VIII-15 South China Sea: LME #36

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The South China Sea LME is bordered by China, Indonesia, Malaysia, Philippines, Taiwan and Vietnam. It covers an area of 3.2 million km^2, of which 0.31% is protected, and contains 7.04% and 0.93% of the world's coral reefs and sea mounts, respectively (Sea Around Us 2007). Coastal waters are relatively shallow (less than 200 m) and are influenced by marine as well as by river and terrestrial inputs. The South China Sea Basin and Palawan Trough are deeper than 1,000 m. Numerous rivers (120) drain a total catchment area of 2.5 million km^2 into the LME. Most of the region lies within the sub-tropical and equatorial zones and the climate is governed by the northeast and southwest monsoon regimes. The northern and central parts of the region are affected by typhoons during the southwest monsoon months, bringing intense rains and destructive winds to coastal areas. This LME is particularly sensitive to ENSO, which has caused significant changes in rainfall patterns, for example, in Indonesia and Malaysia. Major oceanographic currents include those generated by the seasonal monsoons. Waters from the LME may flow seasonally into the Sulu Sea and Java Sea, contributing to the Indonesian Throughflow. The component subsystems of this LME have been documented in Pauly & Christensen (1993). Other reports pertaining to this LME are listed in the references (see also Talaue-McManus 2000, UNEP 2005).

I. Productivity

The South China Sea LME is a biologically diverse marine ecosystem with a tropical climate. It is considered a Class II, moderate production ecosystem (150-300 $gCm^{-2}yr^{-1}$). The Indo-West Pacific marine biogeographic province, which includes the South China Sea LME, is well-recognised as a global centre of marine shallow-water, tropical biodiversity (Spalding *et al*. 1997, Tomascik *et al*. 1997). Over 450 coral species have been recorded from the Philippines. Recent estimates suggest that approximately 2 million ha of mangrove forest or 12% of the world total are located in the countries bordering the South China Sea LME (Talaue-McManus 2000). Six species of marine turtles, all considered as either Endangered or Vulnerable by the IUCN, the dugong and several other species of marine mammal included on IUCN's Red List of Threatened Animals occur in this LME. Many of these exhibit transboundary migratory behaviour, which presents major challenges for their conservation.

Oceanic fronts: Fronts observed within this LME (Figure VIII-15.1) are quite diverse (Belkin & Cornillon 2003). The South China Inner Shelf Front (SCISF) and South China Outer Shelf Front (SCOSF) extend along southern China coast from Hainan Island into Taiwan Strait. The Gulf of Tonkin Front (GTF) is of the estuarine origin; the salinity differential across this front is controlled by a massive river discharge into the Gulf, mostly by the Red River. The Vietnam Coastal Front (VCF) is largely caused by wind-induced coastal upwelling and is thus strongly monsoon-dependent. The West Luzon Front (WLF) appears as a relatively broad frontal zone southwest of the Luzon Strait; it is likely caused by the inflow of the Pacific waters; the wind-induced upwelling also contributes to frontal maintenance.

