A STUDY ON THE RELATIONSHIPS OF THE NUTRIENTS NEAR THE CHANGJIANG RIVER ESTUARY WITH THE FLOW OF THE CHANGJIANG RIVER WATER*

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Abstract

Investigations from August, 1985 to July, 1986 showed that the high concentration area of PO_4-P, SiO_3-Si and NO_3-N gradually reduced with the reduction of the area of the Changjiang River diluted water from summer, autumn to winter, and that the seasonal distributions and variations of the nutrients concentrations were mainly controlled by the river flow and were also related to the growth and decline of phytoplankton. The conservation of SiO_3-Si and NO_3-N in the estuary in the flood season was poorer than that in the dry season. The behaviour of PO_4-P in the estuary shows that aside from biological removal, buffering of PO_4-P is possible in the estuary. The highest monthly average concentrations and annual average concentrations in the river mouth were respectively 0.88 and 0.57 μmol/L for PO_4-P, 191.5 and 96.2 μmol/L for SiO_3-Si, and 81.6 and 58.6 μmol/L for NO_3-N. The Changjiang's annual transports of PO_4-P, SiO_3-Si and NO_3-N to the sea were about 1.4×10^4 tons, 204.4×10^4 tons and 63.6×10^4 tons respectively. The investigation shows that the seasonal variations of the nutrients transport closely correlate with that of the flow of the Changjiang River.

Key words: nutrients, Changjiang River, flow, estuary

It is well known that the 6 300 km long Changjiang River is the largest river in China and the third largest in the world. The average Changjiang River runoff into the East China Sea is $9.794\times10^{11}\,m^3/a$ or $3.106\times10^4\,m^3/s$. Flood season (May to October) runoff is 71.7% of annual runoff. After entering the sea, the Changjiang River diluted water is mixed continuously with Taiwan Warm Current water from the south and Yellow Sea water from the north. The convergence of various water masses in the area near the Changjiang River estuary and the great quantity of nutrient material transported annually by river water to the estuary makes the area a most important fishing ground in China and known as one of the best in the world. This paper is mainly based on the results of 11 investigations near the Changjiang River estuary from August, 1985 to July, 1986 (station locations in Fig. 1). The seasonal variations of the nutrients (PO_4-P, SiO_3-Si and NO_3-N) and their relation to the Changjiang River flow, and effects on the transportation, distributions, variations and the behaviour of the nutrients in the estuary, etc. are discussed.

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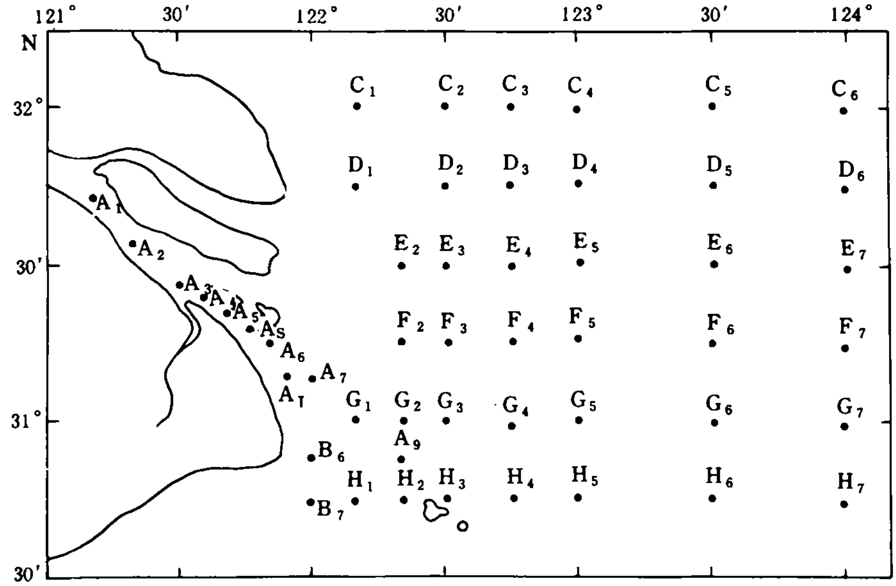

