

VIII-11 Gulf of Thailand: LME #35

S. Heileman and R. Chuenpagdee

The Gulf of Thailand LME is located in Southeast Asia and bordered by Cambodia, Malaysia, Thailand and Vietnam. It covers a surface area of about 400,000 km², of which 0.80% is protected, and contains about 0.46% of the world's coral reefs and 18 major estuaries (Sea Around Us 2007). The mean depth is 45 m and maximum depth 80 m (Piyakarnchana 1989, 1999). The tropical climate is governed by the northeast and southwest monsoon regimes, which have profound effects on the conditions within the Gulf (Piyakarnchana 1989, 1999). Geographically, the LME can be divided into the inner and outer Gulf. The inner Gulf is primarily influenced by river outflow while the outer Gulf is influenced by seawater intrusion from the South China Sea. Water circulation is complex and influenced by tides and wind as well as differences in water densities. These and other aspects of the oceanography and biogeochemical characteristics are discussed in Wyrki (1961) and Longhurst (1998). Book chapters and reports pertaining to this LME are by Piyakarnchana (1989, 1999), Talaue-McManus (2000), Pauly & Chuenpagdee (2003) and UNEP (2005).

I. Productivity

This LME is considered a Class I, highly productive ecosystem (>300 gCm⁻²yr⁻¹). Its high primary production is the result of high nutrient input through rivers and from agricultural fertilisers, household sewage and shrimp farms (Piyakarnchana 1999). The Chao Phraya watershed is the largest watershed in Thailand, covering approximately 35% of the nation's land, and draining an area of 157,924 km². Nutrient content and dissolved oxygen levels vary seasonally in the inner Gulf, with most nutrients except nitrate being higher and oxygen concentration being lower, in the rainy season. Peaks in phytoplankton densities are correlated with the rainy season. Higher productivity also occurs close to estuaries. Increasing input of nutrients is leading to the occurrence of phytoplankton blooms, including Harmful Algal Blooms (HABs) (Piyakarnchana 1999). The coastal development in the GoT has been very rapid during the last decade especially for medium and small industries. Shrimp farming, on the other hand, has been largely terminated in the inner Gulf area. This is likely to affect the productivity in the LME.

Oceanic fronts: The Gulf of Thailand Front (GTF) is the only major front within this LME located near its boundary, at the entrance to the Gulf (Figure VIII-11.1). This front is largely a salinity front between low-salinity waters of the Gulf, diluted by the Mekong River outflow, and the saline waters of the South China Sea. The salinity contrast between the Gulf waters and South China Sea waters varies seasonally and interannually depending on the Mekong River discharge and the South China Sea circulation that brings Mekong River waters into the Gulf. This contrast can be as high as 3 ppt across the front (Belkin & Cornillon 2003, Belkin *et al.* 2009). The attendant thermal front has the cross-frontal range of 2°C to 3°C. The monsoon plays a major role in the front's seasonal evolution since the Mekong River discharge is largely monsoon-dependent; the snowmelt component of the Mekong runoff is of secondary importance.

Gulf of Thailand SST (after Belkin 2009):

Linear SST trend since 1957: 0.40°C.

Linear SST trend since 1982: 0.16°C.

In general, the thermal history of the Gulf of Thailand shows a moderate-to-slow warming, which is strongly correlated with the one of the South China Sea LME, as could be expected since the Gulf of Thailand is the largest gulf of the South China Sea. The relative magnitude of corresponding peaks and troughs is however different among these LMEs. The Gulf of Thailand's steady, slow warming was modulated by relatively strong interannual variability with year-to-year variations exceeding 0.5°C. The SST peak of 1998 stands out. This event was likely related to the El Niño 1997-98. Other pronounced events are:

- (1) near-all-time minimum of 1963, simultaneous with an SST minimum in the South China Sea LME;
- (2) absolute minimum of 1976, which corresponds to a minimum in the South China Sea.

The major warm event of 1998 caused the first extensive coral bleaching in the Gulf in April-June 1998, which resulted in severe degradation of coral reefs; the smaller warm event of 2003 caused mild bleaching (Yeemin, 2004).

Seasonal variability of vertical stratification plays a significant role in the Gulf of Thailand's thermal regime (Yanagi et al., 2001). Stratification is best developed in spring owing to strong surface heating and weak winds. The Mekong River runoff also affects stratification over most of the Gulf. The above parameters – incident solar radiation, winds and runoff – eventually depend on monsoon, therefore interannual variability of monsoon is expected to strongly modulate the SST regime of the Gulf.