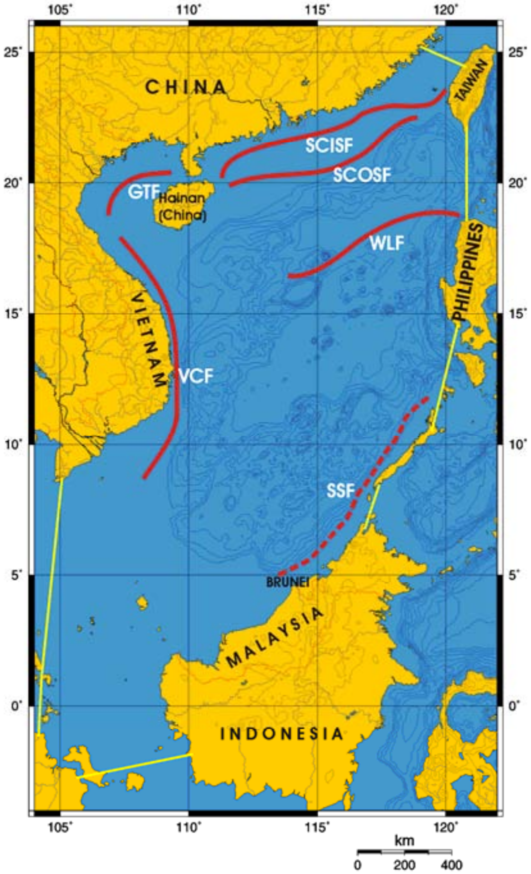

Figure VIII-15.1. Fronts of the South China Sea LME. GTF, Gulf of Tonkin Front; SCISF, South China Inner Shelf Front; SCOSF, South China Outer Shelf Front; SSF, Shelf-Slope Front (the most probable location); VCF, Vietnam Coastal Front; WLF, West Luzon Front. Yellow line, LME boundary. After Belkin et al. (2009) and Belkin and Cornillon (2003).

South China Sea SST (Belkin, 2009)
Linear SST trend since 1957: 0.80°C.
Linear SST trend since 1982: 0.44°C.

The thermal history of the South China Sea (Figure VIII-15.2) is strongly correlated with the Gulf of Thailand LME and largely decorrelated from other neighboring LMEs. The all-time maximum of 1998 is an exception since this event was linked to the global El Niño 1997-98. Interannual and decadal variability in the South China Sea are relatively small. The observed stability of the South China Sea can be partly explained by the existence of the so-called South China Warm Pool (Li et al., 2007); such warm pools are known to be relatively stable owing to anticyclonic circulations that enclose them; a good example of a large-scale warm pool is a gyre in the western part of the Sargasso Sea. The South China Warm Pool changes seasonally and interannually (He et al., 2000): it grows in summer and shrinks and retreats to the southwest in winter, and it is modulated by the ENSO (El Niño-Southern Oscillation).

A recent study of the ERA-40 reanalysis and other data sets, including HadISST and SODA (Simple Ocean Data Assimilation), has shown that “due to the impact of global climate warming, the winter and summer monsoon flows became weak over the offshore area of China and its adjacent ocean after 1976, which caused the weakening of winter and summer sea surface wind stresses, especially the meridional sea surface wind stresses, and obvious increase of SST in the area.” (Cai et al., 2006, p. 239).

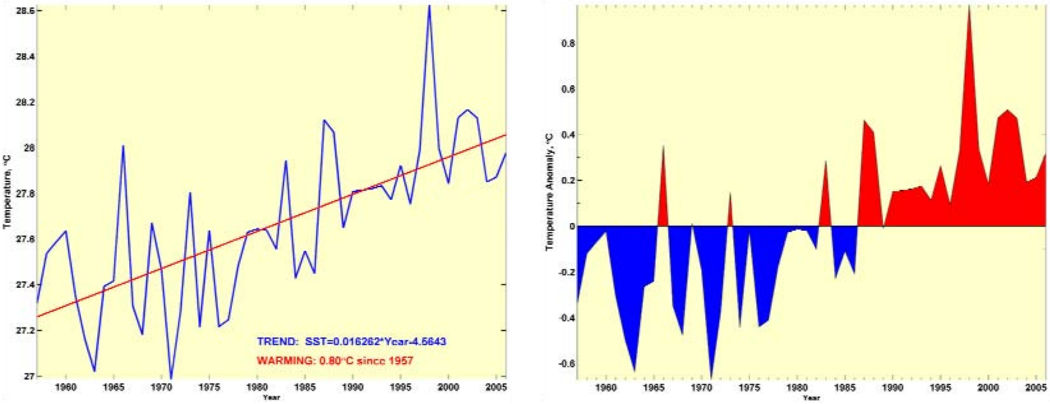

Figure VIII-15.2. South China Sea LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

***South China Sea LME Chlorophyll and Primary Productivity*: South China Sea LME** is considered a Class II, moderate production ecosystem (150-300 $gCm^{-2}yr^{-1}$).

