Li Daoji and Dag Daler

Ocean Pollution from Land-based Sources: East China Sea, China

The environment of East China Sea (ECS) has been faced by huge stresses from anthropogenic activities and population growth in the Yangtze River drainage basin and the areas along the coasts. Improper use of natural resources and short-term economic objectives have resulted in severe environmental degradation in a fairly short time frame and the degradation has now reached a level where the health and well being of the coastal populations are threatened. The main pollutants are inorganic nitrogen, phosphate, oil hydrocarbons, organic matters and heavy metals. Nutrients cause eutrophication of the coastal waters and the estuarine area and very often stimulate the occurrence of red tides. The environmental pollution of Yangtze River basin directly impact on the state of the marine environment in the ECS. The ecosystem stability is maintained by a steady water discharge from the river, that mixes with the marine salty water in the estuary, and the sediment loads from the river that balance ocean erosion in the delta and its adjacent coastal area. The large-scale water transfer and dam constructions in the Yangtze River basin will change this basis. For the ECS the challenge is to reverse the negative processes taking place and to restore ecosystem balance. The main challenge is to integrate socioeconomic and environmental decision making in order to promote sustainable development. A better understanding of the driving forces in society that cause these environmental pressures is required in order to overcome these obstacles. International cooperation may be an important contributor to the progress and in particular provide access to financial, technological, scientific and human resource assistance.

INTRODUCTION

In the past two decades the East China Sea environment has faced huge stresses from anthropogenic activities and population growth in the Yangtze River drainage basin and the coastal areas. Many pollutants from land-based sources, such as sewage, oil hydrocarbons, sediments, nutrients, pesticides, litter and marine debris and toxic wastes, enter the sea with river water and other runoff from land. Pollutants constitute a threat to coastal and marine ecosystems as well as to the health of coastal inhabitants by limiting phytoplankton growth, increasing the mortality of fish and benthos, increasing eutrophication, red-tide occurrence, decreasing fishery yields, and nonreversible changes in ecosystem health. In addition, the Three Gorge Dam (TGD), the south to north water transfer engineering, and the sea level rise caused by global climate warming will impact these ecosystems. Therefore, investigation of these impacts is necessary to protect marine ecosystems and to secure and support sustainable development, the economy, and the environment in the countries around the East China Sea.

In the 1970s, developed countries began to undertake studies of coastal area environments and the oceans. By the 1990s, significant environment improvements were observed in many developed regions. Recently, aspects of the dynamics of the ecosystems, ecosystem services, ecosystem health, ecosystem restoration, and ecosystem diversity protection have become more focused. Emphasis has shifted towards macro-scale studies of marine ecosystems through international efforts (1). The UN Conference on Environment and Development held in Rio de Janeiro in 1992 and Agenda 21 discussed the role and status of coastal resources and ecosystems and the need to improve their protection and to develop more sustainable methods of using marine resources. These ambitions have become part of the UN Millennium Goals and they were reconfirmed by the World Summit on Sustainable Development (WSDD) in Johannesburg in 2002. The WSSD pinpointed the importance of fisheries as a source of protein for human consumption and in that context also underscored the importance of healthy marine ecosystems for sustainable development.

During 1958-1960, China carried out a program of National Ocean Integrated Investigation. This was followed by the National Coastal Zone Resource Integrated Investigation and the National Islands Resource Integrated Investigation during 1980-1986 and 1989-1992, respectively. Other large research programs for coastal oceans were also undertaken. The results from these investigations, although limited in scope, constitute a firm basis for understanding the present conditions of coastal-ocean ecosystem health and the value of marine resources. Currently, China has launched a program called *The Blue Sea* to regulate and restore Bohai ecosystem with an investment of about 52 billion Yuan. A similar program will be undertaken in the Pearl River estuary, Guangdong province, with the ambition to mitigate environmental stresses from anthropogenic activities in the coastal zone. A series of projects to improve management for the protection of the environment are also being carried out in cities along the Yangtze River basin. However, actions and investments to ameliorate environment problems in the Yangtze River estuary and adjacent East China Sea still lag behind the abovementioned areas, despite the economic scale of investments and development that are ongoing in this area.

This paper attempts to describe the evolution of the environmental problems and impacts and to evaluate the current environmental condition of the East China Sea. This is necessary in order to promote discussions on questions of effects on ecosystems and to develop some strategies to prevent ocean pollution and to protect the ecosystems of the East China Sea in the future.

COASTAL OCEAN POLLUTION IN CHINA

The population along the coastal provinces of China had reached 529 millions in 2000; from 243 millions in 1953 (Table 1) (2). In some cities, such as Shenzhen (3), seasonal

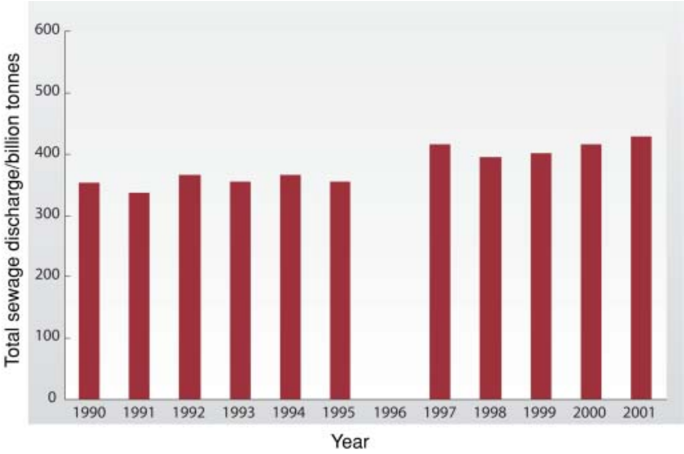

Figure 1. Total sewage discharge variations in China from 1990 to 2001 (Township enterprise discharge were not included in the data from 1990 to 1995, because they were not surveyed before 1996) (5–16).

