to that in 1959~1960. Chl a in the early 1980s was 0.6~0.7 μg l^{-1}; therefore, it was assumed that Chl a in 1959~1960 was also 0.6~0.7 μg l^{-1} (Sun, 2008).

According to the historical and present median, National Sea Water Quality Standard of China (NSQS, 1997) and Bricker et al. (2003), the thresholds and ranges of parameters were presented in Table 3.2. In this program, we accept Class III as criteria of the assessment parameters, i.e. 0.4 mg l^{-1} (DIN, 28.6 μM), 0.03 mg l^{-1} (DIP, 0.97μM), 20 μg l^{-1} (maximum of Chla), 5 μg l^{-1} (mean of Chl a), 2 mg l^{-1}(DO in bottom layer) and 4 mg l^{-1} (COD). As for DIN/DIP ratio, 16 was used in this program (Table 3.3).

Table 3.2 Thresholds of assessment parameters in the National Sea Water Quality Standard of China (NSQS, 1997)

Parameters	Class			
	I	II	III	IV
DIN(mg l^{-1})	0.2	0.3	0.4	0.5
DIP(mg l^{-1})	0.015	0.03		0.045
COD(mg l^{-1})	2	3	4	5

Table 3.3 Reference concentrations used in this study

Category	Parameters	Reference concentrations
I	DIN	0.4 mg l^{-1}(28.6 μM)
	DIP	0.03 mg l^{-1}(0.97μM)
	DIN/DIP ratio	16
II	maximum of Chlorophyll a	20 μg l^{-1}
	mean of Chl *a*	5 μg l^{-1}
III	DO in bottom layer	2 mg l^{-1}
	COD	4 mg l^{-1}

4 Assessment process and results

4.1 Assessment categories

Eutrophication assessment of Changjiang River Estuary was based on the information and data. Since some data were from literature, there was no data of all sites. Therefore, mean of parameters in the study area was used to assess.

4.1.1 Assessment of Category I

Riverine input of DIN, DIP were presented in Fig. 4.1~4.2. Change of riverine input of DIN presented an increasing trend, DIP presented fluctuation. DIN, DIP and DIN/DIP ratio were presented in Fig. 4.3~4.5. The nutrients input of Changjiang River fluctuates. Except in 1963, the DIN concentrations were higher than reference concentration. On the contrary, the DIP concentration was generally lower than reference concentration. Therefore, the DIN pollution was serious in this estuary, which resulted in the high DIN/DIP ratio.