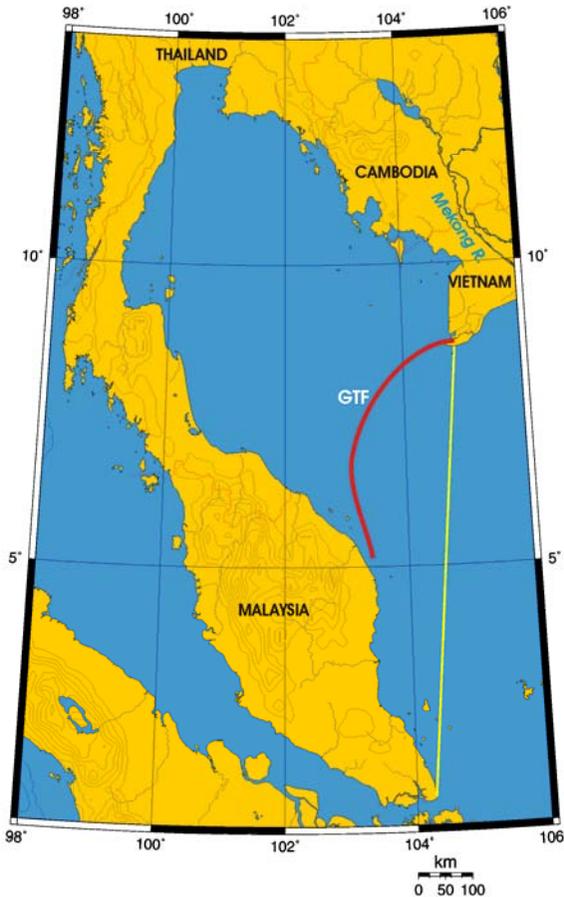


Figure VIII-11.1. Fronts of the Gulf of Thailand LME. GTF, Gulf of Thailand Front. Yellow line, LME boundary (from Belkin et al. 2009).

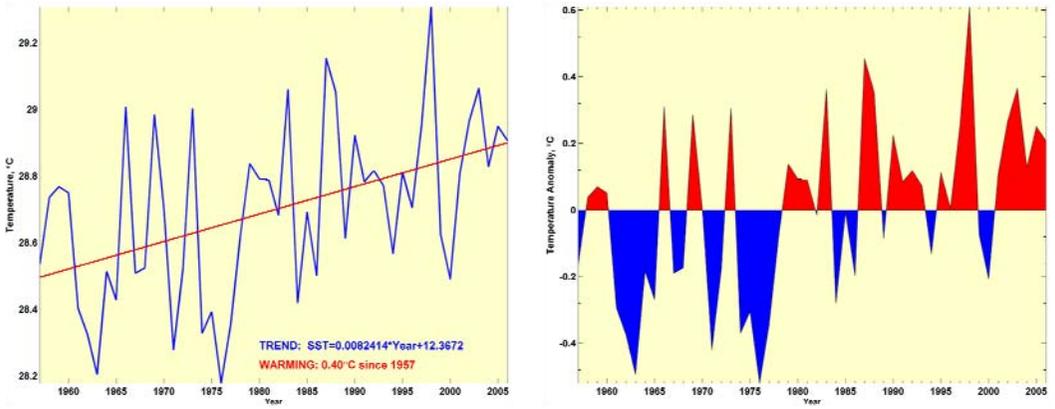


Figure VIII-11.2. Gulf of Thailand LME, annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Gulf of Thailand LME Trends in Chlorophyll and Primary Productivity: This LME is considered a Class I, highly productive ecosystem ($>300 \text{ gCm}^{-2}\text{yr}^{-1}$).

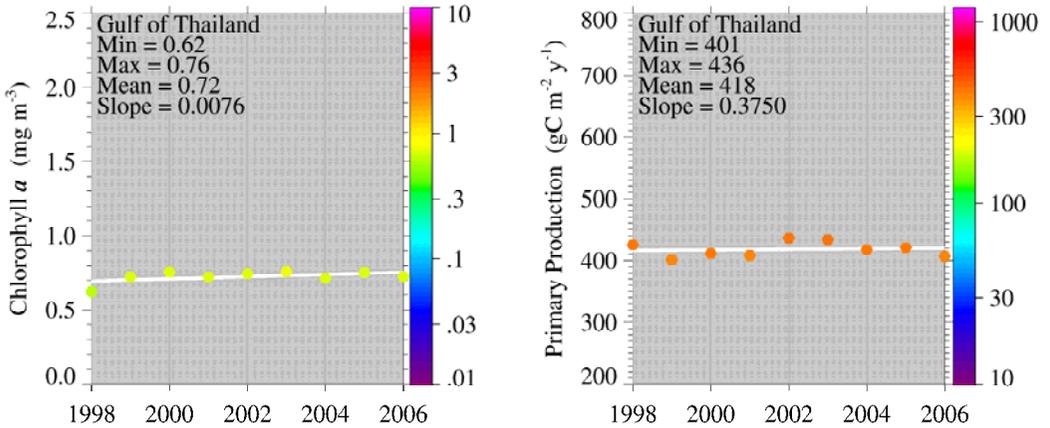


Figure VIII-11.3. Gulf of Thailand LME, trends in chlorophyll *a* and primary productivity, 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The catch composition of the Gulf of Thailand LME is a tropical multi-species mix and includes food fish, trash fish, squid and cuttlefish, shrimp, shellfish and crab. Until the early 1960s, the fisheries were dominated by small pelagics (mainly Indian mackerels, *Rastrelliger* spp. and anchovies, *Stolephorus* spp.), which were caught by artisanal fishers for the local market (Pauly & Chuenpagdee 2003). In the 1960s, the introduction of trawl gear led to the development of demersal trawl fisheries (Piyakarnchana 1989, Chuenpagdee and Pauly 2004), targeting threadfin bream (*Nemipterus* spp.), big-eye (*Pempheris adspersa*), lizardfish (*Saurida elongata*), croaker (*Johnius* sp., *Larimichthys* sp., *Pennahia* sp.), shrimps (*Penaeus* spp.), flatfish and squid.

