X-22 East China Sea: LME #47

S. Heileman and Q. Tang

The East China Sea LME is bordered by the China mainland, northern coast of Taiwan, Japanese Archipelago, and southern coast of the Korean Peninsula. It has a surface area of about 775,000 km^2, of which 0.09% is protected, and contains 0.34% and 0.02 % of the world's coral reefs and sea mounts, respectively, and 8 major estuaries (Sea Around Us 2007). A monsoonal climate with alternating winter and summer monsoons and the occurrence of typhoons and cyclones characterise the LME. The main currents are the Kuroshio Current along the shelf break, Taiwan Warm Current on the continental shelf and the East China Sea Coastal Current in the coastal zone (Su 1998). The latter is formed by the coastal current from the Yellow Sea and the combined waters of the several large rivers. Its hydrology is strongly influenced by the above mentioned currents, freshwater and terrigenous sediment inputs, notably from the Changjiang (Yangtze River), Qiantangjiang and Mingjiang. A book chapter and a report pertaining to this LME are by Chen & Shen (1999) and UNEP (2005).

I. Productivity

The East China Sea LME is a Class I, highly productive ecosystem (>300 $gCm^{-2}y^{-1}$), based on satellite data used throughout this report. However, from Chinese surveys' in situ data, it appears that the East China Sea is a Class II, moderately productive ecosystem (between 150 and 300 $gCm^{-2}y^{-1}$)(Q.Tang, personal communication, 2008). Indeed, based on Chinese survey data, primary production was 143 $gCm^{-2}y^{-1}$ in 1997-2000 (Tang 2006); 220 $gCm^{-2}y^{-1}$ in 1984-1985(Chen & Shen 1999); based on remote sensing and survey data, average primary production was 182$gCm^{-2}y^{-1}$ in 1984-2007 (unpublished data by Q.Tang, personal communication, 2008).

The Kuroshio Current has a significant impact on the LME's nutrient budget. The Kuroshio Subsurface Waters have higher phosphorus/nitrogen and silica/nitrogen ratios than terrigenous discharge, which provides a signature of its upwelling over the continental slope. This high nutrient content results in high primary productivity in the water column. Phytoplankton abundance shows two peaks, with the higher peak from July to September and a secondary peak in April. Chen & Shen (1999) reported the identification of 209 species of phytoplankton, with key species including *Nitzchia* spp., *Coscinodiscus* spp. and *Skeletonema costatum*, and six species of zooplankton, with *Calanus sinicus* being one of the main species. Zooplankton biomass increases sharply after March with increasing water temperature and runoff, and is highest where coastal waters converge with the Yellow Sea and Kuroshio Currents. Fishing is the primary driving force, and climatic and environmental variation the secondary driving force of biomass change in this LME.

Oceanic fronts (Belkin et al. (2009): The East China Sea LME features diverse fronts (Hickox *et al*. 2000, Belkin & Cornillon 2003) (Figure X-22.1). In the north, the Yangtze Bank Ring Front (YBRF) surrounds the Yangtze Bank (Shoal). This front is caused by the huge fresh discharge of the Yangtze River and is maintained by tidal rectification that results in a clockwise current (and a closed quasi-circular front) around the Bank. A coastal front (FZF) exists along the Fujian-Zhejiang Coast between warm, saline waters of the Taiwan Warm Current flowing northward and the cold, fresh waters flowing southward along the coast. The Kuroshio Front (KF) invades the shelf north of Taiwan. These excursions are important for the cross-shelf exchange of heat, salt and nutrients. Sharp fronts exist between warm, saline waters of the Kuroshio and continental shelf water along the shelf break. Two distinct fronts exist west and east of Cheju Island (WCF and ECF respectively) that separate warm, salty waters carried by the Taiwan-Tsushima Current from colder, fresher resident inshore waters.