Fig.1 Sampling stations

1. The seasonal variations of the nutrients in the Changjiang River Mouth freshwater

The seasonal variations of the average nutrients concentrations in the Changjiang River Mouth freshwater and the average flow of the Changjiang River at Da Tong are indicated in Fig. 2. The concentrations of PO_4-P and NO_3-N

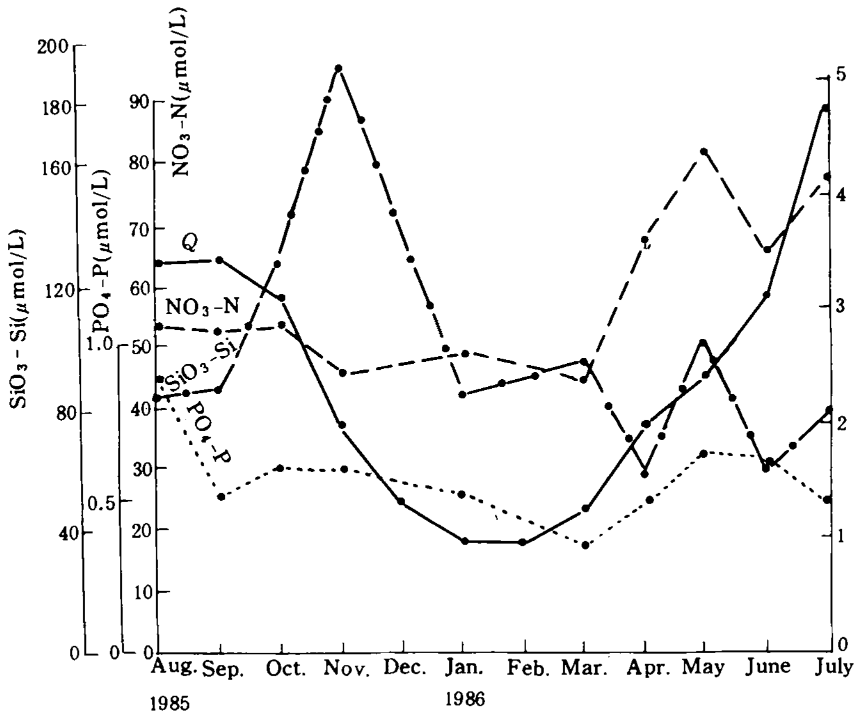

Fig.2 The seasonal variations of the nutrients in the Changjiang River water and its flow

were high (average 0.62 and 63.7 μmol/L respectively) in the flood season and low (average 0.48 and 51.1 μmol/L respectively) in the dry season. The highest concentrations were in August for PO_4-P (average 0.88 μmol/L) and in May for NO_3-N (average 81.6 μmol/L), and the lowest were in March (average 0.34 and 43.7 μmol/L respectively). The relationship between the seasonal variation of SiO_3-Si concentration and the flow of the Changjiang River water was not regular. The highest concentration of SiO_3-Si was 191.5 μmol/L in November and the lowest was 58.5 μmol/L in April.

2. The relationships between the seasonal variations of the nutrients concentrations at the seaward end of the Changjiang River estuary and the flow of the river water