Table 1. Population changes of the coastal provinces in China (2).

Years	1953	1964	1982	1990	2000
Coastal Provinces populations (thousand)	243 896	292 195	409 206	463 424	529 620
Whole nation populations (thousand)	601 938	723 070	1 031 882	1 160 017	1 295 330

[1]Data from the 1st, 2nd, 3rd,4th and 5th National Census Reports of China (2).

tourism and a significant number of temporary inhabitants, engaged in construction work and other short-term employment, or simply employment seeking, constitute more than 50% of local populations. It is estimated that population migration from the mid and western to the eastern coastal area will continue at least until 2020 and as a result coastal populations will increase by 8–10 million annually for the next 20 years (3, 4). This huge coastal area population will increase environmental pressure, land use, urbanization, pollution, and will result in a series of other environmental problems, such as increased sewage discharge (Fig. 1) (5–16). Since it is estimated that about 80% of ocean pollutants are from land-based sources, it is inevitable that the impact on the health of the marine ecosystems also will increase. Large amounts of pollutants are discharged and dumped directly into the ocean. Sewage and the major toxic materials discharged into the ocean, from factories and cities along the coasts of China account for more than 10 billion tonnes (t) and 146 million t yr^{-1}, respectively (16).

In 2001, more than 173 000 km^2 of the Chinese coastal waters were of a quality les than Class I of the Sea Water Quality Standard of China (SWQS, GB3097-1997) (Fig. 2) (17–26). Very heavily polluted areas, worse than Class IV of SWQS, cover about 32 000 km^2, and are mainly close to medium and large cities and estuaries with high population densities. Very heavy pollution areas increased by 4000 km^2 compared to the year 2000 (26). Contamination from land runoff is the most significant contributor to coastal environmental pollution at present. The dominating pollutants are inorganic nitrogen, phosphate, oil hydrocarbons, organic matter, and heavy metals. Although the volume of runoff from industrial effluent into coastal waters has been decreasing since 1999, municipal sewage and other runoff from land show an increasing trend. In 2000, red tide events occurred 28 times involving an area of 10 000 km^2, and 77 times in 2001 affecting 15 000 km^2 (26). If pollution from inorganic nitrogen is classified as slight, moderate, or very heavy, the 2001 figures for coastal ocean areas are about 25 000 km^2, 14 490 km^2, and 32 490 km^2, respectively. For phosphate the figures are 13 000 km^2 and 9232 km^2 for moderate and very heavy pollution, respectively (26).

Sediment monitoring data of the coastal ocean of China in 2001 indicated that pollution resulting from Total-Ag, Cu, Cd, Pb, As, DDT, PCBs, oil hydrocarbons, sulfide, organic matter, etc. occurred in different degrees in different regions (26):

– Dalian Bay: Total-Ag, Cu, Pb, oil hydrocarbons, sulfide, organic matter. The maximum value of sulfide is 969 mg kg^{-1}, which exceed Class III of the Marine Sediment Quality Standard (MSQS,GB-interim of China). The maximum value of oil hydrocarbons was 7795 mg kg^{-1}, more than 5 times MSQS and the maximum value of T-Ag exceeded MSQS 3-fold.

– Jinzhou Bay; Total-Ag, Cu, Cd, and Pb. The amounts of pollutants exceeded the Class I of MSQS, in which the highest value of T-Ag was more than 3-fold MSQS; sulfide exceeded the limits of Class I of MSQS. About 7 km^2 of the seabed had no organic life.

– Qinhuangdao and its adjacent sea: oil hydrocarbons, sulfide, organic matter, Ag, and Cu. The highest values of oil hydrocarbons and sulfide exceeded the limits of Class III of MSQS; values of organic matter, Total-Ag, and Cu exceeded the limits of Class I of MSQS.

– Yangtze River estuary and its adjacent sea: The DDT content exceeded the limits of Class I, MSQS.

– Bohai coastal waters: The DDT content exceeded the limits Class I, MSQS.

– Qinzhou Bay: The highest content of DDT exceeded Class II limits, MSQS.

– Minjiang estuary and its adjacent sea: Ag and oil hydrocarbons. The maximum content of oil hydrocarbons exceeded the Class III limits, MSQS.

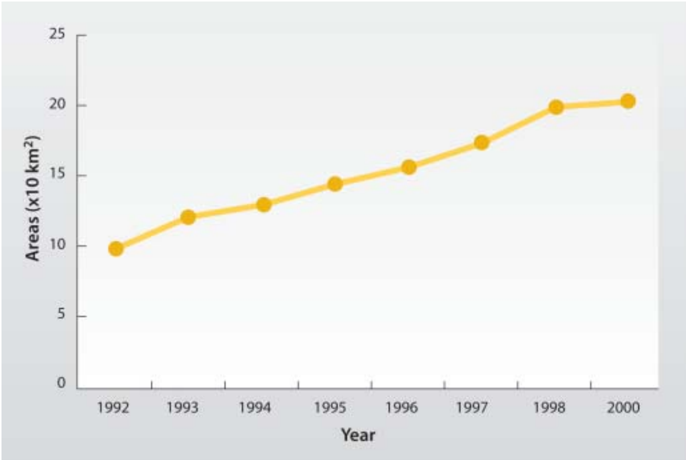

Figure 2. Area comparison of water quality worse than Class I of SWQS along China coastal ocean in 1990s (17–25).