Total reported landings rose to over a million tonnes in 1969, but this is probably due to misreporting of fish caught outside the Gulf. After 1969, the landings declined to less than 500,000 tonnes by the late 1970s, but gradually returned to 700,000 tonnes by 2004 (Figure VIII-11.4). Again, a large fraction of the increased landings in recent years was probably caught outside of the LME, particularly for large pelagic species such as tuna. Note the high level of 'mixed group' in the reported landings, due to the poor quality of the underlying statistics which report a majority of the landings simply as unidentified marine fish. The value of the reported landings peaked at about 1.1 billion US\$ (in 2000 real US\$) in 1968 (Figure VIII-11.5).

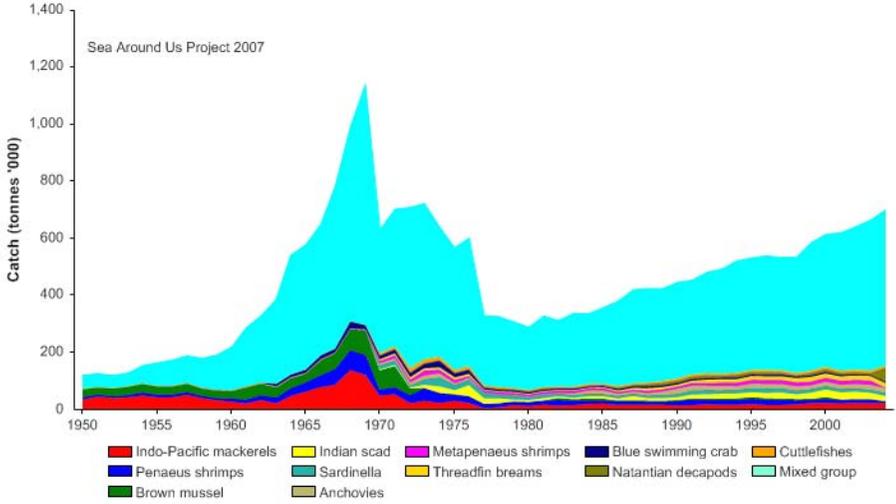


Figure VIII-11.4. Total reported landings in the Gulf of Thailand LME by species (Sea Around Us 2007).

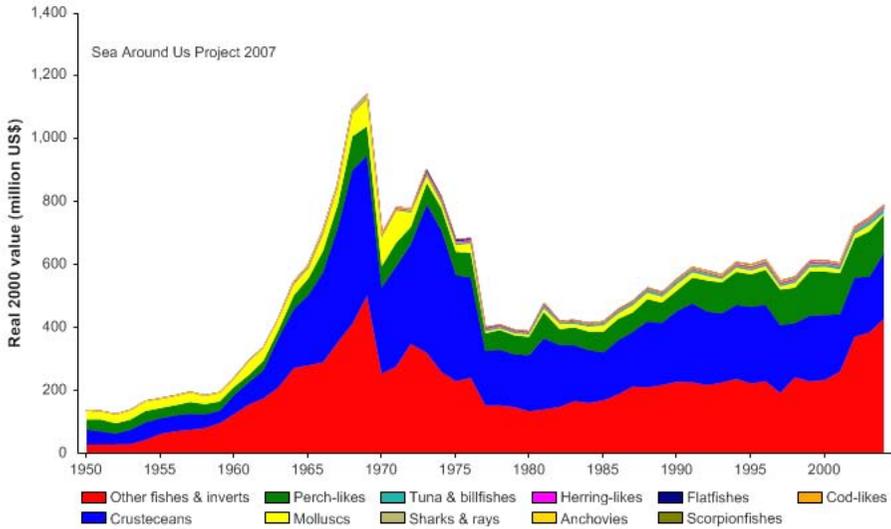


Figure VIII-11.5. Value of reported landings in the Gulf of Thailand LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME peaked in the early 1970s at 30% of the observed primary production, and following a period of low PPR, has reached this level in recent years (Figure VIII-11-6). The countries bordering the LME, namely Thailand, Malaysia and Vietnam, account for most of the ecological footprint in this LME.