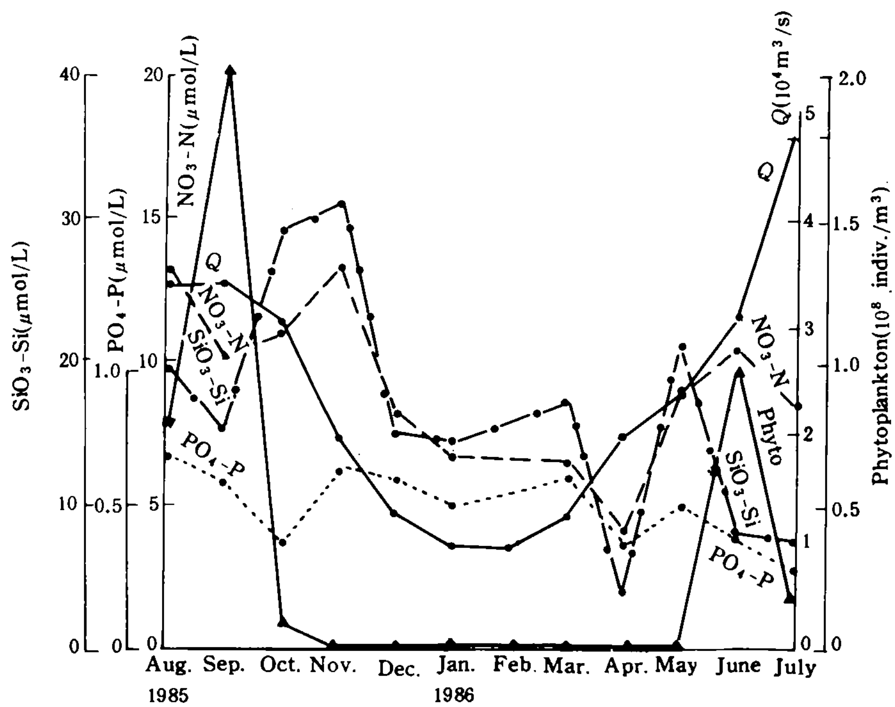

Fig.3 The relationships among the seasonal variations of the nutrients at the seaward end of the Changjiang River estuary and the flow of the Changjiang River water and phytoplankton

The relationships among the seasonal variations of the average concentrations of the nutrients in the surface seawater (the area west of 123 °30′ E), the flow of the river water, and phytoplankton are indicated in Fig. 3 which shows that during the annual phytoplankton peak in the flood season (August to September) PO_4-P, SiO_3-Si and NO_3-N concentrations all decreased. After September, although the flow was higher, there was a rapid decrease of phytoplankton and marked increase in the concentrations of SiO_3-Si and NO_3-N to the annual maximum of 30.9 μmol/L for SiO_3-Si and 13.3 μmol/L for NO_3-N in November. The concentration of PO_4-P rose only after October and reached a peak in November. In late autumn and winter (dry season) phytoplankton was at low ebb; the concentrations decreased a little for PO_4-P and markedly for SiO_3-Si and NO_3-N. The annual lowest values of SiO_3-Si and NO_3-N appeared in April.

Then, all nutrients concentrations increased with the increase of the river water flow. In May to June, due to phytoplankton bloom, all of them decreased. The seasonal variations of PO_4-P, SiO_3-Si and NO_3-N show that in addition to control by the Changjiang River water flow, their concentrations were also related to the growth and decline of phytoplankton.

The seasonal variations of the nutrients concentrations in the sea area were similar in many ways to those in the Changjiang River Mouth. The maximum concentrations of PO_4-P all appeared in August and the seasonal variations were small. The monthly average concentrations of PO_4-P at the seaward side of the river mouth were between 0.29 and 0.68 μmol/L and a little higher in winter than in summer, which may be related to oxidation and decomposition of organisms. The change of SiO_3-Si concentration here was very similar to that in the river freshwater, maximum in November, second in October, and minimum in April. The relationship between them was as follows:

$$SiO_3\text{-}Si\ (\text{in seawater}) = 0.200\ SiO_3\text{-}Si - 2.454\ (\text{in river water})$$
$$(r = 0.877,\ n = 10)$$

The concentration of NO_3-N in the sea area was also higher in the flood season (average 10.4 μmol/L) than in the dry season (average 7.6 μmol/L), and there was a delay in the seasonal variation as compared with that in the river water area. The concentration of NO_3-N in the river water area decreased to minimum from October to next March, and rapidly rose again until May and then decreased again. No_3-N concentration in the sea area decreased from November to next April (minimum in April) and rapidly rose again until June, then decreased again.

3. The effects of the Changjiang River water flow on the distributions and changes of the nutrients in the sea area

For August, November and January, in the flood to dry season in the Changjiang River, the average runoffs into the sea were 3.38×10^4, 1.95×10^4