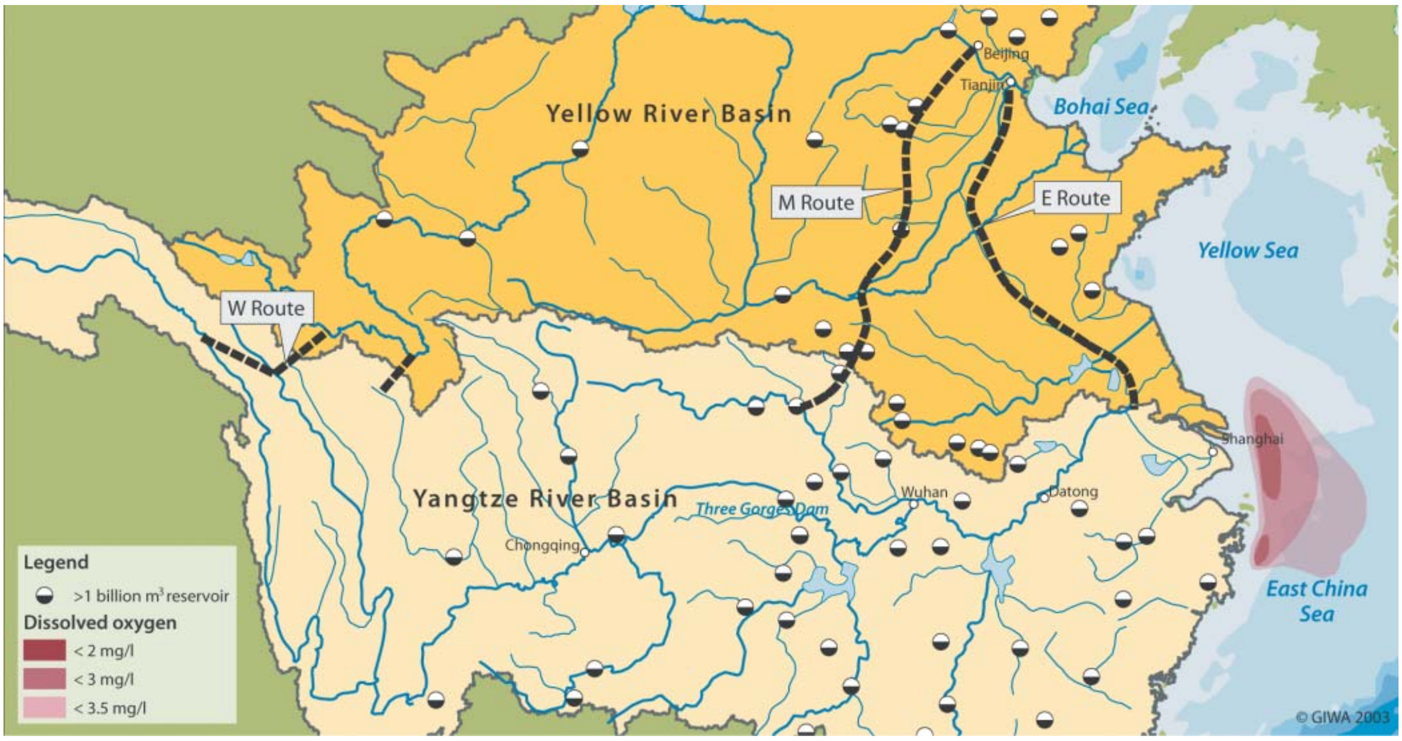

Figure 3. The Yangtze River drainage basin and the estimated hypoxy areas in the ECS (35).

The levels of pollutants in 20 species of mollusks sampled from 50 sites in 11 provinces along the Chinese coast have been monitored. The results for 2001 have shown that the pollutant content of marine organisms in the coastal ocean of China were generally low and only in few places were pollutants such as Cd, As, and oil hydrocarbons found to be of sizeable levels indicating that the sediments are stable (26).

Along with the development of the coastal economy of China, the runoff volume of pollutants into the ocean are not likely to decrease in the near future, and the persistent organic pollutants loading will probably show an increasing trend. Therefore, the prospects for the state of environment in the Chinese coastal zones are not optimistic and greater attention must be given to the situation.

SOURCES OF LAND POLLUTANTS INTO THE EAST CHINA SEA

East China Sea (ECS) is a marginal sea characterized by both shallow and deep-water features. The bathymetry of ECS is very complicated. Its western part is occupied by continental shelf covering about two thirds of the total area, and the southern part is occupied by the continental slope and is deep trough (Okinawa Trough), with a maximum depth exceeding 2700 m. On the western side a large amount of runoff ca. 12 x 10^{11} m^3 yr^{-1} is discharged into ECS from the Yangtze River (Fig. 4) (27). The strong Kuroshio current is on the eastern side, its transport volume is around 20–30 SV (Sverdrup) (28). The sea surface is also affected by the monsoon, the direction changing twice a year. Since materials carried by the Kuroshio Current and summer monsoon eastward into the ocean current from ECS are not contaminated, the main sources of pollutants are the Yellow Sea and the eastern rivers, coasts, and the atmosphere of the Chinese mainland. Yangtze River is the main source of land-based pollutants discharging into ECS.