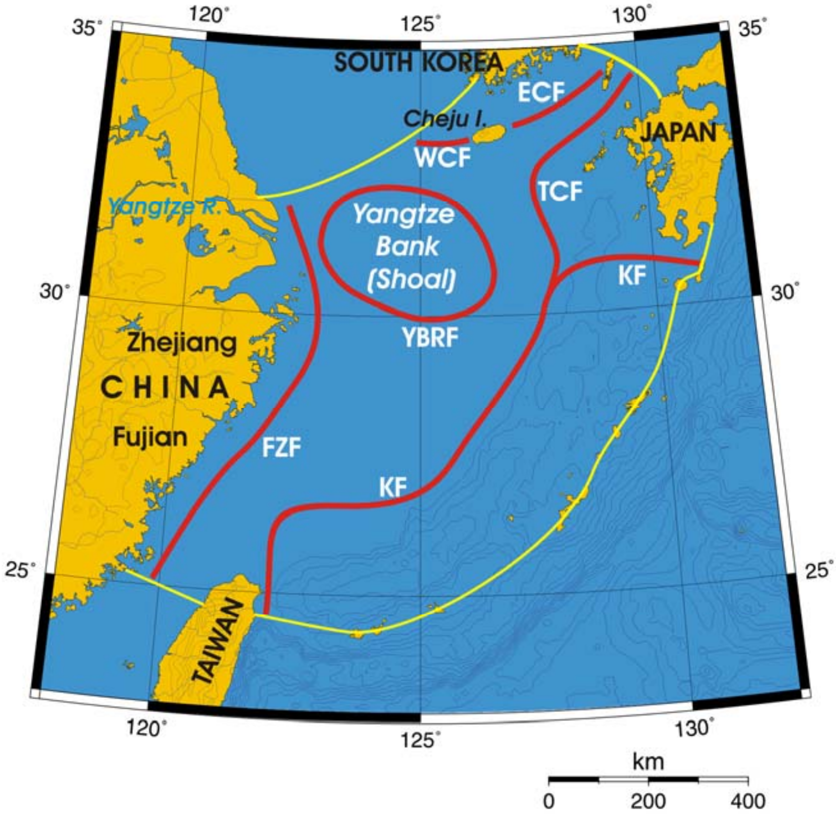

Figure X-22.1. Fronts of the East China Sea LME. ECF, East Cheju Front; FZF, Fujian-Zhejiang Front; KF, Kuroshio Front; TCF, Tsushima Current Front; WCF, West Cheju Front; YBRF, Yangtze Bank Ring Front. Yellow line, LME boundary. After Belkin et al. (2009).

East China Sea SST (after Belkin, 2009)
Linear SST trend since 1957: 1.55°C.
Linear SST trend since 1982: 1.22°C.

The East China Sea has experienced a dramatic 2°C warming since 1982 (Figure X-22.2). During 1957-1981, the SST was relatively stable. Then, SST increased from 20.6°C to 22.9°C at a rate of 0.13°C per year. A recent study of the ERA-40 reanalysis and other data sets, including HadISST and SODA (Simple Ocean Data Assimilation), has shown that climate warming caused weakening of the winter and summer monsoons over the East China and Yellow Seas after 1976, hence a weakening of wind stresses, particularly over the East China Sea, leading to the observed SST increase (Cai et al., 2006). The East China Sea warming was not spatially uniform (Wang, 2006). In summer, SSTs rose in most parts of the sea, including the Kuroshio and Taiwan Warm Current, but cooled in the north. The coastal zone warmed at a rate of >0.02°C/a, whereas the Kuroshio rate was <0.02°C/a. In winter, the fastest SST warming rate of >0.08°C/a was in the west, in the Taiwan Warm Current, suggesting rapid warming of its source, the Kuroshio. The recent warming could be partly offset in the future by a decrease of the Yangtze River runoff caused by the Three Gorges Dam (Yang et al., 2002, 2003). The runoff decrease leads to a salinity increase of the upper mixed layer, hence stability decrease and enhanced winter cooling and convective mixing. On the other hand, a decrease in the Yangtze River sediment transport increases water transparency and enhances radiative warming of water column.

