Observation and analysis of the diluted water and red tide in the sea off the Changjiang River mouth in middle and late June 2003

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Abstract An interdisciplinary comprehensive survey was conducted in middle and late June 2003 with the Multi-Parameter Environmental Monitoring System YSI6600 and water sample analysis in the sea off the Changjiang River mouth. The Changjiang diluted water (CDW) extended offshore with a bimodal structure during the observation, one extending toward the southeast, the other toward the northeast. The main axis of the CDW extended toward the northeast. A severe red tide with wide spatial extent and brown water color happened. Chlorophyll-a (Chl-a) distribution near the Changjiang River mouth also presented a bimodal structure, and its position and shape were roughly consistent with the extension of the CDW. Water sample analysis indicated that the serious eutrophication produced by the huge amount of nutrient load via the Changjiang River was the main cause of red tide bloom. The dominant algal specie at the most measurement stations was skeletonema costatum. There existed three centers of higher Chl-a concentration, locating at (122.45°E, 31.5°N), (122.4°E, 30.8°N) and (123.25°E, 30.0°N), respectively. The red tide at (122.45°E, 31.5°N) was located in the major modal of CDW and higher turbid seawater, its dominant algal specie was prorocentrum dentatum with density 2.23×10⁶ ind/L. The red tide at (122.4°E, 30.8°N) was located in the second modal of CDW and lower turbid seawater, its dominant algal specie was skeletonema costatum with density 1.0×10⁵ ind/L. The dominant algal specie at (123.25°E, 30.0°N) was Heterocapsa circularisquama horiguchi with density 2.0×10⁶ ind/L, which was found for the first time forming red tide in the sea off the Changjiang River mouth.

Keywords: Changjiang diluted water, red tide, eutrophication, ecosystem dynamics.

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Chl-a composed of phytoplankton is the primary production in ocean, and the red tide happens when its concentration exceeds 20 μg/L. Red tide is a disaster abnormal phenomena of ocean ecology with an explosive breed or dense assemble of one or several phytoplanktons in a specific ocean environment condition, colors the seawater, influences and harms ocean living things. The formation of red tide is controlled mainly by a complex interplay of biological, physical and chemical processes, but the most principal cause influencing the occurrence of red tide is the seawater eutrophication, i.e. the excess of nutrients such as nitrogen and phosphorus in ocean. The nitrogen and phosphorus originate from devil water, sewage and waster produced by human’s production and living. The Changjiang River basin encompasses a surface area 1.8×10⁶ km², and the freshwater discharging into the East China Sea reaches 9.32×10¹⁰ m³ annually, along with a load of sediment 4.68×10⁸ t/a, nitrate 6.3×10⁶ t/a, phosphate 0.13×10⁶ t/a, dissolved silica 20.4×10⁶ t/a[1,2]. The content of N and PO₄-P was 0.17—1.441 and 0.009—0.036 mg/L in the sea in May 2001, and was 0.105—0.436 and 0.024—0.055 mg/L in July[3]. Wang[4] reported that the transports of N and P during flood season (May—October) amount to 79.5% and 87.6% of annual total value respectively, and the nutrient loadings of the river during this period play an important role in the formation of red tide. The distributions of Chl-a in the sea represented an obvious spatial regional phenomenon[2,5—8], and the front of phytoplankton quantity is located in the diluted water near 123°E. The phytoplankton quantity at the river mouth was lower due to light limit, and was nutrient limit in the adjacent sea, mainly the phosphorus limit[9,10]. The nutrient, current, monsoon and impact of the pychocline on the vertical mixing are the main factors influencing spatial and seasonal variation of Chl-a in the sea[11]. With rapid economic development and fast urbanization process in China and continue increase of agriculture and industry devil water and living sewage in the last two decades, the nitrogen and phosphorus transporting into the Changjiang River estuary from its basin increased by about 2 times, that made eutrophication level, occurrence frequency, spatial extent and harmful intensity of the red tides increase[1,12—17].