The Yangtze River is the largest river in China it is also one of the most famous large rivers in the world. It flows through densely populated areas with agriculture and industrial activities along both banks: Shanghai at its mouth is the largest city in China. Environmental pollution of the Yangtze River basin thus greatly influence the state of the marine environment of ECS.

PRESENT STATE AND TREND OF THE EAST CHINA SEA POLLUTION

Sediments

Although large-scale ocean processes influence the ECS, the large water discharge and sediment loads from rivers play an important role in the physical processes, the morphological development, and the ecosystem health of the continental shelf of ECS. The Yangtze River has, due to its size, a significant impact on the ECS ecosystems. Ecosystem stability is maintained by a steady water discharge from the river, that mixes with marine water in the estuary, and the sediment loads from the river that balance the ocean erosion in the delta and its adjacent coastal area. Therefore, the long-term changes in discharge volume and material flux into ECS, especially from the Yangtze River, are alarming.

At present, annual average runoff and sediment discharge, which is monitored at Datong Station in the lower Yangtze River, are 29 300 m^3 s^{-1} and 10 700 kg s^{-1}, respectively (Fig. 4) (29). Some 48 000 reservoirs have been constructed in the Yangtze River drainage basin over the past 50 years (Fig. 3), of which 965 reservoirs are of medium or large size. In addition, there are innumerable water transfer engineering schemes (30). However, retaining water in reservoirs only regulates water volume in the time domain and has no significant influence on total runoff volume. The variations of annual average runoff and sediment discharge at Datong Station over the past 50 years show that both have periodic fluctuations, but annual average sediment discharge shows a decreasing trend while annual average runoff shows no obvious change (Fig. 5) (29). Therefore, material discharge flux, including organic particles, solid nutrient fluxes and other suspended solids, must have the same decreasing trend. The decreasing material flux to the sea is most likely due to the constructions and the water transfer schemes in the Yangtze drainage basin.

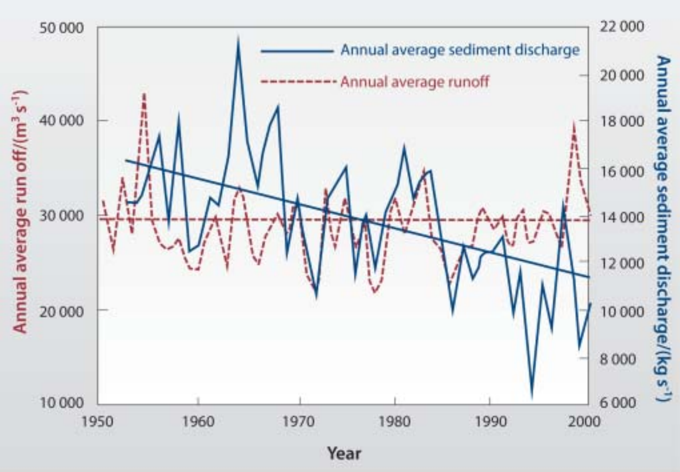

Figure 4. Variations of annual average runoff and sediment discharge at Datong Station in the lower Yangtze River (29).

Persistent Organic Pollutants

The persistent organic pollutants and other organic compounds originate from industrial activities and from the use of pesticides and herbicides in agriculture. Persistent organic pollutants accumulate in the food chain with resulting diseases and genetic modifications of the marine species that make them unsuitable for human consumption, or at least limits their use as food. Persistent organic pollutants are spread both by water runoff and atmospheric transport.

According to the monitoring data of variations of BHC (biogenic hydrocarbon) and DDT contents in the surface sediments of the Yangtze River estuary over the last decades, as well as the changes in BHC and DDT contents in sedimentary cores dated by ^{210}Pb, it can be seen that BHC and DDT contents have decreased rapidly after the use of organochlorinated pesticides was banned by the Chinese Government in 1983 (Table 2) (31). Although remaining pesticides can still affect the marine environment and marine organism for decades to come, the concentrations of organochlorinated pesticides in ECS are not high by any standard and significantly lower than the requirements of SWQS.

Table 2. Variations of BHC and DDT contents in surface sediments in the Yangtze Estuary since the 1980s (ng g^{-1}) (31).

Time	BHC	DDT
Aug. 1981	3.26	12.38
Jan. 1992	-	0.94
Oct. 1997	0.38	0.17

Sewage

The total amount of industrial sewage from 11 provinces along the coast of China was 10.02 billion tonnes (t) in 1999, of which 3.67 billion t were directly discharged into the sea. Sewage quantities into Chinese seas were 0.56 billion t in Bohai, 0.71 billion t in the Yellow Sea, 1.48 billion t in ECS, and 0.92 billion t in the South China Sea. The ECS received 40.3% of total industrial effluent and as such was the largest recipient of industrial effluent in China (24).

In the same year, the total amount of sewage in human settlements from the 11 provinces along the coasts of China was 10.81 billion t, and directly discharged into the sea was 3.95 billion t, of which 40.3% discharged into ECS. Therefore, ECS also had the largest sewage load of the Chinese seas (24).

There are 25 oil/gas offshore explorations in China's jurisdictional waters in 2000. Annual discharge of oil-contained effluents (oily water) was 4.648 million t, of which ECS with 1 oil/gas exploration site discharged 300 000 t (Table 3). Oil pollution in ECS is most severe in the Yangtze River estuary, Hangzhou Bay, and the Zhoushan Fishing Ground, where oil content in water exceeded the Fishery Water Quality Standard. Recently, there has been an increasing trend of oil pollution in the ECS.