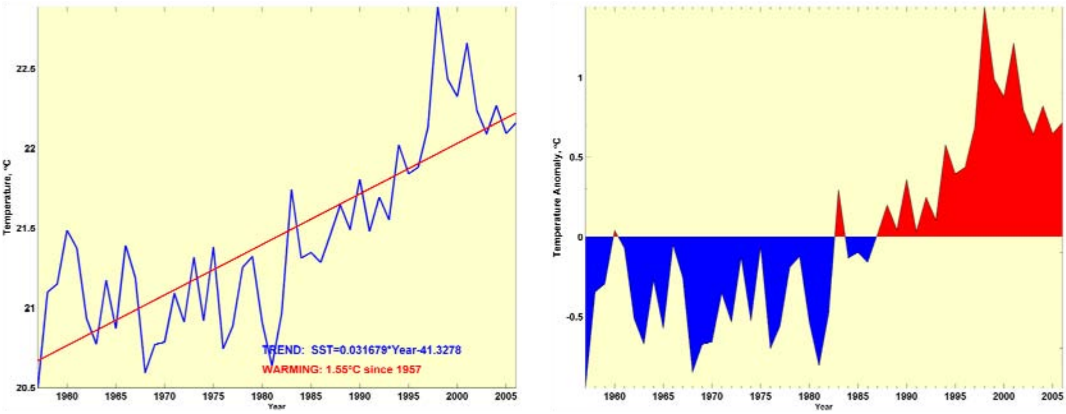

Figure X-22.2. East China Sea LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

East China Sea LME Chlorophyll and Primary Productivity: The East China Sea LME is a Class I, highly productive ecosystem (>300 $gCm^{-2}y^{-1}$), based on source data used throughout this report.

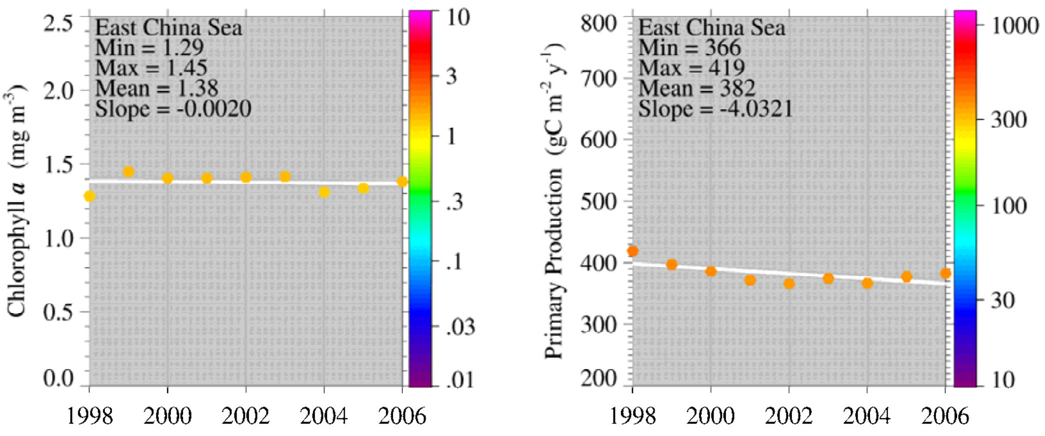

Figure X-22-3. East China Sea trends in chlorophyll *a* and primary productivity, 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Fish and other living resources are heavily exploited in the East China Sea LME, with about 200 species of fish and invertebrates commercially fished. Total reported landings have increased to about 4.5 million tonnes in 2000, and recorded at a level of 4 million tonnes in 2004 (Figure X-22.4), though there is a serious concern as to the validity of the underlying reported landings statistics (see Watson & Pauly 2001). Significant changes in fish biomass and catch composition have occurred in the region, and are attributed to overexploitation and pollution (Chen & Shen 1999). Over the past three decades, the value of the annual catch ranged between US$8 billion and US$5 billion (in 2000 US dollars) except in 1977 and 1979 when extremely high values of US$9.7 billion and US$10 billion were recorded, respectively (Figure X-22.5).

