**Supplementary supporting materials**

1. **Calculation procedure of TN and TP flows and fluxes of rivers entering the PRE**

Estimation process of total nitrogen and phosphorus fluxes to the sea in the Pearl River Estuary:

The monthly flux (mol) of TN and TP from the rivers entering the sea in th month is calculated by：

= (1)

Where(g/m3) represents the concentration of nutrients at the outlet of the river in th month,(108m3) represents the total outlet flow of river entering the sea in th month, and (g/mol) represents the atomic mass of nutrients. However, the total flow () of rivers cannot be measured directly. Therefore, in this study, the total discharge at the outlet of river in th month is estimated by using the monthly average discharge (108m3) of East River, Northern River, and West River, the three tributaries of the Pearl River, and the amount of water entering the sea in the Pearl River Delta and the average water diversion ratio of the outlets of five river in the PRE. The monthly average discharge(，，) of the three tributaries is extracted from the 2019 Pearl River Basin Sediment Bulletin (Pearl River Water Resources Commission, Ministry of Water Resources, 2019)(Table S4), and the inflow water volume () (108m3) of the Pearl River Delta is derived from published reports (Department of Water Resources in Guangdong Province, 2021). The data of average water diversion ratio of river outfalls in the PRE is from the published article (Lu et al.,2009), and the specific data are shown (Table S5), where the five river outfalls in the PRE are referred to Humen (HM), Jiaomen (JM), Hongqili (HQ), Hengmen (HE) and Modaomen (MD). The total displacement () of the three tributaries of the Pearl River in th month can be obtained as follows:

(2)

The weight coefficient ()of each month is:

(3)

The discharge () of all rivers entering the sea in th month is calculated as follows:

(4)

Calculate the total discharge () of the rivers entering the sea in th month:

(5)

Where is the average water diversion ratio at the outlet of the river . is not the same in wet season and dry season, and the average water diversion ratio of the river outlet in normal season is taken as the average of both. Therefore, the annual fluxes (mol) of TN and TP flowing into the PRE are calculated as follows:

= (6)

Table S1

The concentrations of TN and TP in the eight rivers of the PRE (Unit: μmol/L).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Monitoring station | | Shatiansisheng | Lianhuashan | Hongqili | Jiaomen | Shenzhen Estuary | Zhongshan Port wharf | Jitimen Bridge | Zhuhai Bridge |
| Symbol | Month | A | B | C | D | E | F | G | H |
| TN | Jan | 277.14 | 311.43 | 177.14 | 170.71 | 547.14 | 167.14 | 159.29 | 157.14 |
| Feb | 227.14 | 352.86 | 160.71 | 184.29 | 325.71 | 150.00 | 154.29 | 151.43 |
| Mar | 237.14 | 258.57 | 160.71 | 173.57 | 750.00 | 191.43 | 142.14 | 145.71 |
| Apr | 180.00 | 252.86 | 148.57 | 152.14 | 418.57 | 157.14 | 161.43 | 142.86 |
| May | 227.86 | 202.14 | 145.00 | 134.29 | 530.00 | 135.00 | 152.86 | 148.57 |
| Jun | 182.86 | 200.71 | 142.14 | 142.86 | 373.57 | 132.86 | 127.14 | 130.00 |
| Jul | 191.43 | 157.86 | 130.00 | 122.14 | 441.43 | 120.71 | 137.86 | 124.29 |
| Aug | 183.57 | 190.71 | 125.00 | 127.14 | 406.43 | 132.86 | 147.14 | 128.57 |
| Sept | 140.71 | 197.86 | 135.71 | 127.14 | 295.00 | 146.43 | 143.57 | 145.00 |
| Oct | 207.86 | 275.00 | 141.43 | 137.86 | 460.71 | 157.14 | 131.43 | 130.71 |
| Nov | 254.29 | 280.71 | 145.71 | 155.71 | 532.14 | 154.29 | 125.71 | 117.86 |
| Dec | 228.57 | 306.43 | 177.14 | 170.00 | 528.57 | 167.14 | 127.14 | 122.86 |
| Annual average | | 211.55 | 248.93 | 149.11 | 149.82 | 467.44 | 151.01 | 142.50 | 137.08 |
| TP | Jan | 2.58 | 2.90 | 2.26 | 2.58 | 6.13 | 1.94 | 1.94 | 2.90 |
| Feb | 2.90 | 6.13 | 1.94 | 3.55 | 7.42 | 1.94 | 1.94 | 1.94 |
| Mar | 6.13 | 5.48 | 3.87 | 3.87 | 6.13 | 3.23 | 2.26 | 2.90 |
| Apr | 2.58 | 4.52 | 1.94 | 2.90 | 12.26 | 2.26 | 1.61 | 1.94 |
| May | 5.16 | 3.87 | 2.90 | 3.23 | 7.74 | 2.90 | 2.90 | 2.58 |
| Jun | 2.90 | 4.84 | 2.58 | 2.58 | 7.74 | 0.97 | 2.58 | 3.23 |
| Jul | 4.19 | 4.19 | 2.26 | 3.23 | 7.74 | 2.26 | 1.94 | 2.26 |
| Aug | 3.87 | 3.87 | 1.61 | 2.58 | 9.35 | 2.58 | 1.94 | 1.94 |
| Sept | 4.19 | 4.52 | 2.26 | 5.16 | 8.71 | 2.58 | 1.61 | 0.97 |
| Oct | 3.23 | 6.13 | 2.26 | 2.26 | 5.48 | 2.90 | 0.65 | 0.65 |
| Nov | 3.55 | 3.23 | 3.23 | 4.19 | 5.81 | 2.90 | 1.94 | 1.94 |
| Dec | 3.23 | 2.90 | 2.58 | 2.58 | 6.13 | 2.90 | 3.55 | 3.55 |
| Annual average | | 3.71 | 4.38 | 2.47 | 3.23 | 7.55 | 2.45 | 2.07 | 2.23 |