The Yangtze River is by far the largest source of sewage and effluents from land-based activities that are discharged into the ECS. The Yangtze River basin receives 45% of the total industrial effluent of China and 37.5% of the municipal sewage of China (32). Annual sewage discharge from the 21 cities along the main stream of the Yangtze River is 6.3 billion t, and the amount is growing by 3.3% annually. 70% of the cities do not comply with the national discharge standard. More than 500 km of the river receive pollution from cities, Eventually, most of this sewage is discharged into ECS through the Yangtze River estuary.

Table 3. Statistics of distribution and sewage discharge of oil/gas wells of China in 2000 (25).

Sea regions	Oil/gas field developments	Oil sewage discharge (x10^4 tonnes)	Oil discharge (x10^4 tonnes)
Bohai	8	246	54
ECS	1	30	5
SCS	16	4372	1302
Total	25	4648	1358

Nutrients

Nutrients are the dominant pollutant of the Yangtze River estuary and the adjacent ECS. Nutrients cause eutrophication of the coastal ocean and the estuarine area and very often stimulate the occurrence red tides. In the past two decades, nutrient pollution has become much more severe and the polluted areas are expanding continuously. The use of fertilizers in agriculture are the major source of nutrients, and this use has increased significantly over the past 20 years (33) (Fig. 5).

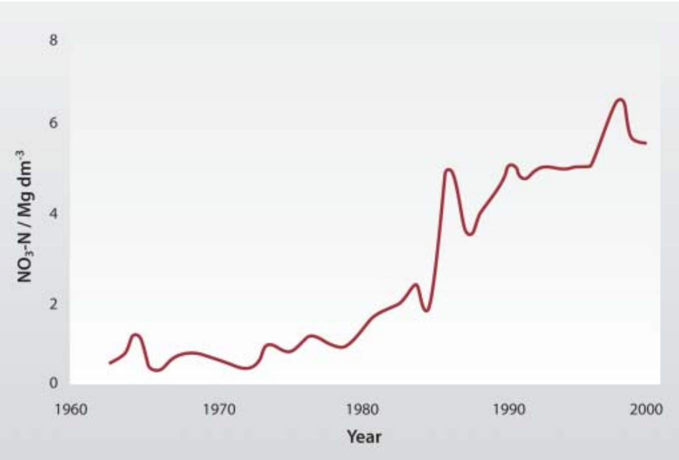

Figure 5. Historical variations of nitrate concentrations at Datong station (33).

The average content of inorganic nitrogen in the Yangtze estuary and its adjacent sea was more severe than Class I of SWQS in 1985, and by 1991 inorganic content exceeded the standard by more than 9-fold. In 1994, large sea areas were polluted by nutrients and concentrations exceeded the standard by more than 14-fold. For phosphorus pollution in ECS inorganic phosphorus, concentrations exceeded the SWQS early in 1985. Compared with other sea regions in China, ECS is the most heavily polluted. The monitoring data of N and P in ECS for 2000, indicate that the extent of polluted area in ECS can be estimated to reach a distance of about 200 km from the east coast of China (Fig. 6) (34).

Eutrophication frequently causes harmful algae blooms. In the East China Sea algae blooms occur every summer. Algae bloom can cause fish death, poisoning of shellfish and allergic skin reactions in bathers or those working in the water. The blooms also cause heavy stress on the ecosystems of the Yangtze River estuaries and the ECS environment, resulting in loss of productivity. Large amounts of nutrients from the river basin area and from the atmosphere lead to enhanced primary production and particulate organic matter production in the estuaries, and hypoxia (dissolved oxygen < 2 mg L^{-1}) in bottom waters (Fig. 3) (35). Overproduction of phytoplankton efficiently blocks light from reaching macro-algal communities, and the ecosystem supporting marine life becomes a "plankton culture", with environmental conditions unsuitable for most organisms higher in the food chain. The hypoxic water found in the bottom layer of the East China Sea off the Yangtze River mouth during summer demonstrates that nutrients from the Yangtze River are enhancing the eutrophication in the Yangtze Estuary and in the adjacent marine environment of ECS (Fig. 3).

Solid Waste

The total volume of solid waste dumped in the ECS was 36.44 million m^3 in 2001, most of which came from mud dredging in harbors, inland rivers, and navigation channels (36). Generally, more solid waste is dumped in the dry season. Of the total dumped volumes, 73.2% were in the sea region of Shanghai, 9.5% in the sea region of Lianyungang, Jiangsu, 16.1% in the sea region of Zhejiang and 0.3% in the sea region of Fujian. Materials dumped into ECS mainly belong to Class III dredge materials according to the Dredging Dumping Quality Standard of China. The composition of these dredging materials is mainly compounds of Cu, Pb, Zn, and As; Cd, Cr, organic matter, sulfide, PCBs, DDT, BHC, oil hydrocarbons, etc. The Cu, Pb, Zn, Cd, As and oil hydrocarbons content occasionally exceed the standard. These pollutants originate from land-based activities. Along with the increased dredging activities, waste deposits in the ECS will also increase.