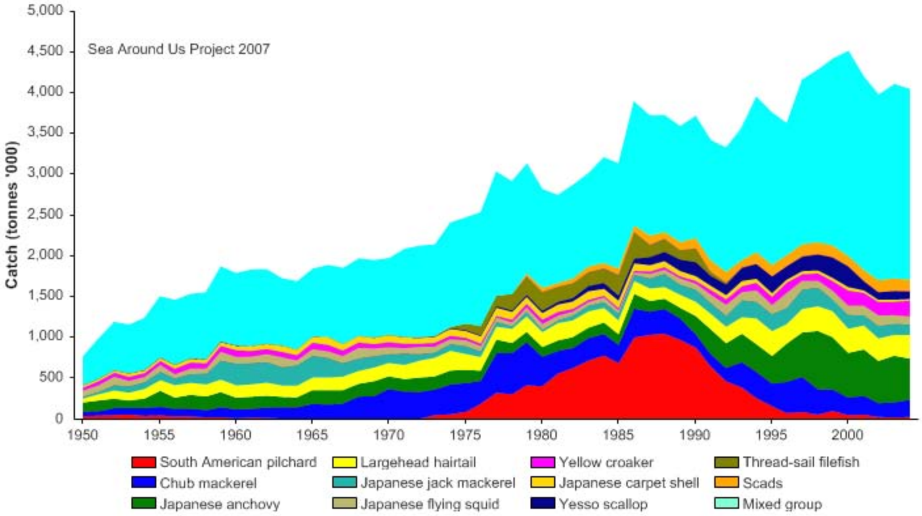

Figure X-22.4. Total reported landings in the East China Sea LME by species (Sea Around Us 2007).

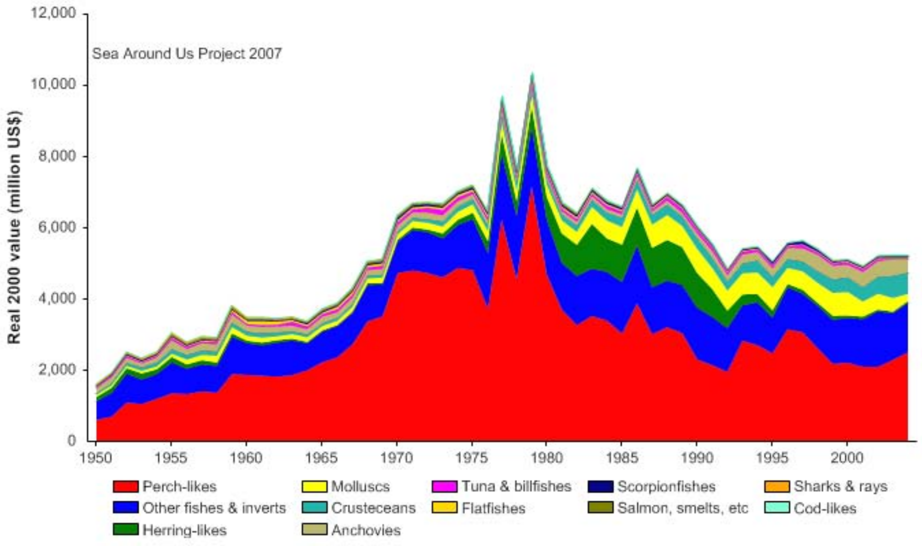

Figure X-22.5. Value of reported landings in the East China Sea LME by commercial groups (Sea Around Us 2007).

In recent years, the primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME has exceeded the observed primary production (Figure X-22.6), which indicates serious problems either with the methodology, assumptions and primary productivity data used by Pauly & Christensen (1995) or with the underlying reported landings statistics. In this particular case, the unrealistic PPR may have been a result of either the primary production values derived from satellite images are under-estimating the true primary production (with the high coastal turbidity of the LME, this is a distinct possibility) or the landings reported in the underlying statistics are exaggerated by including catches made outside the LME.

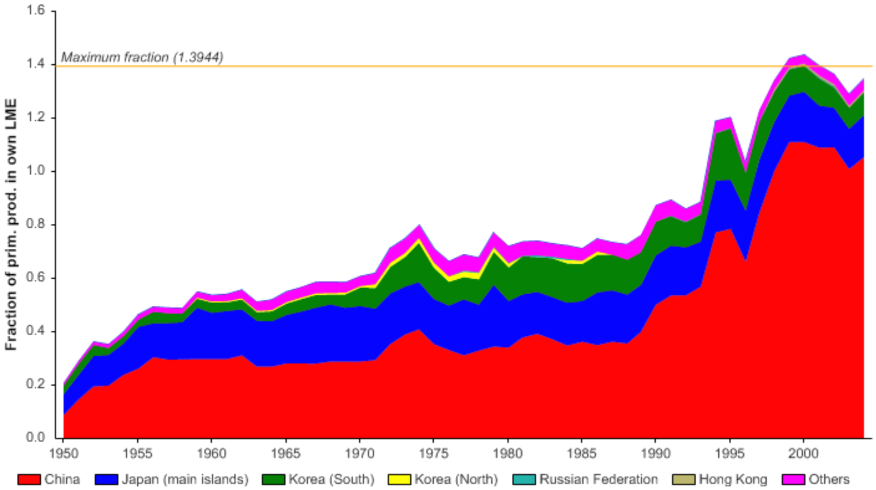

Figure X-22.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the East China Sea LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