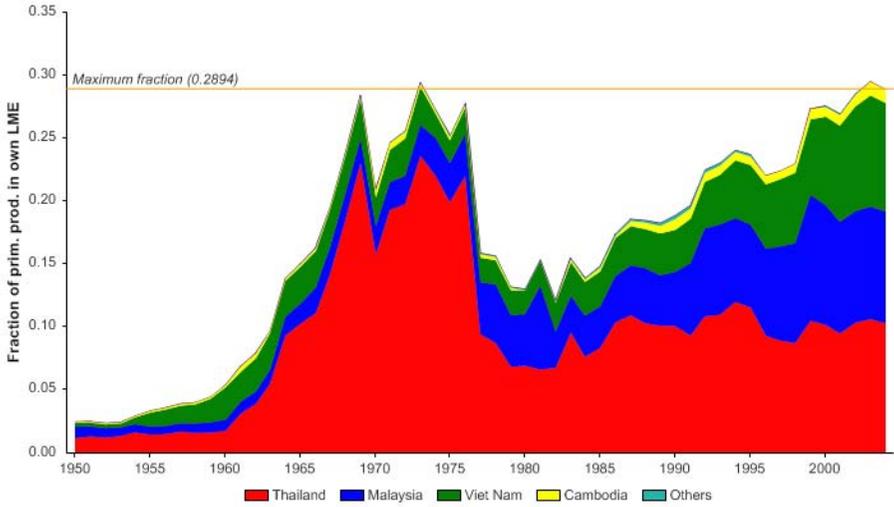


Figure VIII-11.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Gulf of Thailand LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The trends in the mean trophic level (i.e., the MTI; Pauly & Watson 2005) and the FiB are indicative of growing fisheries in the LME (Figure VII-11.7). However, due to the poor taxonomic details in the underlying landings statistics (Figure VII-11.4), it is highly likely that such diagnosis is incorrect.

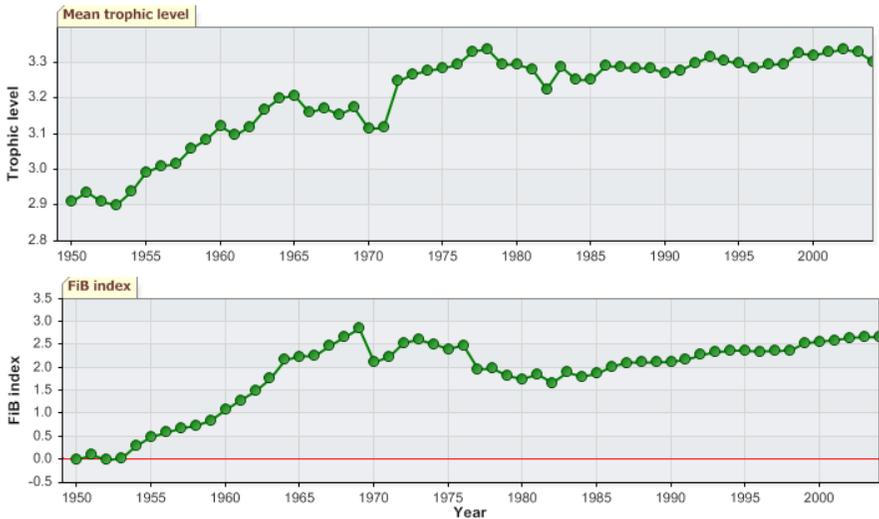


Figure VIII-11.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Gulf of Thailand LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that over 60% of the stocks in the LME are either collapsed or overexploited (Figure VIII-11.8, top), and that they contribute over 60% of the catch (Figure VIII-11.8, bottom). Again, the high degree of taxonomic aggregation in the underlying statistics must be noted in regards to problems in the interpretation of these plots.

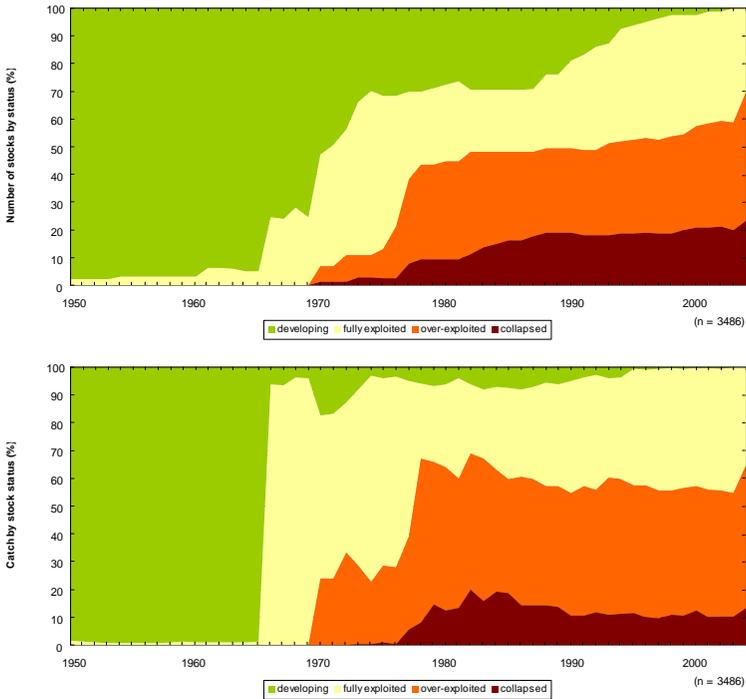


Figure VIII-11.8. Stock-Catch Status Plots for the Gulf of Thailand LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