There were 44 red tide events happening in the sea from 1986 to 2001 with a serious development trend toward high frequency, wide spatial extent and long last period[10—19]. The red tides frequently occurred in a region bounded by 30°05′—31°51′N and 122°15′—123°10′E with the highest frequency in May through August[20,21]. The marked lower salinity due to the freshwater loading from the Changjiang River resulted in obvious difference of composition of phytoplankton species compared with that in other seas. The outstanding phenomenon is that the eurythermal and low saline skeletonema costatum is the dominant algal specie with the maximum density exceeding 1×10⁹ ind/m³[22]. The dense area of skeletonema costatum is in the region with salinity 14—23 and temperature 20—28°C, and was roughly located in the tongue of
the CDW, reflecting that this algal specie is more suitable to lower saline environment. The other low saline algal species in the sea are Ch. Abnormis and bellerochea malleus, and so on, but their quantity is much smaller than skeletonema costatum. Wu et al.\cite{3} also pointed out that the skeletonema costatum is the dominant algal specie among the phytoplankton based on the observation data of the four season surveys in 2001 and 2002 in the sea. Wang\cite{19} indicated that there were 68 algal species in the sea based on the analysis of the field data, the main species are skeletonema costatum, noctiluce scientillans, Prorocentrum micans, P. triestinum, Gymnodinium rhombones and Trichodesmium thiebantii. Skeletonema costatum and noctiluce scientillans are the most common and high frequency algal species in the sea, sometimes bloom simultaneously, and form hybrid red tide. Prorocentrum dentatum is the algal specie blooming red tides with wide spatial extent many times in recent years, in which one red tide reached to an area of 7000 km² and lasted 20 d in May 2000, one red tide reached to wide area of 1000 km² in May 2001. This algal specie is suitable for 18—21°C and salinity 21—31 psu, often forms red tides in spring and early summer. The phytoplankton and red tide are of many species and particularities.

1 Cruise observation

The phenomenon of red tide in the sea off the Changjiang River mouth is related to the extension of the CDW, distribution of suspended sediment and nutrient and hydrodynamics\cite{23}. In order to further understand and analyze the extension of the CDW and phenomenon of red tide, the State Key Laboratory of Estuarine and Coastal Research, East China Normal University and East China Sea Environmental Monitor Center, SOA conducted an interdisciplinary comprehensive survey during 16 through 30 in June 2003 with the Multi-Parameter Environmental Monitoring System YSI6600 to measure seawater salinity, temperature, suspended sediment concentration, dissolved oxygen (DO), pH and Chl-a in the region bounded by 29.5°N southerly, 32.5°N northerly and 124.5°E easterly. The cruise measurement had total 6 east-west transects and 80 stations (black dots in Fig. 1), and enhanced observation was considered in the area of eurythermal front and high frequent red tide. The YSI6600 was dropped to the sea bottom from the surface slowly by the electromotion winch, and then slowly left to sea surface. The sample time interval of the YSI6600 was set to be 1 s. Water samples were analyzed chemically and biologically at the measurement stations C01 through C12 (blank squares in Fig. 1) with the method and standard GB17378-1998. The probes of YSI6600 were calibrated with standard liquid strictly according to the specification before the observation. The recorded data of the YSI6600 were further calibrated with the analyzed data of the water samples after the observation. Compared with the analyzed data of the water samples, Chl-a was almost the same, pH was slightly high and DO was systematically large. The observation data are used to analyze the hydrology, nutrient and red tide in this paper.

2 Analysis of ecosystem dynamics

The northeastward extension of the CDW is the most outstanding hydrology phenomenon in the Yellow Sea and East China Sea in summer. The previous studies indicated that the CDW is blocked by the plume off the mouth and splits into two branches upon entering the shelf near the mouth\cite{24,25}. One flows southeastward, the other northeast-northward, and their relative intensity is affected by the discharge of the Changjiang River. The southeastward branch is stronger when the discharge is larger, and the northeast-northward branch is stronger when the discharge is smaller. In view of the distribution of salinity at a depth of 1.5 m below the surface (Fig. 2), the CDW extended with a bimodal shape after it left the mouth, one is southeastward, the other is northeastward, and the strength and area of the latter are obviously larger than that of the former, the CDW northeastward extended obviously. The Changjiang River discharge at Datong Station during the observation was 32000—40000 m³/s, lower than the 40-a mean value 43000 m³/s in middle and late June. This means that smaller discharge of the Changjiang River is really favorable northeast-northward extension of the CDW. The temperature of the Changjiang River water was higher than the seawater in summer, it still had the higher temperature feature after entering the sea in the region of bimodal shape of the CDW, but there appeared colder water of temperature 22.5 and 23°C on the west side of the submerged river valley. The previous observation and dynamic analysis indicated that it was produced by the bottom Ekman layer effect on the northward flowing Taiwan