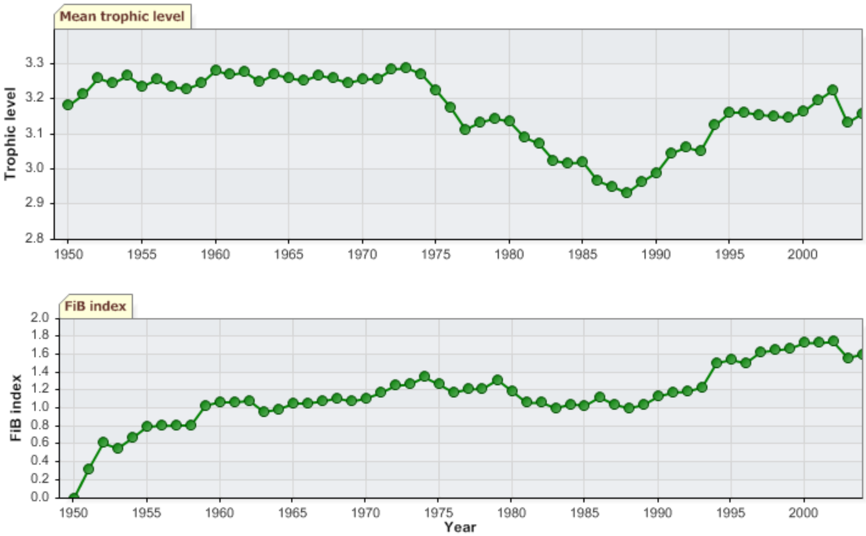

Figure X-22.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the East China Sea LME (Sea Around Us 2007)

The concerns over the quality of the underlying landings statistics are also highlighted in the long-term trends of the mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005; Figure X-22.7, top) and the FiB index (Figure X-22.7, bottom). Both indices show a familiar pattern of overexploitation in the region up to the late 1980s, with a slow expansion of the fisheries implied by the increase in the FiB index, followed by a period of a decline in the mean trophic level or a 'fishing down' of the local food webs (Pauly *et al.* 1998). Yet, in the 1990s both indices show a significant increase. Since such increases can not be attributed to increased catches of tunas and other large pelagic fishes (recalculation of the indices without tunas and other large pelagic species resulted in similar long-term trends as Figure X-22.7), it is possible that the underlying landings statistics include a large amount of catches from outside of the LME. However, from Chinese in situ data it appears that the East China Sea's trophic level is much higher. Indeed, based on Chinese survey data, trophic level in the East China Sea was estimated as 3.7 in 2000-2001 (Zhang and Tang 2004), higher than the corresponding data in Fig X-22.7 (Q.Tang, personal communication, 2008).