There is, in spite of uncertainties in the available statistics, much evidence that fishing has impacted the LME at the ecosystem level and has become a primary driving force of biomass change. A 'fishing down' of the food web (Pauly *et al.* 1998) has been documented for the Gulf of Thailand (Christensen 1998, Pauly & Chuenpagdee 2003) and is fundamentally altering ecosystem structure and impacting its productive capacity. Overfishing caused by overcapacity of the local trawl fisheries is well documented (e.g., Pope 1979, Pauly 1979, Christensen 1998, Piyakarnchana 1999, Pauly & Chuenpagdee 2003, Silvestre *et al.* 2003, Chuenpagdee & Pauly 2004) and the South China Sea TDA, which includes the Gulf of Thailand LME, has identified loss in fisheries productivity as a major transboundary issue in this region (Talaue-McManus 2000). As a consequence of high fishing effort by non-selective trawl gear, its demersal catch composition has changed towards smaller individuals and a mix of predominantly small, short-lived species or 'trash fish' (Pauly & Chuenpagdee 2003). There is also a rapid decrease in the catch per unit effort, from over 300 kg per hour in the early 1960s to 50 kg per hour in the 1980s, and a further decline to 20-30 kg per hour in the 1990s (Eiamsa-Ard & Amornchairojkul 1997).

In addition to overexploitation, destructive fishing was found to be severe in the region (UNEP 2005) and the use of small meshes in trawl nets has contributed to overexploitation of the local demersal fish stocks (Christensen 1998). Impacts from

fishing with explosives and poisons are also severe, particularly on coral reefs (Bryant *et al.* 1998, Talaue-McManus 2000, (UNEP SCS 2008) and other types of fishing gear, such as push nets and mackerel purse seines, have contributed further to the unsustainable condition of the local fisheries (Pauly & Chuenpagdee 2003). Excessive bycatch is also a severe problem (UNEP 2005). Small mesh sizes and minimal use of bycatch-exclusion devices have resulted in massive overexploitation of fisheries resources as bycatch. Yet, discarding is insignificant, as virtually all of the bycatch is utilised, with smaller 'trash' fish taken in trawls being used as aquaculture feed. There is widespread capture, either intentional or accidental, of rare, threatened and endangered species such as turtles and dugong, by artisanal and commercial fisheries. In 2003 an international training course on the use of turtle excluder devices (TEDs) and juvenile and trash excluder devices (JTEDs) was conducted by the Southeast Asian Fisheries Development Center in cooperation with FAO and GEF to train participants in how to minimize bycatch in the fisheries of Southeast Asia, particularly in the excluding of turtles from shrimp trawling. Substantial, though unquantified, levels of bycatch are also produced by distant waters fleets, through use of blast fishing and poison, and in the shrimp fry fisheries, where juvenile fishes are often discarded (UNEP SCS 2008).

Fish stocks in the inner Gulf have been affected by rapid environmental deterioration, including eutrophication, HABS and oxygen depletion (Eiamsa-Ard & Amornchairojkul 1997, Piyakarnchana 1999). The relative effects of environmental deterioration and overexploitation on the region's fisheries resources need to be further explored but, at the same time, there is growing recognition that there is an urgent need for Thailand to reduce and manage fishing capacity (Stobutzki *et al.* 2006; Pauly & Chuenpagdee 2003, Ahmed *et al.* 2007).

As with the neighbouring LMEs, the status and future viability of the fisheries are not well-understood, and there are significant gaps in data. In fact, the status of many fisheries may be summarised as Illegal, Unreported and Unregulated (IUU; UNEP 2005). Based on present consumption and population growth patterns, pressure on the fisheries resources is likely to increase significantly in the immediate future and overexploitation is expected to remain severe or get worse if adequate measures are not taken to address this problem (UNEP 2005). A substantial reduction of fishing effort, especially of bottom trawlers, may reduce the fishing pressure on the local stocks and slow further ecological degradation in the region (Pauly & Chuenpagdee 2003; Stobutzki *et al.* 2006; Ahmed *et al.* 2007).

III. Pollution and Ecosystem Health

Pollution: Rapid economic development and population growth in the coastal areas have caused pollution that is severe in localised coastal hotspots (UNEP 2005). Liquid wastes from domestic, agricultural and industrial sources, as well as sediments and solid wastes are the major land-based pollutants affecting the coastal areas (Talaue-McManus 2000, Fortes 2006). Outflow from the Chao Phraya River, is critical to the productivity of the system, especially since it contains nutrients and other substances, including pollution. As a consequence, problems such as eutrophication, sedimentation, and shallowness of the inner Gulf are common. Pollution has potential transboundary impacts due to the possibility of long-shore transport of pollutants as a result of the water circulation pattern on the Sunda Shelf (Talaue-McManus 2000). Water quality is lower than acceptable standards in the inner Gulf region, especially at river mouths, the popular tourist spots along the coast and near certain islands. Many cities have no sewage treatment and discharge raw sewage directly into the coastal areas (UNEP 2005).