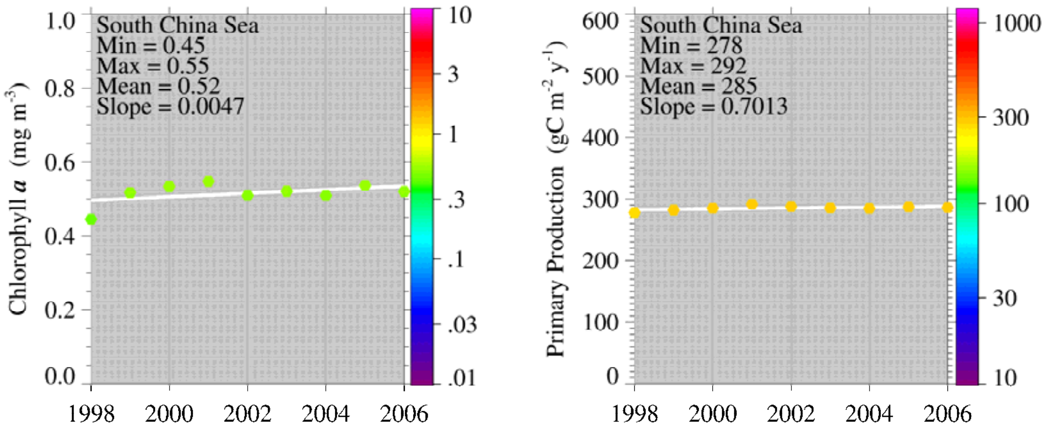

Figure VIII-15.3. South China Sea trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O’Reilly and K. Hyde. Sources discussed p. 15 this volume.

I. Fish and Fisheries

Reported landings from the South China Sea LME are in the order of 6 million tonnes (Figure VIII-15.4), although substantial uncertainty is associated with these figures. The marine fisheries are important to the food security and economy of the bordering countries and targeted groups include flying fishes, tunas, billfishes, mackerels and sharks for the pelagic species, and a large array of demersal fish and invertebrates, especially penaeid shrimps. There is also a high percentage of reef fish and other small coastal pelagic fishes such as herring, sardine and anchovy in the landings. Like adjacent LMEs, the status and future viability of fish stocks of this LME are not well understood, and there are significant gaps in the available data with many fisheries that may be classified as Illegal, Unreported and Unregulated (IUU; UNEP 2005). The steady increase of the reported landings, from 600,000 tonnes in 1950 to over 6 million tonnes in 2004 (Figure VIII-15.4) is primarily due to a significant increase in the landings of unidentified fishes (included in 'mixed group'), which account for two-third of the landings in recent years. In general, a high proportion of unidentified catches in landings statistics is a symptom of deficiencies in a reporting system, and therefore, we should be wary of the large, continuous increases reported in this LME. Due to the large increase in the reported landings, the value of the landings also rose steadily, reaching US$6 billion (in 2000 US dollars) in the early 2000s (Figure VIII-15.5).

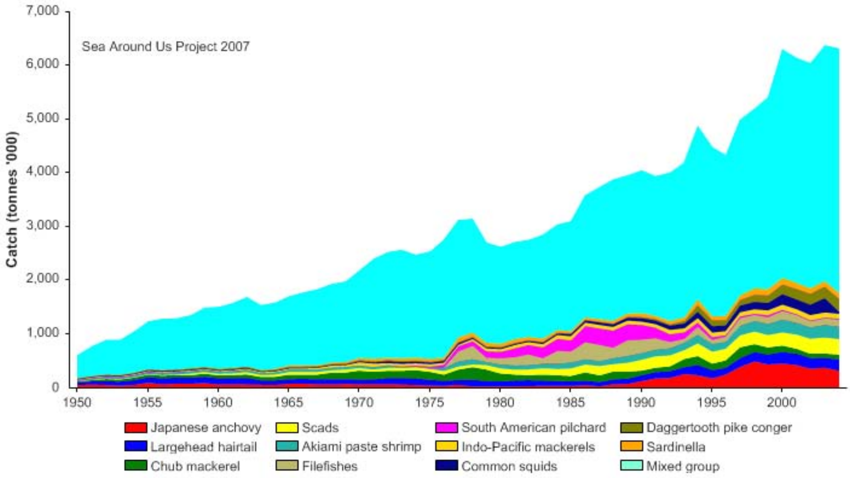

Figure VIII-15.4. Total reported landings in the South China Sea LME by species (Sea Around Us 2007).