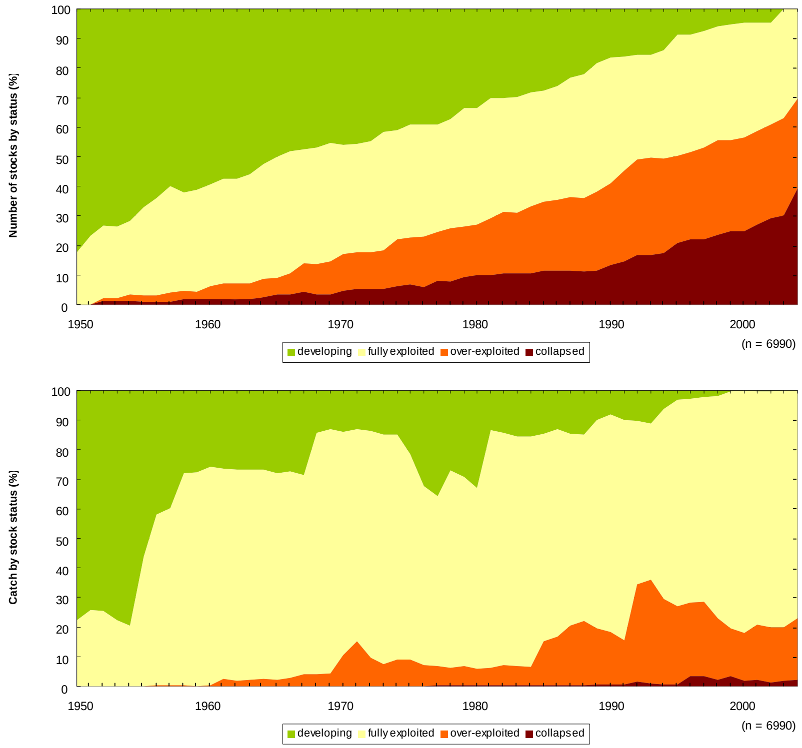

Figure X-22.8. Stock-Catch Status Plots for the East China Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

The Stock-Catch Status Plots indicate that the number of collapsed and overexploited stocks has been rapidly increasing, now accounting for over 60% of the commercially exploited stocks (Figure X-22.8, top), yet, with 80% of the reported landings biomass from fully exploited stocks (Figure X-22.8, bottom). Again, the quality of the underlying statistics must be questioned.

Overexploitation was found to be severe in this LME (UNEP 2005). Stocks of the major high-value demersal species such as croaker have decreased (Zhong & Power 1997) and catch per unit effort has declined by more than 50%. Before the 1970s, the popular fishing method of boat-knocking[1] resulted in the reduction of large and small yellow croaker stocks after the mid-1970s and their subsequent economic extinction in the mid-1980s. Meanwhile, catches of some small-sized, low-value species such as filefish, crabs and cephalopods increased rapidly. Individual species are becoming sexually mature at an earlier age and showing smaller size and lower age in the catch (Chen & Shen 1999). This is particularly so for species such as hairtail and yellow croaker, despite efforts to control fishing of these resources.

In recognition of the severe overexploitation condition, fishing effort and intensity have been reduced for Chinese fishers with a suspension of fishing during the 3 months of summer initiated in 1995 to protect fisheries (Tang 2003)

III. Pollution and Ecosystem Health

Pollution: Rapid economic development and a growing population in eastern China have led to significant increases in the discharge of inadequately treated industrial and domestic wastewater and sewage into the LME. The main pollutants carried by the Changjiang, Mingjiang and Jiulongjiang include COD, nutrients, petroleum hydrocarbon and heavy metals, which have all shown increases in recent years **(**SOA 2000-2002)**.** Aquaculture has also become one of the primary sources of pollution in localised coastal areas. Sewage discharge has resulted in microbiological pollution in some coastal localities, for example, Shenjiamen, Wenzhou and Taizhou Bay, where the amount of faecal *Escherichia coli* in shellfish has exceeded the national biological quality standard by as much as 1.5 to 8 times (ZOFA 2001**)**. Excessive nitrogen input from sewage as well as runoff of chemical fertilisers is causing eutrophication and HABS, which are ubiquitous in coastal areas. Concentrations of chlorophyll *a* of up to 16 mg m^{-3} have been recorded in some areas.

Occurrences of major harmful algal blooms (HABs) with wide geographical distribution have increased in frequency, but are largely confined to the summer from June to October (Chen & Shen 1999). In 2003, there were 86 HAB events covering a total area of 12,990 km^2, a significant increase from 1993 (SOA 2003). HABs have occurred primarily off the Changjiang Estuary, which has accounted for 70% of the total number of HAB occurrences, as well as in the Xiamen, Xiangshan and Sanmen Bays. Extensive loss of cultivated shellfish caused by HABs has been reported.

Soil erosion, deforestation and intensive cultivation are the main sources of high levels of suspended solids in coastal waters. In the Changjiang drainage basin, for instance, the area affected by soil erosion increased from 304,200 km^2 in 1987 to 572,400 km^2 in 1992 (CNRD 2004), resulting in significant input of suspended solids to coastal areas. Other activities such as dredging of waterways, building of bridges and dams, sand mining and reclamation increase the concentration of suspended solids in the coastal areas.

Accidental oil spills, offshore oil fields and marine transportation, especially ballast water from oil tankers, are major sources coastal and marine area pollution, particularly in estuaries. In 2002 and 2003, the total amounts of oil pollutants discharged into the LME by the Changjiang, Mingjiang and Jiulongjiang were 119,500, 10,600 and 1,000 tonnes, respectively **(**SOA 2000-2002)**.** Other land-based pollutants include heavy metals, which have been increasing in recent years. In 2001, pollutant residues such as petroleum hydrocarbon and arsenic were high in some commercially produced mussels and oysters. DDT and PCBs were also detected, but were within the limit for human consumption (ZOFA 2001).