Eutrophication is a growing problem, due to the increasing input of nutrients from land-based sources (Piyakarnchana 1999). The increased nutrient loading has caused

phytoplankton blooms in several areas, reducing water clarity as well as dissolved oxygen in bay areas and this pattern is reportedly spreading. There have been frequent occurrences of toxic and non-toxic algal blooms, as well as cases of paralytic shellfish poisoning in parts of the region (Talaue-McManus 2000).

High levels of suspended solids have severe impacts in coastal waters throughout most of the region (UNEP 2005). Major changes in turbidity and levels of suspended sediments have resulted from activities such as extensive deforestation, logging, land reclamation, dredging and urban development. Pollution from solid wastes is also severe in localised areas, particularly around many towns and villages where waste management is poor or non-existent.

The use of agricultural pesticides and industrial effluents creates a significant problem in some areas such as near river mouths and industrial discharges (UNEP 2005). Releases of chemical and other forms of pollution from shipping in harbours also commonly occurs since regulations and controls relating to ship-derived pollution are rarely enforced. Pollution by petroleum hydrocarbons and the occurrence of oil spills have been reported in the Gulf (Piyakarnchana 1999).

Habitat and community modification: Habitat and community modification was assessed as severe (UNEP 2005), with land use and land cover changes being the major contributors (Piyakarnchana 1999). The causes of mangrove destruction along the coastlines bordering the South China Sea, including the Gulf of Thailand LME, include conversion to aquaculture ponds, particularly of shrimp, clear felling of timber for woodchip and pulp production, land clearance for urban and port development and human settlements and harvest of timber products for domestic use (UNEP 2004a). However, as noted by Talaue-McManus (2000) and UNEP (2004a), shrimp culture appears to be the most pervasive economic imperative for mangrove conversion in the region. In 1961, mangrove forests surrounding the LME covered 367,000 ha, but by 1991 this was reduced to 173,600 ha, with at least three out of 24 provinces having lost all their mangrove forests (Piyakarnchana 1999). The clearing of these forests has led to a deterioration of the coastal zone (Piyakarnchana 1999). From a global perspective, the major transboundary issues surrounding the loss of mangrove habitats include the loss of unique biological diversity and the loss of mangrove services (UNEP 2004a).

Over the past 15 years, progressive degradation of coral reefs in several locations of the South China Sea (including the Gulf of Thailand LME) has been noted, with reefs located near large human population centres having suffered the most serious degradation (UNEP 2004b). Rapid population growth, coastal development, land-based pollution, tourism, overfishing and destructive fishing practices all contribute to this decline (Sudara & Yeemin 1997, Talaue-McManus 2000, UNEP 2004b). Heavy sedimentation resulting from various anthropogenic disturbances in the coastal areas and poor land use practices in the watersheds has also impacted the region's reefs (Sudara *et al.* 1991). In addition, global warming of the sea surface has caused considerable and widespread damage to the LME's reefs after the severe 1998 bleaching event (UNEP 2004b). A comprehensive reef survey programme covering 251 sites in the Gulf of Thailand showed 16.4% of the reefs to be in excellent condition, 29% good, 30.8% fair and 23.8% poor (Chou *et al.* 2002).

Seagrass beds are subjected to a number of threats from various sources, the root cause being associated with coastal human populations (UNEP 2004c). High sediment loads associated with deforestation (including of mangroves), dredging and land reclamation; fluctuation in freshwater input due to irrigation and land clearing; increased pollution; coastal development; and destructive fishing methods are among the causes of degradation of the region's seagrass habitats (UNEP 2004c). There is evidence of

widespread modification of seagrass habitats throughout the region. For example, between 20% to 50% of seagrass beds in Malaysia and Thailand have been damaged (Talaue-McManus 2000) and Vietnam has lost an estimated 40% to 50% over the past two decades (UNEP 2004c).

Ecosystem health may deteriorate further as a consequence of expected future increases in pollution and habitat modification (UNEP 2005). Despite increasing measures for pollution mitigation and control (e.g., sewage treatment), 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. Some positive steps are being taken to address habitat modification, including mangrove rehabilitation programmes, watershed protection and establishment of marine protected areas. Both the direction of change and the rates of environmental deterioration or improvement, however, will depend on the success of ongoing and planned interventions.

IV. Socioeconomic Conditions

The population in the Gulf of Thailand LME region is 112 million (Talaue-McManus 2000; UNEP 2005). For the larger South China Sea region, some 270 million people (5% of the world's population) inhabit coastal areas and this population is expected to double in the next three decades. The LME and its resources have provided important benefits to the region's coastal communities, with fisheries, mariculture and tourism being key economic activities in the bordering countries. Marine fisheries, in particular, play a significant socioeconomic role. Subsistence fishing is the major activity of large numbers of people outside of the main urban and industrial centres. Fisheries are an important source of food, employment and foreign exchange. Despite nutritional requirements and current population growth rates, South China Sea countries in general are net exporters of fishery products (Talaue-McManus 2000). Fishing contributes about 2% to the GDP of Thailand, which is a major world exporter of fishery commodities and among the leading exporters of farmed shrimp (FAO 2005).