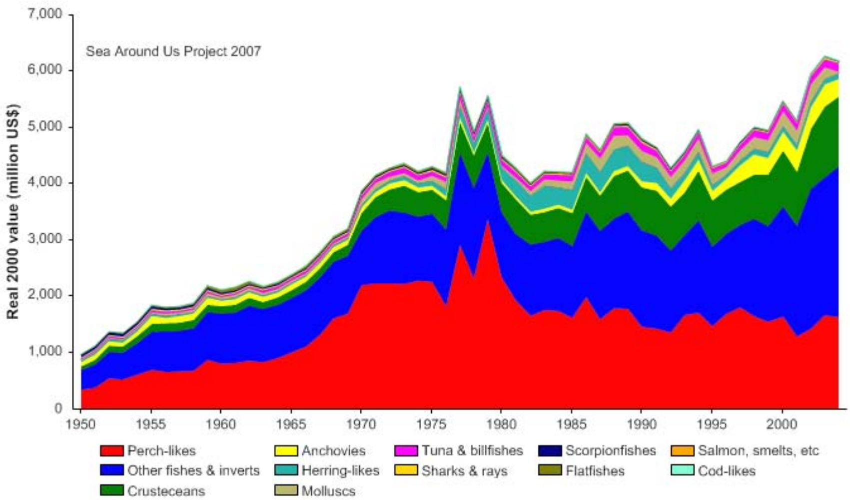

Figure VIII-15.5. Value of reported landings in South China Sea LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is increasing with the reported landings, and is presently over 60% of the observed primary production (Figure VIII-15.6)--yet another indication that the reported landings from this LME may be unrealistically high. China accounts for the largest share of the ecological footprint in this LME.

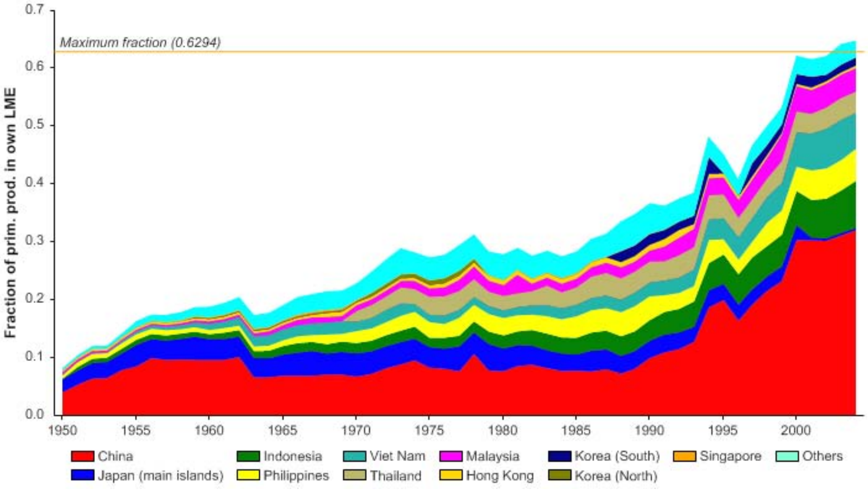

Figure VIII-15.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the South China Sea LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The trends of both the mean trophic level (i.e., the MTI; Pauly & Watson 2005; Figure VIII-15.7 top) and the FiB index (Figure VIII-15.7 bottom) until the mid-1980s are both suggestive of a 'fishing down' in the food web (Pauly *et al.* 1998) with a limited geographic expansion of fisheries with the MTI declining and and the FiB index showing a limited increase.