Sandstorms are caused by strong windstorms, that occur in the semiarid areas of the deserts, carrying clouds of sand or dust, and usually causing serious air pollution. Sand dust may contain pollutants that are transported into the ocean from the atmosphere. China has frequently been subjected to sandstorms raging across the country's northern regions, particularly in the drought-prone northwest. Global climate change and droughts in China over the past few years are major causes of sandstorms. Desertification, caused by over-logging or overgrazing, the overexploitation of water resources and large-scale construction projects such as rapid urbanization, are also influencing the climate. Statistics from the China Meteorological Administration indicate that in 2002

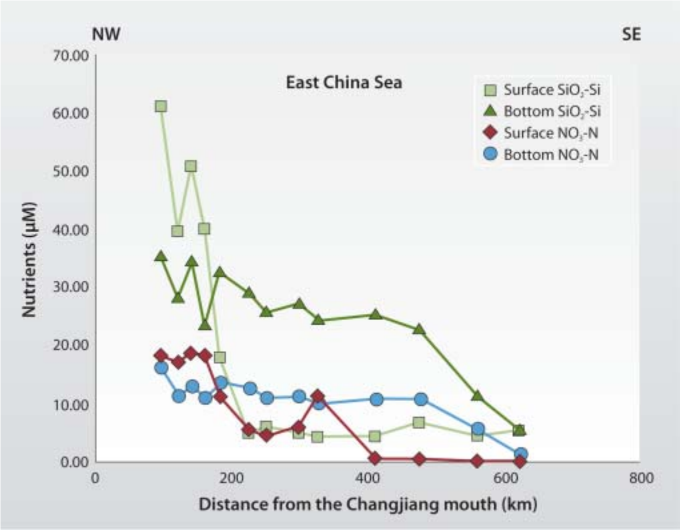

Figure 6. Distribution of nutrient concentrations in ECS (34).

by mid-May, sandstorms had occurred 18 times, bringing sand and/or dust to the north, northwest, and parts of northeastern China, and even across the Japan Sea and northern Pacific Ocean to reach North America. Estimation of the amount of pollutants brought to the sea by sandstorms is difficult, but all asessments indicate that the amount is significant. To cope with this problem, a series of countermeasures have been introduced, including massive reforestation throughout China. By turning large farmland areas into forests or grasslands in the western regions, the ambition is to reduce the damage caused by sand or duststorms in coming years.

EFFECTS OF THE THREE GORGES DAM AND WATER TRANSFER IN THE YANGTZE RIVER BASIN

The present discharge volume and material flux into the ECS in dry and flood seasons is the basis for stabilizing ECS ecosystems and keeping them environmentally healthy. The large-scale water transfer and dam constructions in the Yangtze River basin are expected to change this basis and are highly inappropriate from an environmental point of view, unless efficient countermeasures are taken. Water transfer will affect discharge volume and dam construction will influence not only discharge volume but also material flux. Since annual precipitation and discharge are not uniform throughout the Yangtze River basin, the composition of materials in the sediments vary. Therefore, water transfer schemes will definitely affect long-term periodic variations in material loads. This will affect the condition of the marine life in the estuary and in particular the migrating species who have a limited residence time. Therefore, there will be a negative influence on the ecosystems of the estuary. Moreover, if the long-term effects of future population growth and climate change are not adequately considered, pressure on the environment will increase, and demands for water take-off in the lower reaches of the Yangtze River will increase. The amount of runoff to the ECS, after water transfer in the dry season, will be questionable. Will the Yangtze River become a second "Yellow River"? If so, the ECS environmental conditions will be negatively affected.

ROAD MAP TO SUSTAINABLE MANAGEMENT OF THE EAST CHINA SEA ECOSYSTEMS

For the East China Sea the challenge is to reverse negative processes and to restore balance to the ecosystem. Degradation of the estuary, the marine and the coastal areas, is mainly caused by land-based activities. Improper use of natural resources and short-term economic objectives have resulted in severe environmental degradation in a fairly short timeframe, and degradation has now reached a level where the health and well being of the coastal population is threatened.

The main challenge is to integrate socioeconomic and environmental decision making in order to promote sustainable development of the East China Sea. Practical steps towards improved environmental and health conditions can easily be outlined, the realization of these steps depends on financial possibilities and stakeholder willingness. Public support for environmental protection is weak, despite the severity of the environmental problems. Sectorial thinking prevails. For example, agricultural practices are still developed without taking the marine environment into consideration. The view is that environmental protection can only be achieved at the expense of economic development. These are the key obstacles to sustainable management of the East China Sea ecosystem. The upside is that from a holistic point of view the situation is different; economic returns for investment in environmental infrastructure can be significant because of improvements in public health, ecosystem productivity, and the damage that is avoided.

A better understanding of the driving forces in society that lead to environmental pressures is required in order to overcome the obstacles. The tools for sustainable management must be based on an analysis of cultural heritage, norms, policies, and institutions and identification of the causal relationships that underly the deterioration of the marine environment in the East China Sea. The overwhelming challenges involved in the reversal of environmental degradation in the East China Sea require common efforts from local, national and international stakeholders.

Legislative and Regulatory Actions at National Levels

Reduction of emissions from industries, oil-related pollution, nutrient release from agriculture, and treatment of municipal sewage and industrial wastewater is necessary to prevent further degradation of the marine environment. National legislation should be established and/or improved to ensure compliance and enforcement of national and intergovernmental protocols and policies. Best Environmental Practices and Best Available Technologies should be promoted nationally, whenever financially realistic. The Precautionary Principle should be adopted whenever there are reasons to believe that an activity might harm human health, living resources or marine ecosystems, damage amenities or interfere with other legitimate uses of the sea. The Polluter-Pays Principle should serve as the economic basis for the control of environmentally harmful activities, emphasizing the importance of responsibility by forcing polluters to pay for the true costs of their activities.