The socioeconomic impacts of overexploitation of fisheries and environmental deterioration are significant (UNEP 2005). There have been reduced economic returns and loss of employment from the collapse of fisheries in the region. Higher investment is now required per unit of commercial catch, reducing the profitability of fishing enterprises. The degradation of mangrove forests, seagrass and coral reefs, critical for fish spawning, feeding and recruitment, has also contributed to declining fish catch, especially in near-shore areas. This has had a marked negative impact on the livelihoods of poor artisanal fishing communities. Competition for fisheries resources among fishers has also been increasing.

The socioeconomic impacts of pollution include economic losses in mariculture and the shellfish industry as a result of high levels of toxicity and HABs and risk to human health. Other socioeconomic impacts of pollution are associated with the costs of clean-up and coastal restoration. Land-use conflicts have also arisen. The socioeconomic impacts of habitat and community modification range from slight to severe (UNEP 2005), primarily because of reduced capacity of local populations to meet basic human needs and loss of employment. Other impacts include loss or reduction of existing and future income and foreign exchange from fisheries and tourism 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).

V. Governance

Governance of the LME is shared by the four bordering countries. A range of measures and programmes has been established to arrest and reverse overexploitation as well as environmental degradation in the LME. Following on its adoption of the FAO Code of Conduct for Responsible Fisheries, the Thai Department of Fisheries issued licensing regulations to control the number of trawlers and push nets. The number of registered trawlers has gradually decreased from about 10,500 units in 1980 to 8,000 units in early 2000 (DoF 2002). The Ministry of Agriculture and Cooperatives in Thailand governs the Department of Fisheries. The Ministry of Natural Resources and Environment governs coastal resources and the environment. The countries have made a commitment to devolve authority for natural resources management from state to community and from central to more local levels of government (Ratner *et al.* 2004). For instance, in Thailand the 1999 Decentralization Act has placed a range of decision-making powers with sub-district government units (Tambon Administrative Organisations).

The Gulf of Thailand LME comes under the UNEP-administered East Asian Regional Seas Programme. The Action Plan for the Protection and Development of the Marine and Coastal Areas of the East Asian Region was approved in 1981, and currently involves 10 countries. There is no regional convention. Instead, the programme promotes compliance with existing environmental treaties and is based on member country goodwill. The Action Plan is steered from Bangkok by its coordinating body, COBSEA. The East Asian Seas Regional Coordinating Unit serves as the secretariat and is responsible for coordinating the activities of governments, NGOs, UN and donor agencies and individuals in caring for the region's marine environment. Other regional action plans include the ASEAN Strategic Plan of Action on the Environment, ASEAN Cooperation on Transboundary Pollution and Regional Action Programme for Environmentally Sound and Sustainable Development. Regional research programmes include the International Cooperative Study of the Gulf of Thailand for the sustainable management of the Gulf, sponsored by the UNESCO Intergovernmental Oceanographic Commission-Sub Commission for the Western Pacific (IOC-WESTPAC), the Southeast Asian Programme in Ocean Law, Policy and Management and the Southeast Asia START Global Change Regional Centre.

The Council of Directors of the Southeast Asian Fisheries Development Centre approved a programme for the 'regionalisation' of the FAO Code of Conduct in 1998. It has also produced three volumes of Regional Guidelines for Responsible Fisheries in Southeast Asia — Responsible Fishing Operations, Responsible Aquaculture and Responsible Fisheries Management (SEAFDEC 2003). The Asia-Pacific Fishery Commission is assisting its member countries to achieve accelerated fisheries development and management.

To help address the problems in the coastal fisheries of Asia, the WorldFish Centre joined forces with fisheries agencies from Bangladesh, India, Indonesia, Malaysia, The Philippines, Sri Lanka, Thailand and Vietnam and the Asian Development Bank, to implement the project 'Sustainable Management of Coastal Fish Stocks in Asia' (TrawlBase project) between 1998 and 2001 (Silvestre *et al.* 2003). Among the main achievements of this partnership was the development of a database called 'Fisheries Resource Information System and Tools' (FiRST), which contains trawl research survey data and socioeconomic information for selected fisheries, and facilitates its analysis. The project has also strengthened national capacity in coastal fisheries assessment, planning and management, and illustrated the benefits of collaborative efforts in addressing issues of regional concern.

GEF is currently supporting three projects involving this LME. The project 'Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand' aims to foster and encourage regional collaboration and partnership in addressing transboundary environmental problems between all stakeholders and at all levels. The project also seeks to enhance the capacity of the participating governments to integrate environmental considerations into national development planning. A comprehensive TDA for the South China Sea, which includes the Gulf of Thailand LME, has been produced under this project.