---

[1]Boat knocking: fishing method in which the side of the boat is struck with heavy objects, generating sound which damage the auditory mechanism of fish, and thus renders them susceptible to capture.

Habitat and community modification: The LME's habitats are being degraded as a result of unprecedented rapid industrial development and population growth over the last decade. Reclamation has contributed to a dramatic reduction in mangrove wetland area in recent years. Since 1949, about 840 km^2 of coastal wetlands have been reclaimed in Shanghai, while 120 km^2 of coastal wetlands were converted to other uses from 1995 to 2000 (Jin 2004). China has planned to reclaim a further 45% of its mudflats. The combined effects of reclamation and reduced sediment input due to changes to the Changjiang will result in the further loss of intertidal areas. The development of ports, industries and tourist facilities has severely damaged areas of rocky coast, particularly in Zhejiang Province. Populations of some native species are threatened by the introduction of alien species (Ding & Xie 1996). Continued population and industrial growth, as well as agricultural expansion, will place further pressure on the LME's health. The heavy reliance of the bordering countries on marine resources demands continued efforts to reclaim the environmental sustainability of this LME and its resources.

IV. Socioeconomic Conditions

The Changjiang Delta, with an average urbanisation level of nearly 50%, is the most industrial and densely populated area in the East China Sea LME. The Changjiang watershed covers 20% of China's total area and is home to about 400 million people. The area also supports about 40% of China's total agricultural and industrial production. In the last few decades, the economy of China, particularly in most coastal cities and provinces including Shanghai, Zhejiang, Jiangsu and Fujian, has increased rapidly.

Aquaculture and tourism are becoming increasingly important in coastal regions in China. Marine fisheries are a major economic sector, with about 4% of the world's fishery production coming from this LME. The fisheries provide employment opportunities, income generation and food security, particularly for the coastal populations. Overexploitation has significant economic impacts in the bordering countries (UNEP 2005). Fisheries resources and aquaculture operations are affected by HABs, which also cause public health problems. For instance, HABs resulted in direct economic losses of US$3.6 million in the Changjiang Estuary and the coastal waters off the Zhejiang in 2000 (UNEP 2005).

V. Governance

An important governance initiative in this LME will be to take measures for the recovery of depleted fisheries resources and improve ecological and environmental conditions. Appropriate laws and regulations will need to be enacted in order to protect fishing grounds and fisheries resources. Regional cooperation and coordination are facilitated through the Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific (NOWPAP), under the UNEP North-West Pacific Regional Seas Programme. NOWPAP's goals are to: develop regional monitoring and assessment activities; develop public outreach and environmental education; implement and further develop a Regional Contingency Plan for Oil Spills, signed and adopted by NOWPAP members in November 2004; and prepare a regional Strategic Action Plan to Abate Pollution from Land-based Activities including the mitigation of marine and coastal litter. NOWPAP is comprised of 6 priority projects, implementation of which is supported by a network of Regional Activity Centres in China, Russian Federation, Republic of Korea and Japan. NOWPAP has not yet adopted a legally binding Convention.

The North Pacific Marine Science Organisation (PICES) is an intergovernmental scientific organisation established in 1992. Its present members are Canada, China, Japan, Republic of Korea, Russian Federation and the U.S. PICES' role is to promote and coordinate marine research in the northern North Pacific and adjacent seas; advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impacts of human activities; and to promote the collection and rapid exchange of scientific information on these issues.

GEF supported the Regional Programme for Marine Pollution Prevention and Management in the East Asian Seas region from 1994 to 1999. The PEMSEA project is the five-year follow-on phase (2000-2005) meant to develop stronger partnerships in addressing environmental management problems in the region (www.pemsea.org).

References

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I. M. and Cornillon, P.C. (2003) SST fronts of the Pacific coastal and marginal seas. Pacific Oceanography 1(2): 90-113.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2009). Fronts in Large Marine Ecosystems. Progress in Oceanography, in press.