National planning as a basis for a management regime that takes environmental considerations into account is of prime importance in order to alter the negative trend. Such planning should cover all aspects of the coastal and marine activities and should encompass land-use practices, establishment of marine protected areas, plans for sewage treatment facilities, management plans for waste disposal sites and outdated industrial facilities, etc. Environmental Impact Assessment studies (EIA) should be a mandatory prerequisite for decisions regarding any project that may impact environmental or human health. Thus, EIAs should always precede the construction of new installations such as dams, hydroelectric installations, power plants, bridges, ports, etc., or decisions on the location of urban settlements and the location of industrial centers.

Institutional Strengthening

Agreements made at the regional level have to be implemented on national and local levels. While the national government has the overall legal responsibility, the capability to oversee and enforce environmental legislation primarily lies within the realm of local governments. To fulfill laws, rules, and regulations the implementing and supporting institutions and organizations must be strengthened. Capacity building, enhancing the competence and capacity of the relevant institutions, is therefore an important activity in order to achieve improvements in the East China Sea. There is still a huge knowledge gap concerning environmental degradation and the link to human development and health in the East China Sea. Continued monitoring and surveillance of the East China Sea is necessary to fully access the current situation and to survey the efforts towards improvement. It is of great importance that the decisions made in existing and future regional bodies and executing organizations are based on scientifically sound information.

Building public awareness is another important activity. Environmental awareness is generally low in China and should be targeted. In particular, exposed stakeholder groups, such as farmers and fishermen should be subject to specific awareness building programs. Without public awareness and public participation commercial interests will often take priority over environmental considerations. Public participation is commonly manifested through nongovernmental organizations (NGOs) and other community-based organizations. These organizations should therefore be involved in projects that may affect the environment, and in projects that can lead to improvement of regional environments.

Infrastructure and Technical Facilities

Infrastructure and technical facilities have to be improved in order to ensure safe living conditions and to halt environmental degradation. This includes improvement of existing facilities for municipal and industrial waste treatment and the construction of new facilities, improvement of irrigation systems, and equipment and facilities for oil extraction and transport. Considering the large financial expenditure needed, implementation is likely to be a long-term process. Thus, clear priorities need to be developed and financing and investment programs ought to be part of all planning made by national or local authorities.

Many of the necessary actions require a substantial economic input, such as improved wastewater treatment and adoption to modern technology. China is in a transitional state and economic means to ensure a safe and sound environment is limited. It is therefore essential and necessary that international donor organizations such as the GEF, the World Bank, and the ADB provide funds in the form of grants and loans for these ecosystem recovery projects.

The Role of International Cooperation

Although many of the environmental problems in the East China Sea originate from the Chinese mainland, further international cooperation will have significant positive impact on the efforts to mitigate the degradation of the marine ecosystems. International cooperation may be an important contributor to the progress, which in particular can provide access to financial, technological, scientific, and human resource assistance.

The Partnership in Environmental Management for the Seas of East Asia (PEMSA) was established in 1999 as a dialog forum for governments to address issues and problems in the region. Likewise, the UN has initiated programs in the area such as the UNEP Regional Seas program and the GPA/LBA program (Global Plan of Action for Protection of the Marine Environment from Land-based Pollution Sources).

Through such international cooperation regional agreements may be achieved for conventions and protocols for limits on use of fertilizers, agrochemicals in agriculture, and chemical pollutants in industrial wastewater and aerial emissions, and commitments to action plans with visions, goals time plans and defined actions may also be established.

The relations established between UNEP-GIWA and SKLEC (The State Laboratory of Estuarine and Coastal Research, East China Normal University), whereby SKLEC is the main focal point for the GIWA assessments work in Chinese waters is also an important undertaking in order to foster such broad international cooperation.