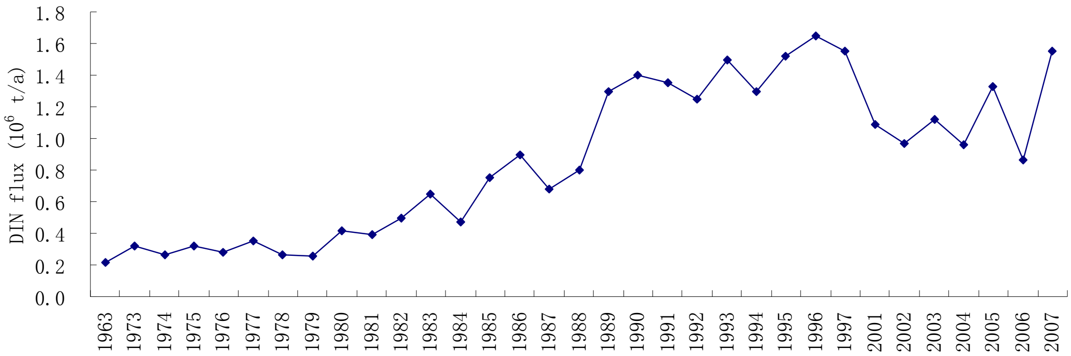

Fig. 4.1 Change of riverine input of DIN

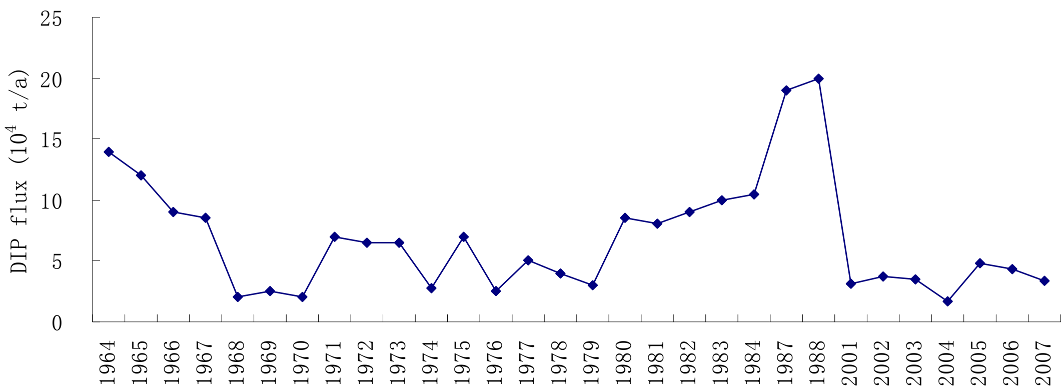

Fig. 4.2 Change of riverine input of DIP

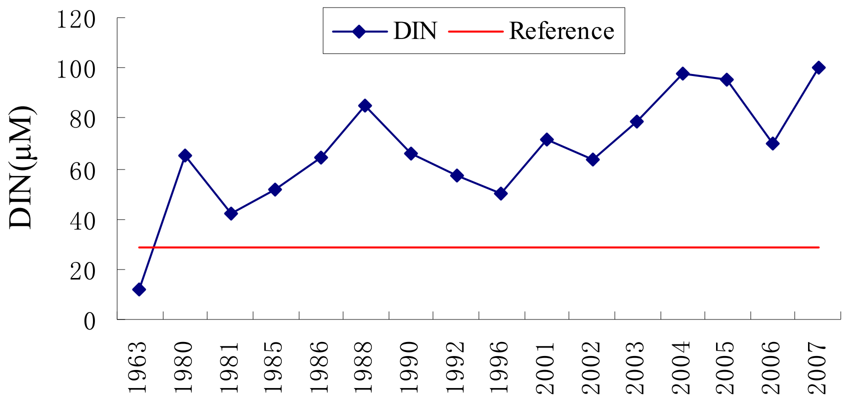

Fig. 4.3 Change of mean of DIN concentration

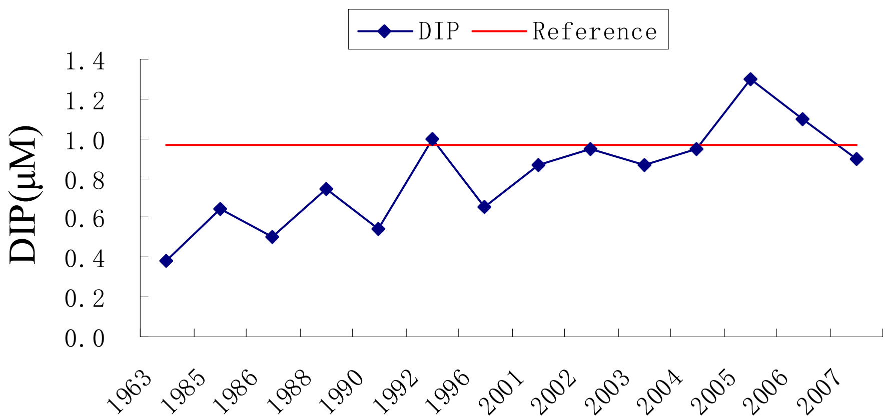

Fig. 4.4 Change of mean of DIP concentration

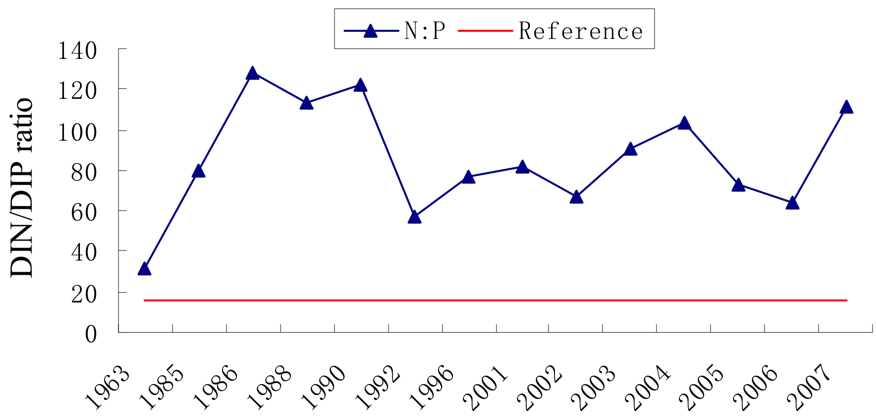

Fig. 4.5 Change of mean of DIN/DIP ratio

Results of non-parametric Mann-Kendall test was presented in Table 4.1. DIN and DIP concentrations presented upward trend, but there was no trend in DIN/DIP ratio (Table 4.1).