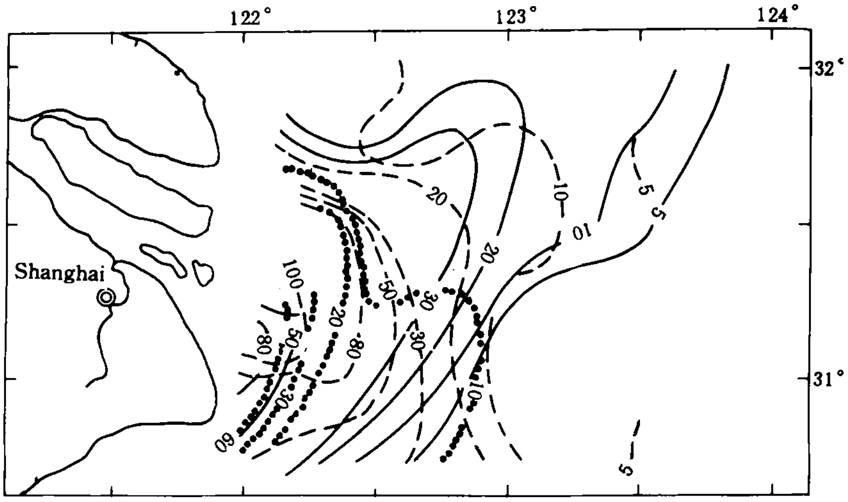

Fig.4 Distribution of SiO_3-Si in surface seawater
—— August, - - - - November, · · · · · · January

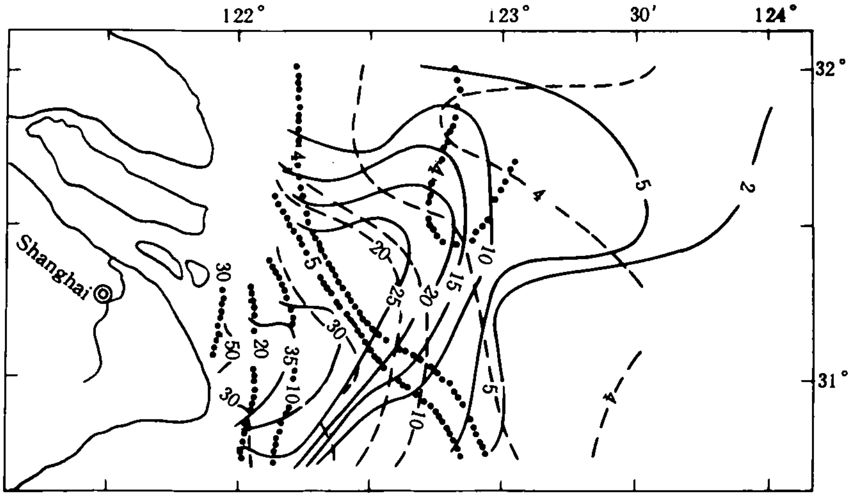

Fig.5 Distribution of NO_3-N in surface seawater
—— August, ‐ ‐ ‐ ‐ November, · · · · · · January

and 0. $96\times10^4\,m^3/s$ respectively. The Changjiang River diluted water area gradually reduced from August to January and the 30 isohaline contracted toward the river mouth. The research shows positive linear correlationships between the Changjiang River diluted water area and the Changjiang River runoff into the sea (Zhang et al., 1987). With the reduction of the area of the diluted water, the higher concentration areas of the nutrients were reduced and all the isograms gradually moved toward the river mouth. For SiO_3-S and NO_3-N (see Figs.4 and 5), the areas covered by the 20 μmol/L isogram were smaller and smaller from summer to winter, and in winter the waters of 20 μmol/L concentration for SiO_3-Si were limited to west of 122 °30′ E and for NO_3-N near the river mouth. This shows that the seasonal distributions and changes of the nutrients are mainly controlled by the seaward flow of the Changjiang River.

4. The effects of the Changjiang River flow on the behaviours of the nutrients in the estuary

Correlation statistics show that there were monthly negative linear correlationships between SiO_3-Si or NO_3-N and salinity and that the correlationship between PO_4-P and salinity was not close. The correlation coefficients and statistical ranges are listed in Table 1. The relationships between SiO_3-Si and salinity and between NO_3-N and salinity (Figs.6 and 7) in August and January show that the correlationships between SiO_3-Si or NO_3-N and salinity respectively in the flood season were poorer than that in the dry season. This was due to the phytoplankton bloom (average $7\,648\times10^4$ phytoplankter/m^3 in August). in the Changjiang River flood season when the nutrients were largely taken up by phytoplankton in surface seawater and the decomposition of organisms released nutrients in the lower seawater (mainly in the waters of salinity higher than 30). It is evident that the change of SiO_3-Si with salinity was similar to that of NO_3-N with salinity and that there was positive linear correlationship between SiO_3-Si and NO_3-N (in August) indicated as:

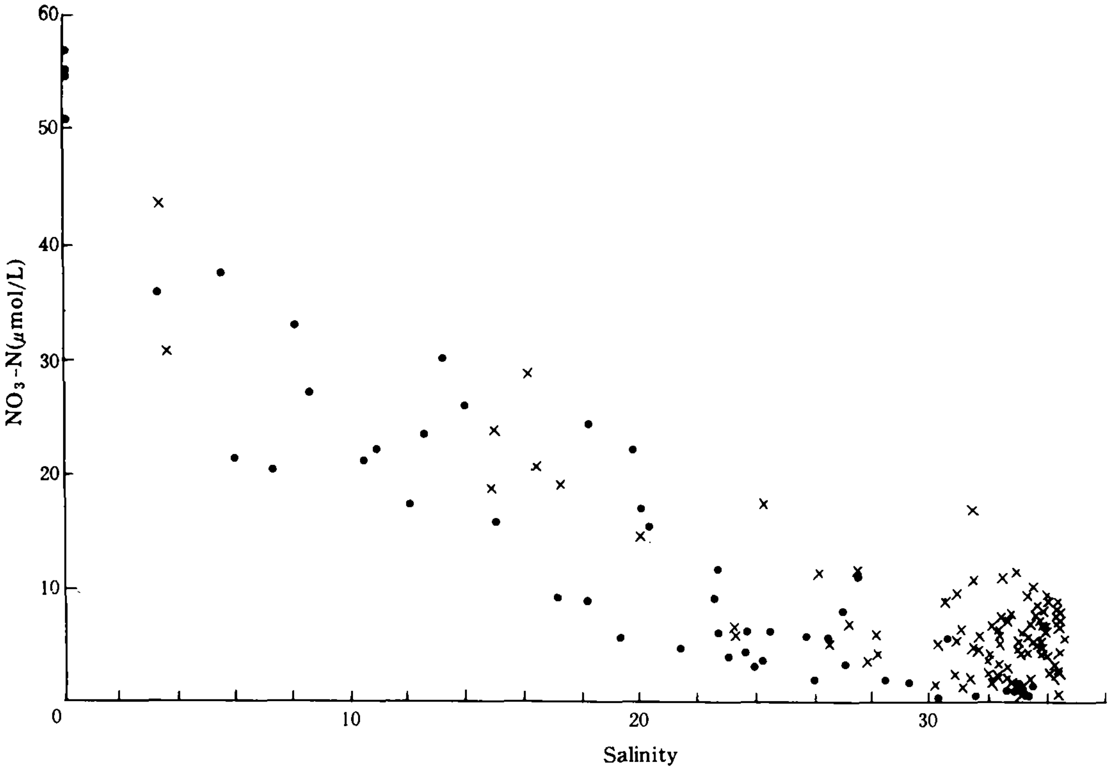

Fig.6 The relationship between NO3-N and salinity (August)
• surface，× lower layer