References and Notes

1. Duda, A.M. and Sherman, K. 2002. A new imperative for improving management of large marine ecosystems. *Ocean Coastal Mgmt 45,* 797-833
2. The 1st, 2nd, 3rd, 4th and 5th National Census Reports of China, National Bureau of Statistics of China. (In Chinese).
3. Lu, J.H. and Wang, G.Z. 2000. Influences of population changes on marine resources since the reforming and opening in China. *Popul. Res. 24,* 35-42. (In Chinese).
4. Hu,Y. 2003. Analysis on numbers of population transfers from rural area to urban area during urbanization. *Statist Res. 7*, 20-24. (In Chinese).
5. *Report on the State of the Environment in China* 1990. The State Environmental Protection Administration, China. (In Chinese).
6. *Report on the State of the Environment in China* 1991. The State Environmental Protection Administration, China. (In Chinese).
7. *Report on the State of the Environment in China* 1992. The State Environmental Protection Administration, China. (In Chinese).
8. *Report on the State of the Environment in China* 1993. The State Environmental Protection Administration, China. (In Chinese).
9. *Report on the State of the Environment in China* 1994. The State Environmental Protection Administration, China. (In Chinese).
10. *Report on the State of the Environment in China* 1995. The State Environmental Protection Administration, China. (In Chinese).
11. *Report on the State of the Environment in China* 1996. The State Environmental Protection Administration, China. (In Chinese).
12. *Report on the State of the Environment in China* 1997. The State Environmental Protection Administration, China. (In Chinese).
13. *Report on the State of the Environment in China* 1998. The State Environmental Protection Administration, China. (In Chinese).
14. *Report on the State of the Environment in China* 1999. The State Environmental Protection Administration, China. (In Chinese).
15. *Report on the State of the Environment in China* 2000. The State Environmental Protection Administration, China. (In Chinese).
16. *Report on the State of the Environment in China* 2001. The State Environmental Protection Administration, China. (In Chinese).
17. *Report on the Marine Environmental Quality in China* 1992. The State Oceanic Administration, China. (In Chinese).
18. *Report on the Marine Environmental Quality in China* 1993. The State Oceanic Administration, China. (In Chinese).
19. *Report on the Marine Environmental Quality in China* 1994. The State Oceanic Administration, China. (In Chinese).
20. *Report on the Marine Environmental Quality in China* 1995. The State Oceanic Administration, China. (In Chinese).
21. *Report on the Marine Environmental Quality in China* 1996. The State Oceanic Administration, China. (In Chinese).
22. *Report on the Marine Environmental Quality in China* 1997. The State Oceanic Administration, China. (In Chinese).
23. *Report on the Marine Environmental Quality in China* 1998. The State Oceanic Administration, China. (In Chinese).
24. *Report on the Marine Environmental Quality in China* 1999. The State Oceanic Administration, China. (In Chinese).
25. *Report on the Marine Environmental Quality in China* 2000. The State Oceanic Administration, China. (In Chinese).
26. *Report on the Marine Environmental Quality in China* 2001. The State Oceanic Administration, China. (In Chinese).
27. Mao, Z.C. 2001. Change of river discharge into sea early in 21st century and it effect on water quality and ecosystem of the Changjiang river estuary. *Mar. Sci. 25,* 31-34. (In Chinese).
28. Beardsler, R.C., Limeburner, R., Le, K.T., Hu, D.X., Cannon, G.A. and Pashinski, D.J. 1983. Structure of the Changjiang River Plume in the East China Sea During June 1980. In: *Proc. International Symposium on Sedimentation on the Continental Shelf, with Special Reference to the East China Sea.* Acta Oceanologia Sinica (ed.). China Ocean Press, Beijing, p. 1029.
29. *Report on River Sediments of China* 2000. Ministry of Water Resources, P.R.China. (In Chinese).
30. *Rainstorm and Flood of Changjiang River in 1998.* 2002. Hydrological Bureau of Changjiang River Conservation Commission and Hydrological Bureau of Ministry of Water Resources, Water Conservation and Water Electricity Press, Beijing, pp. 325. (In Chinese).
31. Chen, J.F. and Ye, X.R. 1999. Preliminary study on the marine organic pollution history in Changjiang Estuary-Hangzhou Bay BHC and DDT stratigraphical records. *China Environ. Sci. 19,* 206-210. (In Chinese).
32. *Report on Water Resources in China 1999.* Ministry of Water Resources, P.R.China. (In Chinese).
33. Liu, X.C., Shen, H.T. and Huang, Q.H. 2002. Concentration variation and flux estimation of dissolved inorganic nutrient from the Changjiang River into its estuary. *Oceanol. Limnol. Sinica 33*, 332-340. (In Chinese).
34. Li, D.J., Zhang, J. Wu, Y., Cao, Y. and Liang, J. 2003. Impact of water transfer from Changjiang drainage basin on ecosystems of Changjiang estuary and its adjacent sea. In: *Impacts and Countermeasures of the South-to-North Water (East Route) Diversion Projects on the Ecosystem and Environment of the Yangtze Estuary.* Chen, J.Y., Chen, X.Q. and Chen, M.F. (eds). East China Normal University Press, pp. 195-203. (In Chinese).
35. Li, D.J. and Zhang, J. 2002. Oxygen depletion in the Changjiang (Yangtze) estuary. *Sci. China (Series D) 45,* 1137-1146.
36. *Report on Dumping Control of East China Sea* 2001, State Oceanic Administration, P.R. China. (In Chinese).

37. The authors wish to thank the auspices of the National Key Basic Research Program of the Ministry of Science and Technology, P.R.China (2002CB412405) and the UNEP/Global International Waters Assessment (UNEP/GIWA).

Daoji Li is a professor at the State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai, China. He graduated from the Marine Department of Ocean University of China (Former Shandong Ocean College) in 1984, and has worked in the Institute of Estuarine and Coastal Research, East China Normal University. During 1989 to 1990, he worked at The Netherlands Institute for Sea Research and the Delta Institute of Hydrobiological Research. He received his PhD from East China Normal University in 1998. At present, he is studying the ecosystem and biogeochemical processes of the Yangtze River Estuary, the East China Sea, and the impacts of environmental pollution of the Yangtze River Basin on the Yangtze River Estuary and the East China Sea. His address: 1 State Laboratory of Estuarine and Coastal Research, East China Normal University Shanghai 200062, P.R.China
daojili@sklec.ecnu.edu.cn

Dag Daler is Scientific Director of the UNEP/Global International Waters Assessment (UNEP/GIWA). He received his MSc from the University of Trondheim, Norway, in physics and engineering. He also has a MBA from the Heriot-Watt University, Edinburgh. He has 20 years experience from both the public and private sectors as engineering consultant for hydroelectrical power and offshore developments. The last 10 years he has worked with governmental and international organizations with environmental problems in international waters, environmental protection, pollution control, and nuclear safety. His address: GIWA, University of Kalmar, SE-391 82 Kalmar, Sweden.
dag.daler@giwa.net