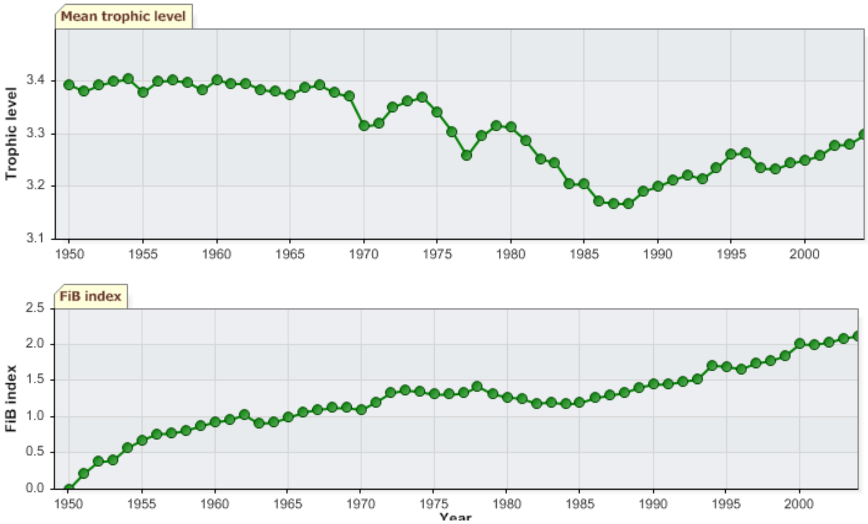

Figure VIII-15.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the South China Sea LME (Sea Around Us 2007).

The trends of these indices from the mid-1980s on, however, is hard to interpret, as the increase in the MTI does not seem to be caused by development of high trophic fisheries such as tuna fisheries (time series of the MTI without tuna catches can be examined at www.seaaroundus.org). Another, more likely explanation for such trends is that the landings statistics for the LME include either catches made outside the LME or exaggerated values. This would also explain why the PPR for the fisheries in the LME is improbably high (Figure VIII-15.6). The Stock-Catch Status Plots indicate that about 40% of the stocks in the LME are collapsed or overexploited (Figure VIII-15.8, top), however, with the majority of the catches supplied by fully exploited stocks (Figure VIII-15.8, bottom). Such diagnosis is probably optimistic, and is again likely a result of the high degree of taxonomic aggregation in the underlying statistics.

While masked in recent years, ‘fishing down’ of the food web is widespread in most, if not all, countries of the South China Sea LME (UNEP 2005). Moreover, catch per unit effort in most fisheries has declined steadily, an indication of severe overexploitation. The increase was accompanied by a change in the major species in the catch, an indication of massive selective fishing pressure (Yanagawa 1997). Intensive fishing is the primary driving force of biomass change in this LME (Sherman 2003). The South China Sea TDA has identified loss of fisheries productivity as a major transboundary issue (Talaue-McManus 2000) and most of the conventional species have been fully exploited at the basin level (Yanagawa 1997).

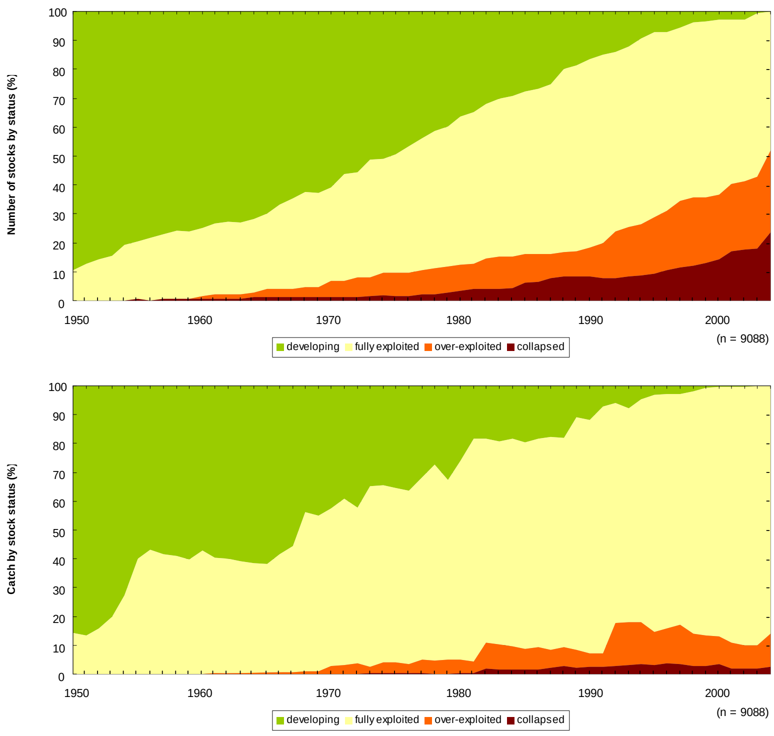

Figure VIII-15.8. Stock-Catch Status Plots for the South China Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