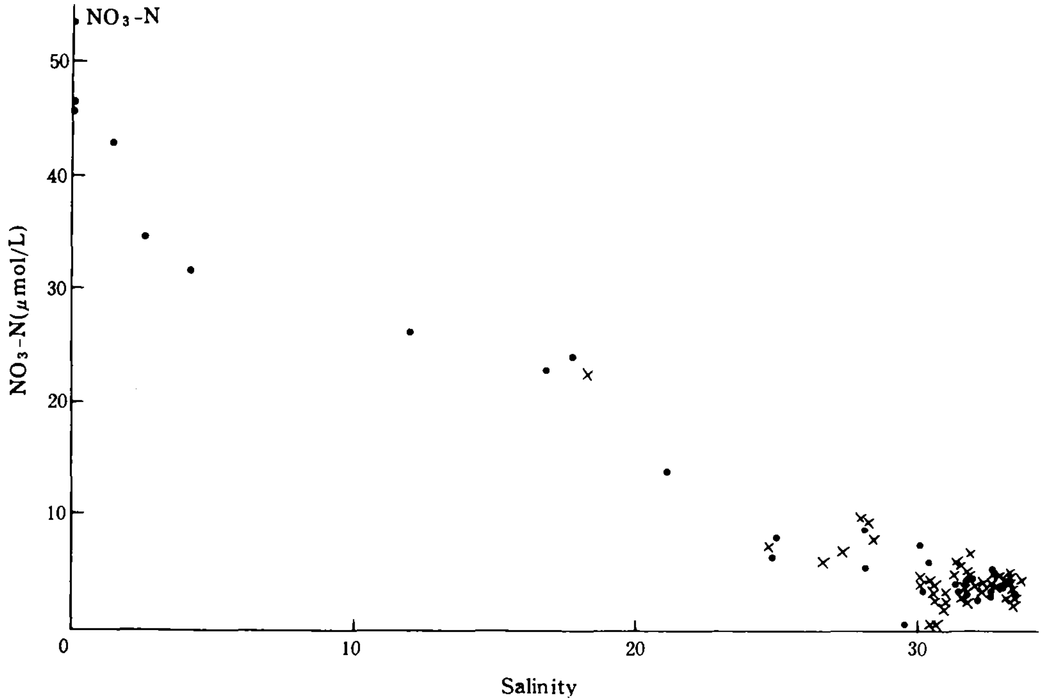

Fig.7 The relationship between NO3-N and salinity (January)
• surface，× lower layer

$$NO_3\text{-}N = 0.582\ SiO_3\text{-}Si + 0.913 \quad (r = 0.936,\ n = 151)$$

that clearly shows that all of them were removed through biological processes.

Table 1 The correlationships between the nutrients and salinity

Months	Water layers	Salinity ranges	PO_4-P		SiO_3-S		NO_3-N	
			r	*n*	*r*	*n*	*r*	*n*
Aug.	All layers	0 — 34.5	−0.177	153	−0.815	153	−0.889	153
Sep.	Surface	0 — 31.7	−0.086	39	−0.819	39	−0.816	39
Oct.	All layers	0 — 33.6	−0.625	149	−0.871	150	−0.921	150
Nov.	All layers	0 — 33.8	−0.249	114	−0.918	114	−0.933	114
Dec.	Surface	15 — 33.2	−0.630	36	−0.914	35	−0.910	36
Jan.	All layers	0 — 33.7	−0.145	109	−0.925	109	−0.964	109
Mar.	Surface	0 — 34.0	0.063	43	−0.898	43	−0.920	43
Apr.	Surface	0 — 33.7	−0.834	36	−0.936	36	−0.940	36
May.	All layers	0 — 33.6	−0.183	122	−0.888	123	−0.905	123
June	Surface	0 — 31.1	−0.864	37	−0.781	37	−0.860	37
July	Surface	0 — 31.1	−0.645	39	−0.761	39	−0.796	39

The correlationship between PO_4-P and salinity was poor in flood or dry season. The investigations show that the concentration of PO_4-P in surface water outside the river mouth was higher than that within the river mouth in many months, and that its distribution was even in some months. In April (see Fig. 8), the concentration of PO_4-P was 0.38 ± 0.058 μmol/L all over the surveyed area where salinity was between 0 and 33.7. The behaviour of PO_4-P in the estuary shows that in addition to biological removal, PO_4-P removal can also possibly be caused by the buffering action of suspensions and sediments of the estuary. The author thinks this is the main reason that in the long term PO_4-P content is at the same level in the sea area of the Changjiang River estuary.

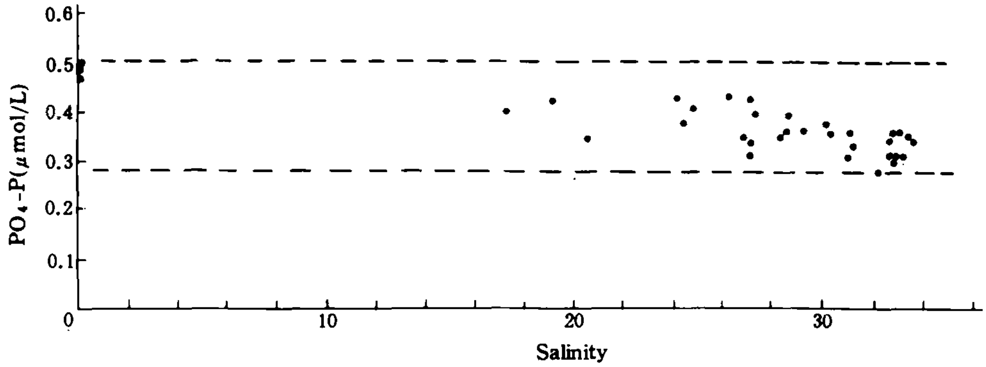

Fig.8 The relationship between PO_4-P and salinity (April)