Table 4.1　Results of non-parametric Mann-Kendall test

Parameters	z	p	trend
Riverine input DIN	5.33072	0.0000000	Upward trend
Riverine input DIP	-0.39288	0.652795	No trend
DIN	2.13531	0.0163678	Upward trend
DIP	3.06571	0.0010858	Upward trend
DIN/DIP ratio	0	0.5	No trend

4.1.2　Assessment of Category II

Maximum and mean of Chla and red tide events were presented in Fig.4.6~4.8. Maximum of Chla was lower than reference concentration in 2005~2006 and 2009. Also, mean of Chla was lower than reference in recent years.

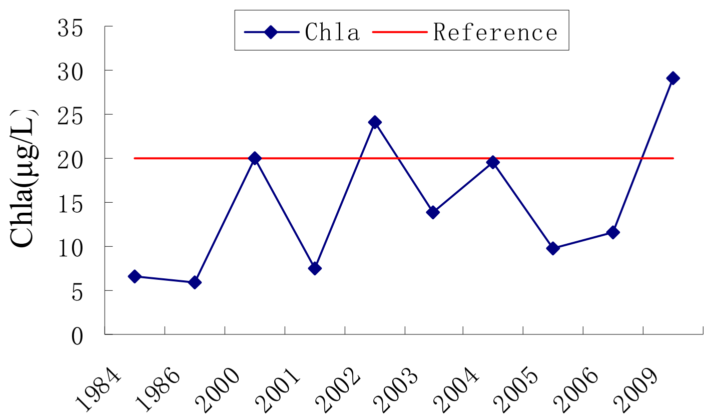

Fig. 4.6　Change of maximum of Chlorophyll a

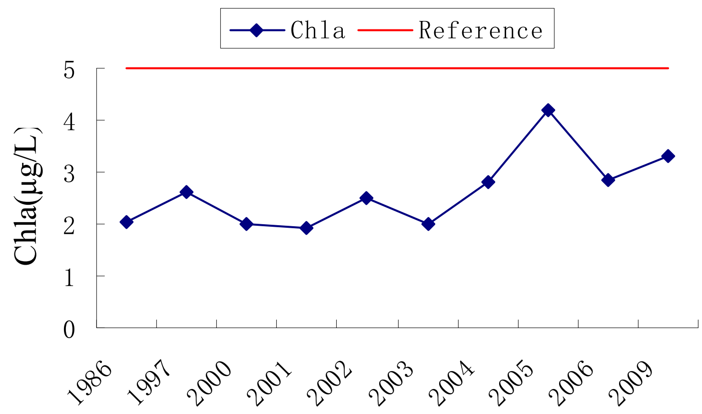

Fig. 4.7　Change of mean of Chlorophyll a

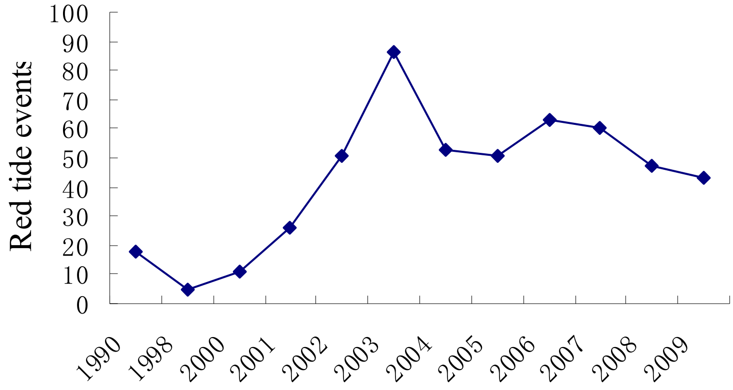

Fig. 4.8 Change of red tides events in East China Sea

Results of non-parametric Mann-Kendall test was presented in Table 4.2. Mean of Chla and Red tide events presented upward trend, but Maximum of Chla presented no trend.

Table 4.2 Results of non-parametric Mann-Kendall test

Parameters	z	p	trend
Maximum of Chla	1.43108	0.0762031	No trend
Mean of Chla	1.96774	0.0245490	Upward trend
Red tide events	2.42467	0.0076611	Upward trend

4.1.3 Assessment of Category III

COD and DO were presented in Fig.4.9~4.10. COD was low in the Changjiang River estuary. In general, COD concentration was lower than 2 mg l^{-1}. DO concentration was generally not lower than 2 mg l^{-1}.