Because of their proximity to shore, fringing reefs are heavily exploited by subsistence fishers and about 70% of the coral reefs in the broader region (including Sulu-Sulawesi Sea and Indonesian Seas) is heavily depleted, producing less than 5 tonnes per km^2 per year in comparison with the remaining 30% of reefs that produce about 15 - 20 tonnes per km^2 per year. Moreover, adult fish are scarce in some reefs in the region (McManus 1994). Reduction and loss of reef fish populations may have transboundary consequences if reef interdependence between oceanic shoals and highly exploited fringing reefs of the South China Sea LME is considered (Talaue-McManus 2000).

Oceanic migratory species such as tuna, billfish, sharks and other pelagic species are also overexploited, with potential transboundary impacts (UNEP 2005). Some shark species that migrate throughout the South China Sea LME, are also targeted and often caught as bycatch in the tuna and swordfish fisheries. Currently, high demand for shark products for exotic food, medicinal and ornamental markets (Chen 1996) is causing concern about overexploitation of sharks in the region (Talaue-McManus 2000). Invertebrate species such as holothurians, molluscs and crustaceans are considered to be heavily exploited, partly through overinvestment and encroachment of large-scale commercial operations, including illegal and unreported incursions of vessels from countries outside the South China Sea LME.

Excessive bycatch is a severe problem in this LME (UNEP 2005). The lack of bycatch exclusion devices has resulted in massive overexploitation of species regarded as bycatch in other regions. However, the quantity of discards in the region's fisheries is insignificant, as virtually all of the bycatch, including turtles, sharks and whales, are utilised. There is also a widespread capture, either intentional or accidental, of rare, threatened and endangered species such as turtles and dugong, by traditional and commercial fisheries. Substantial, though unquantified, levels of bycatch are produced by distant waters fleets, through use of blast fishing and poisons, as well as in the shrimp fry fisheries, where juveniles of all other species are discarded. Destruction by reef bombing and use of poisons is severe, particularly on coral reefs (Bryant *et al*. 1998, Talaue-McManus 2000, UNEP 2005). Massive habitat destruction and fragmentation and changes in population and community structure are occurring from destructive fishing methods in the region. Based on present consumption patterns and population growth rates, the region will have to produce significantly more fish in the future just to meet domestic demand. Pressure on the coastal resources is therefore likely to increase significantly in the near future.

III. Pollution and Ecosystem Health

Pollution: Pollution in the South China Sea LME can be attributed to rapid economic development and population growth in the coastal zone. Overall, pollution was assessed as moderate, but severe in some localised areas (UNEP 2005). Wastes from domestic and industrial sources, agricultural and aquaculture, as well as sediments and solid wastes are the major land-based pollutants affecting coastal areas (Koe & Aziz 1995, Talaue-McManus 2000, Fortes 2006). Inadequate sewage treatment and disposal has led to high faecal coliform bacteria levels in some areas (e.g., Manila Bay). Industries release an estimated minimum of about 430,000 tonnes of Biological Oxygen Demand (BOD) into aquatic systems interacting with the LME (Talaue-McManus 2000). If this is not significantly reduced, the coastal waters of the Sunda Shelf from the Indo-China Peninsula to Malaysia and Indonesia, across to the western Philippine shelf, could become eutrophic. In enclosed bays, harbours, lagoons and in the immediate vicinity of river mouths there has been frequent occurrence of non-toxic algal blooms and HABS, as well as cases of paralytic shellfish poisoning in parts of the region (Talaue-McManus 2000).