5. The contributions of the Changjiang River runoff to nutrients in the sea area of the estuary

The monthly average concentrations of the nutrients in the river water area of the Changjiang River Mouth can be used to calculate the nutrient transport from the Changjiang River. Their seasonal variations and the relationships between them and the Changjiang River runoff to the sea are indicated in Fig. 9. It is evident that the seasonal variations of the nutrients transports F(kg/s) of PO_4-P,

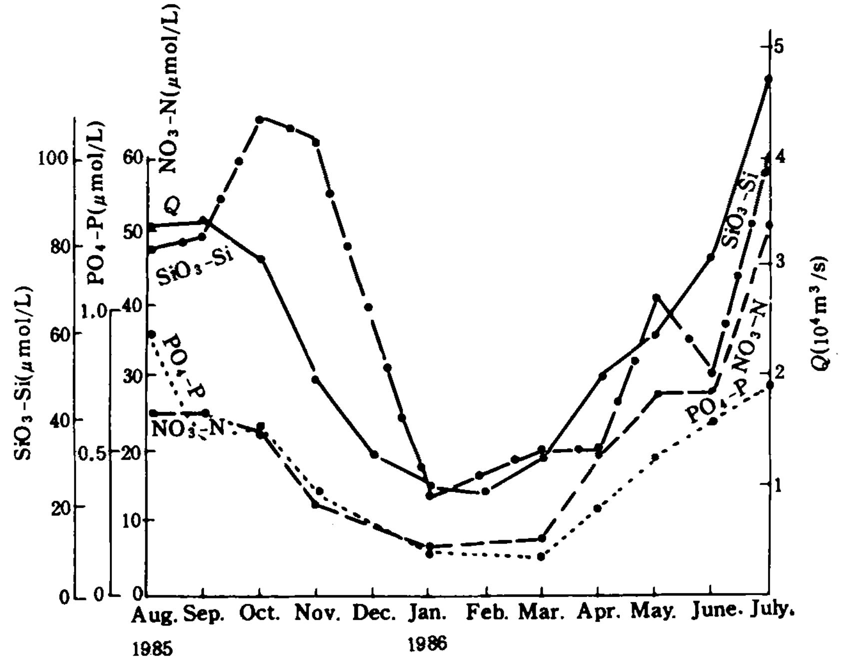

Fig.9 The relationships between the nutrients transports and the flow Q of the Changjiang River

SiO_3-Si and NO_3-N and the water flow Q(m^3/s) of the Changjiang River were very closely correlated as indicated in the equations:

$$F\ (PO_4\text{-}P) = 0.110\exp(0.0000497Q) \quad (r=0.880,\ n=10)$$
$$F\ (SiO_3\text{-}Si) = 23.070\exp(0.0000366Q) \quad (r=0.735,\ n=10)$$
$$F\ (NO_3\text{-}N) = 4.899\exp(0.0000518Q) \quad (r=0.929,\ n=10)$$

that clearly show that the nutrients transports are mainly controlled by the Changjiang River flow. Monthly calculations summing up the Changjiang's annual nutrients transports to the sea listed in Table 2 show them to be 1.4×10^4 tons for PO_4-P, 204.4×10^4 tons for SiO_3-Si and 63.6×10^4 tons for NO_3-N, which are about 10 times that from the Huanghe River (Shen et al., 1988).

Table 2 The nutrients transports

Nutrient transport	PO_4-P	SiO_3-Si	NO_3-N	NO_2-N	NH_4-N
(kg/s)	0.43	63.3	20.0	0.12	7.79
(10^4 t/a)	1.4	204.4	63.6	0.38	24.90

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