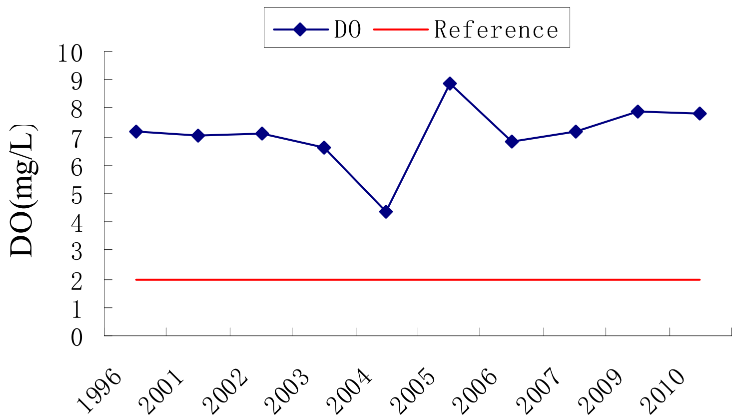

Fig. 4.9 Change of mean of DO

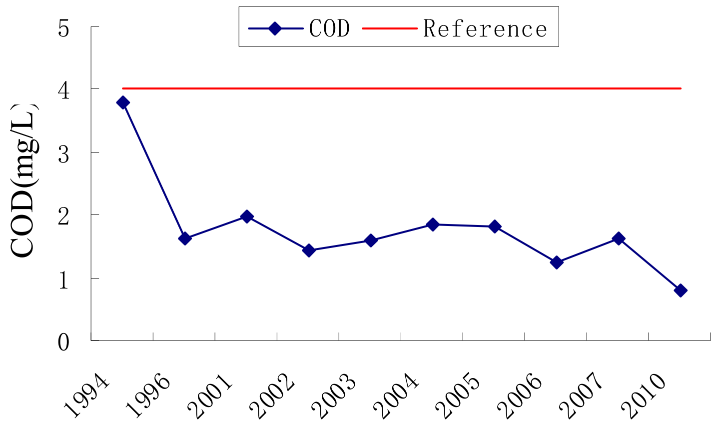

Fig.4.10 Change of mean of COD

Results of non-parametric Mann-Kendall test of DO and COD showed that there was no trend in DO and COD presented downward trend (Table 4.3).

Table 4.3 Results of non-parametric Mann-Kendall test

Parameters	z	p	Trend
DO	0.894427	0.185547	No trend
COD	-1.88586	0.0296572	Downward trend

4.2 Assessment results

The Changjiang River estuary classified each assessment category by majority decisions; the most dominant classification results were chosen as classification result of assessment category.

The eutrophication assessment results of the Changjiang River estuary was presented in Table 4.4. In Category I, Riverine input of DIN presented increasing trend but DIP no trend. DIN and DIN/DIP ratio were higher than reference but DIP was lower. Increase trend was detected in the DIN and DIP. And there was no trend in DIN/DIP ratio. Therefore, the Category I was HI.

In Category II, maximum of Chlorophyll a and red tide events were high and mean of Chlorophyll a was low. Increase trend of all parameters of Category II were detected, and so the Category II was HI.

In Category III, DO and COD were low and no increase trend was detected, and so the Category II was LN.

Table 4.4 Identification of eutrophication status in the Changjiang River estuary

Category	Assessment parameter	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	Riverine input of DIN			I	I	HI
	Riverine input of DIP			N	N	
	DIN	H	×	I	HI	
	DIP	L	×	I	LI	
	DIN/DIP ratio	H	×	N	HN	
II	maximum of Chlorophyll a	L	×	N	LN	LI
	mean of Chlorophyll a	L	×	I	LI	
	red tide events	×	H	I	HI	
III	DO	L	×	N	LN	LN
	COD	L	×	D	LD	

5 Conclusion and recommendations

5.1 Conclusion

1.In Category I, the Changjiang River estuary has current eutrophication status as “High” and “Increase”.
2.In Category II, the Changjiang River estuary has current eutrophication status as “Low” and “Increase”.
3.In Category III, the Changjiang River estuary has current eutrophication status as “Low” and “no trend”.

5.2 Recommendations

1. To get more longterm monitoring assessment parameters(such as riverine input TN, TP and TN, TP concentrations) in sites.
2. To get more detailed monitoring assessment parameters(such as red tides events).
3. To decrease the nutrients input of Changjiang River basin.

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