High levels of suspended solids are found in coastal waters throughout most of the region. This has resulted from activities such as extensive deforestation in many watersheds, logging, mining, land reclamation, dredging and urban development, compounded by high rates of erosion (Naess 1999). There have been major changes in turbidity and levels of suspended sediments in Malaysia, Vietnam, Philippines, Indonesia (Sumatra and Kalimantan) and Thailand. Suspended solids have caused major changes in biodiversity of benthic communities (UNEP 2005). Pollution from solid waste is severe in localised areas, particularly around many towns and villages where waste management is poor or non-existent.

Data provided on heavy metals, though incomplete, show high levels in localised areas. Vietnam, whose major rivers are all transboundary, reports an annual load of heavy metals of about 100,000 tonnes. In the Northern Economic Zone of Vietnam, the concentration of lead, zinc and copper are 7-10 times the allowable limits. The LME contains some of the world's busiest international sea-lanes and two of the busiest ports in the world, Singapore and Hong Kong (Coulter 1996). This has led to moderate pollution from spills, with episodic discharges from shipping and occasional spills from oil exploration and production. International trade is expected to triple by 2020, much of which will be through the sea, increasing the potential for spills.

Habitat and community modification: Ecological goods and services provided by mangrove systems are estimated to be worth about US$16 billion per year (Naess 1999, UNEP 1999). Southeast Asian reefs are estimated to be worth more than US$2.4 billion per year, based on their contribution to food security, employment, tourism, pharmaceutical research and shoreline protection (Burke *et al*. 2002), while the estimated value of seagrass and coastal swamp areas in the South China Sea region is about US$190 billion per year (UNEP 1999).

Growing coastal populations and development, destructive fishing practices, pollution and siltation have resulted in severe habitat and community modification in this LME (UNEP 2005). Significant expanses of coral reefs have already been degraded or are under severe threat (Chou *et al*. 1994, Bryant *et al*. 1998, Burke *et al*. 2002). Coral reefs are most extensive and also the most threatened in Indonesia and the Philippines, with 50% of Indonesian reefs and 85% of Philippines reefs at high risk (Bryant *et al*. 1998). Recent studies suggest that degraded reefs have incurred reductions in biodiversity and at worse, species extinctions (Talaue-McManus 2000).

The reversing monsoonal pattern of wind and surface circulation facilitates connections between oceanic shoal reefs and those fringing the coastal states. McManus (1994) suggests that planktonic larvae of many coral reef biota from the oceanic shoals of the South China Sea can recruit in the fringing reefs of Sabah, the Philippines, Taiwan, coastal China, the Paracell Islands, Vietnam or in the Natuna Islands (Indonesia), depending on the direction of water circulation. Degradation of the coral reefs in the South China Sea LME will have a major impact on the global heritage of reef biodiversity (Bryant *et al*. 1998).

The original area of mangroves has decreased by about 70% during the last 70 years, with millions of hectares of land, mostly mangroves, having already been converted for shrimp mariculture, industrial development and tourist resorts. A continuation of the current trend would result in all mangroves being lost by the year 2030 (UNEP 1999). The disappearance of mangrove systems on such a large scale has led to sediment erosion, water pollution, loss of biodiversity and a critical loss of nursery habitat for young fish and shellfish. Despite the continuing destruction, significant areas supporting good quality coastal and marine habitats still remain (e.g., Spratly and Paracel Islands; western Palawan, Philippines; Con Dao Islands, Vietnam), both within and outside MPAs.

There is evidence of widespread modification of seagrass habitats throughout the region, with 20% to 50% of seagrass beds having been damaged (Talaue-McManus 2000). Sediments from coastal development, destructive fishing methods and land-based pollution are among the major threats to the region's seagrass habitats. Like coral reefs and mangroves, seagrass beds possess high biodiversity and a number of endangered species like sea cows and marine turtles are known to feed in these areas. Numerous species spend various stages of their life cycles among adjacent mangrove, seagrass and coral reef habitats. Degradation and loss of these critical habitats have led to reduction in the essential ecosystem services they provide in maintaining the high biodiversity and fisheries production of this region.

The health of the South China Sea LME may deteriorate further as a consequence of the expected future increase in pollution and habitat modification (UNEP 2005). Despite increasing measures for pollution mitigation and control, environmental quality is likely to worsen, primarily because of the predicted increase in deforestation and agriculture, as well as a major increase in population overriding the improvements in infrastructure (UNEP 2005). Some positive steps are being taken to address habitat modification, including mangrove rehabilitation programmes, watershed protection and establishment of MPAs.