Table S2

Surface water quality standards and seawater quality standards.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Water quality standards | Indicators | Standard Ⅰ | Standard Ⅱ | Standard Ⅲ | Standard Ⅳ | Standard Ⅴ | References |
| Surface Water Quality Standard | TN(μmol/L) | 14.29 | 35.71 | 71.43 | 107.14 | 142.86 | Ministry of Ecology and Environment, PRC, 2002 |
| TP(μmol/L) | 1.43 | 7.14 | 14.29 | 21.43 | 28.57 |
| Seawater Quality Standard | DIN(μmol/L) | 14.29 | 21.43 | 28.57 | 35.71 | None | Ministry of Ecology and Environment, PRC, 1998 |
| DIP(μmol/L) | 0.48 | 0.97 | | 1.45 | None |

Table S3

Monthly fluxes of TN and TP to the sea in the PRE (Unit: mol/month).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Month | FTNj | | | | FTPj | | | |
| East River | Northern River | West River | Total monthly flux | East River | Northern River | West River | Total monthly flux |
| Jan | 1.01×109 | 1.53×109 | 1.67×109 | 4.21×109 | 9.44×106 | 1.83×107 | 2.32×107 | 5.09×107 |
| Feb | 7.17×108 | 1.58×109 | 1.74×109 | 4.04×109 | 9.17×106 | 2.39×107 | 2.22×107 | 5.53×107 |
| Mar | 1.63×109 | 3.10×109 | 4.04×109 | 8.77×109 | 4.20×107 | 7.12×107 | 7.05×107 | 1.84×108 |
| Apr | 1.48×109 | 3.46×109 | 4.62×109 | 9.56×109 | 2.12×107 | 5.34×107 | 5.87×107 | 1.33×108 |
| May | 1.74×109 | 2.92×109 | 4.02×109 | 8.68×109 | 3.94×107 | 5.98×107 | 7.79×107 | 1.77×108 |
| Jun | 3.61×109 | 5.36×109 | 5.96×109 | 1.49×1010 | 5.74×107 | 1.10×108 | 1.03×108 | 2.70×108 |
| Jul | 4.09×109 | 4.89×109 | 6.31×109 | 1.53×1010 | 8.95×107 | 1.15×108 | 1.06×108 | 3.11×108 |
| Aug | 1.95×109 | 2.63×109 | 3.35×109 | 7.93×109 | 4.11×107 | 4.78×107 | 5.31×107 | 1.42×108 |
| Sept | 9.22×108 | 1.69×109 | 2.20×109 | 4.81×109 | 2.75×107 | 4.37×107 | 2.63×107 | 9.75×107 |
| Oct | 6.24×108 | 1.05×109 | 1.19×109 | 2.86×109 | 9.68×106 | 1.96×107 | 1.24×107 | 4.17×107 |
| Nov | 5.97×108 | 8.58×108 | 8.87×108 | 2.34×109 | 8.33×106 | 1.62×107 | 1.52×107 | 3.98×107 |
| Dec | 5.75×108 | 1.05×109 | 9.98×108 | 2.62×109 | 8.11×106 | 1.33×107 | 2.36×107 | 4.50×107 |
| Annual | 1.89×1010 | 3.01×1010 | 3.70×1010 | 8.61×1010 | 3.63×108 | 5.93×108 | 5.92×108 | 1.55×109 |

Table S4

Runoff from the three major tributaries of the PRE.

|  |  |  |  |
| --- | --- | --- | --- |
| Month | East River | Northern River | West River |
| q(108m³) | q(108m³) | q(108m³) |
| Jan | 7.92 | 8.30 | 109.25 |
| Feb | 8.10 | 24.90 | 107.51 |
| Mar | 14.26 | 74.01 | 216.76 |
| Apr | 29.23 | 89.22 | 247.98 |
| May | 29.93 | 99.94 | 209.83 |
| Jun | 61.27 | 103.40 | 390.17 |
| Jul | 36.80 | 52.56 | 509.83 |
| Aug | 33.45 | 32.51 | 232.37 |
| Sept | 17.96 | 20.40 | 145.67 |
| Oct | 11.80 | 13.14 | 78.03 |
| Nov | 9.15 | 8.99 | 62.43 |
| Dec | 9.68 | 7.26 | 69.36 |

Table S5

Average water diversion ratios of five rivers in the PRE.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Outlet | HM | JM | HQ | HM | MD |
| Dry season | 0.111 | 0.105 | 0.171 | 0.155 | 0.249 |
| Wet season | 0.176 | 0.196 | 0.099 | 0.140 | 0.268 |
| Normal season | 0.144 | 0.151 | 0.135 | 0.148 | 0.259 |