Cai, R.-S., Chen, J.-L. and Huang, R.-H. (2006) The response of marine environment in the offshore area of China and its adjacent ocean to recent global climate change, presented at the PICES 15th Annual Meeting, Yokohama, Japan, 13-22 October 2006; www.pices.int/publications/ book_of_abstracts/PICES_15_Book_of_Abstracts.pdf, p. 239, abstract W5-3249.

Chen, Y.Q. and Shen, X.Q. (1999). Changes in the biomass of the East China Sea Ecosystem, p 221-239 in: Sherman, K. and Tang, Q. (eds), Large Marine Ecosystems of the Pacific Rim – Assessment, Sustainability and Management. Blackwell Science, Malden, U.S.

CNRD (2004). China Natural Resource Database. www.data.ac.cn/index.asp

Ding, J. and Xie, Y. (1996). The mechanism of biological invasion and the management strategy, p 125-156 in: Schei, P.J., Wang, S. and Xie, Y. (eds), Conserving China's Biodiversity (II). China Environmental Science Press. Beijing, China.

Hickox, R., Belkin, I.M., Cornillon, P. and Shan, Z. (2000). Climatology and seasonal variability of ocean fronts in the East China, Yellow and Bohai Seas from satellite SST data. Geophysical Research Letters 27(18): 2945-2948.

Jin, Z.X. (2004). Protection and Usage of Wetlands Resources. www.shanghaiwater. gov.cn / wetland/lunwen.asp?id=3

Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. Nature 374: 255-257.

Pauly, D. and Watson, R. (2005). Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Philosophical Transactions of the Royal Society: Biological Sciences 360: 415-423.

Pauly, D., Christensen, V., Dalsgaard, J., Froese R. and Torres, F.C. Jr. (1998). Fishing down marine food webs. Science 279: 860-863.

Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/Summary Info.aspx?LME=47

SOA (2000-2002). Bulletin on the Quality of the Oceanic Environment in China. State Oceanic Administration. (In Chinese).

SOA (2003). China Oceanic Disaster Bulletin. State Oceanic Administration. (In Chinese).

Su, J. (1998). Circulation dynamics of the China Seas: north of 18°N, p 483-506 in: Robinson, A. R. and Brink, K.(eds.), The Sea, Vol. 11, The Global Coastal Ocean: Regional Studies and Syntheses. John Wiley.

Tang Q. (Chief editor),(2006). Living marine resources and inhabiting environment in the Chinese EEZ. *Science Press,* Beijing, 1238pp. (In Chinese).

UNEP (2005). Qu, J., Xu, Z., Long, Q., Wang, L., Shen, X., Zhang, J. and Cai, Y. East China Sea, GIWA Regional Assessment 36. University of Kalmar, Kalmar, Sweden. www.giwa.net/publications/r36.phtml

Wang, F. (2006) Long-term variability of temperature in the Yellow Sea and the East China Sea in the past 40 years, presented at the PICES 15th Annual Meeting, Yokohama, Japan, 13-22 October 2006; www.pices.int/publications/book_of_abstracts/PICES_15_Book_of_Abstracts.pdf p. 175, POC_Paper-3098.

Watson, R., and Pauly, D. (2001). Systematic distortions in world fisheries catch trends. Nature 414: 534-536.

Yang, S.L., Belkin, I.M., Belkina, A.I., Zhao, Q.Y., Zhu, J. and Ding, P.X. (2003). Delta response to decline in sediment supply from the Yangtze River: evidence of the recent four decades and expectations for the next half-century. Estuarine, Coastal and Shelf Science 57 (4): 689-699.

Yang, S-l, Zhao,Q.Y., and Belkin, I.M. (2002) Temporal variation in the sediment load of the Yangtze river and the influences of human activities. Journal of Hydrology 263(1-4) 10 June: 56-71.

Zhang B. and Q. Tang (2004). Trophic level of important resources species of high trophic levels in the Bohai Sea Yellow Sea and East China Sea. Advance in Marine Science, 22(4): 393-404. (In Chinese with English abstract).

Zhong, Y. and Power, G. (1997). Fisheries in China: progress, problem and prospects. Canadian Journal of Fisheries and Aquatic Sciences 54: 224-238.

ZOFA (2001). Bulletin on the Quality of the Oceanic Environment in Zhejiang. Zhejiang Ocean and Fishery Administration. (In Chinese).