IV. Socioeconomic Conditions

About 270 million people live in the coastal areas of the South China Sea LME. This population is expected to double in the next three decades. The South China Sea LME contributes to the livelihood of millions of people engaged in trade, tourism, industry, fisheries and oil exploitation. Fisheries remain a significant source of revenue and food. Economic activities include fisheries, mariculture, tourism and mining. The region is a globally important source of minerals, with considerable reserves of oil and gas.

The socioeconomic impacts of unsustainable exploitation of fisheries and environmental deterioration are significant for the newly developed economies of this region (Talaue-McManus 2000, UNEP 2005). There have been reduced economic returns and loss of employment as well as of livelihood from the fisheries collapse. In many areas, fisher families' children are malnourished, as fish consumption has declined from approximately 36 kg $person^{-1}yr^{-1}$ to 24 kg $person^{-1}yr^{-1}$, with consequent high levels of malnutrition (UNEP 2005). The socioeconomic impacts of pollution are mainly related to poverty in the major urban centres (UNEP 2005). Impacts include economic losses to mariculture and the shellfish industry through regular advisories of high levels of toxicity (e.g., Philippines, Vietnam, Indonesia, Thailand), as well as HABs and cases of mercury poisoning. Other impacts are associated with the costs of clean-up and coastal restoration. There have also been losses in recreational value in parts of the Philippines and land use conflicts in Philippines, Thailand and Malaysia.

Habitat modification has resulted in reduced capacity of local populations to meet basic human needs and loss of employment throughout the LME (UNEP 2005). Other impacts include loss or reduction of existing and future income and foreign exchange from fisheries and tourism, loss of charcoal production, economic conflicts between investors and local users, national and international conflicts and increased risks to capital investment (e.g., failure of coastal aquaculture projects in many parts of the region), costs of restoration of modified ecosystems and intergenerational inequity (UNEP 2005).

V. Governance

Most South China Sea nations recognise that their fisheries resources are threatened, but they also need the fishery products to feed their human populations and to sustain industries based on fisheries (Naess 1999). Thus, there is constant competition between socioeconomic and environmental concerns, where the former often win (Naess 1999). Fishing fleets of individual countries are depleting the common resources of the LME, reaping short-term benefits at the cost of others. There are multilateral attempts at improving the current situation of regulation of fisheries, to an ecosystem-wide approach to which all littoral states commit themselves. Management of the goods and services of the South China Sea LME is presently the focus of a Global Environment Facility and World Bank financed effort to support a country driven project for protecting the environment and living marine resources of the South China Sea LME (www.gef.org).

The losses related to overexploitation and habitat degradation, both in biodiversity and in fisheries yield, are important transboundary issues, not only from a biological point of view (i.e. nursery areas, recruitment of larvae, etc.) but also from an economic perspective where the drivers are international demand for aquarium fish, live food fish and prawns, as well as coastal tourism (Talaue-McManus 2000). The present situation and future prognosis indicate that more extensive and intensive intervention is required, including direct on-the-ground community-based conservation programmes. One of the Policy recommendations is the development of a functional, integrated regional network of MPAs (UNEP 2005). Bordering countries already have many legally designated MPAs and some multilateral conservation agreements have been established. Approximately 125 MPAs have already been gazetted (Spalding *et al*. 2001, Cheung *et al*. 2002) and there are also two World Heritage sites: Halong Bay, Vietnam and Puerto Princesa Subterranean River National Park, Philippines. However, insufficient resources for management and enforcement of fisheries and other regulations in many MPAs limit their effectiveness. Just 10-20% of MPAs are considered as effectively managed (Cheung *et al*. 2002).

The South China Sea LME is included as part of the UNEP-administered East Asian Regional Seas Programme. The GEF-World Bank supported projects underway are moving toward an integrated country based ecosystem approach to recover depleted fish stocks, restore degraded habitats, reduce coastal pollution and nutrient over-enrichment, conserve biodiversity and adapt to the effects of climate change.

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