The project 'Building Partnerships for the Environmental Protection and Management of the Seas of East Asia' (PEMSEA) aims to enable the East Asian Seas Region to collectively protect and manage its coastal and marine environment through inter-governmental and inter-sectoral partnerships (www.pemsea.org). Through partnership building, the project will help countries to develop scientifically-based environmental management strategies and action plans in order to deal with land-based pollution, promote closer regional and sub-regional collaboration in combating environmental disasters arising from maritime accidents as well as increase regional commitments in implementing international conventions that they ratify. The project 'East Asian Seas Region: Development and Implementation of Public-Private Partnerships in Environmental Investments' aims to build confidence and capabilities in public-private sector partnerships as a viable means of financing and sustaining environmental facilities and services for the protection and sustainable use of the marine and coastal resources of the East Asian Seas region.

References

- Ahmed, M., Boonchuwongse, P., Dechboon, W. and Squires, D. (2007) Overfishing in the Gulf of Thailand: Policy challenges and bioeconomic analysis. *Environment and Development Economics* 12 (1): 145-172.
- 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 of the world's oceans: An atlas. *Progress in Oceanography*, in press.
- Bryant, D., Burke, L., McManus, J. and Spalding, M. (1998). Reefs at Risk. A Map-based Indicator of Threats to the World's Coral Reefs. WRI/ICLARM/WCMC/UNEP, Washington D.C., U.S.
- Chou, L.M., Wilkinson, C., Gomez, E. and Suraphol, S. (2002). Status of Coral Reefs in the ASEAN Region, p 8-17 in: Wilkinson, C.R. (ed), *Living Coastal Resources of Southeast Asia: Status and Management*. Report of the Consultative Forum 3rd Association of Southeast Asian Nations-Australia Symposium on Living Coastal Resources. Chulalongkorn University Bangkok, Thailand. Australian Institute of Marine Science, Townsville, Australia.
- Christensen, V. (1998). Fishery induced changes in a marine ecosystem: insight from models of the Gulf of Thailand. *Journal of Fish Biology* 53 (Suppl. A):128-142.
- Chuenpagdee, R. and Pauly, D. (2004). The Gulf of Thailand trawl fisheries, p 203-220 in: Swan, J. and Gréboval, D. (comps), *Report and Documentation of the International Workshop on the Implementation of International Fisheries Instruments and Factors of Unsustainability and Overexploitation in Fisheries*, Mauritius, 3-7 February 2003. FAO Fisheries Report 700. FAO, Rome.
- DoF (2002). *Thai Fishing Vessels Statistics 2000*. Department of Fisheries, Ministry of Agriculture and Cooperatives. Bangkok, Thailand. Document 16/2002.
- Eiamsa-Ard, M. and Amornchairojkul, S. (1997). The marine fisheries of Thailand, with emphasis on the Gulf of Thailand trawl fishery, p 85-95 in: Silvestre, G. and Pauly, D. (eds), *Status and Management of Tropical Coastal Fisheries in Asia*. International Centre for Living Aquatic Resources Management Conference Proceedings 53.

- FAO (2005). Fishery Country Profiles. www.fao.org/fi/fcp/fcp.asp
- Fortes, M. (2006). Seas of East Asia, p 177 -192 in: UNEP/GPA (2006), The State of the Marine Environment: Regional Assessments. UNEP/GPA, The Hague.
- Longhurst, A.R. (1998). Ecological Geography of the Sea. Academic Press, California, U.S.
- Pauly, D, Christensen, V., Dalsgaard, J., Froese, R. and Torres, F. Jr. (1998). Fishing down marine food webs. *Science* 279:860-863.
- Pauly, D. (1979). Theory and management of tropical multispecies stocks: a review, with emphasis on the southeast Asian demersal fisheries. *ICLARM Studies and Reviews* 1, 35 p.
- Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. *Nature* 374: 255-257.
- Pauly, D. and Chuenpagdee, R. (2003). Development of Fisheries in the Gulf of Thailand Large Marine Ecosystem: Analysis of an Unplanned Experiment, p 337-354 in: Hempel, G. and Sherman, K. (eds), Large Marine Ecosystems of the World: Trends in Exploitation, Protection and Research. Elsevier, The Netherlands.
- 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.
- Piyakarnachana, T. (1989). Yield Dynamics as an Index of Biomass Shifts in the Gulf of Thailand, p 95-142 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Symposium 111, Westview Press, Inc., Boulder, U.S.
- Piyakarnchana, T. (1999). Changing State and Health of the Gulf of Thailand Large Marine Ecosystem, p 240-250 in: Sherman, K. and Tang, Q. (eds), Large Marine Ecosystems of the Pacific Rim – Assessment, Sustainability and Management. Blackwell Science, Malden, U.S.
- Pope, J.A. (1979). Stock Assessment in Multispecies Fisheries. South China Sea Fisheries, with Special Reference to the Trawl Fishery in the Gulf of Thailand. South China Sea Development and Coordinating Programme. SCS/DEV/79/19. Manila, Philippines.
- Ratner, B.D., Thanh-ha, D., Kosal, M., Nissapa, A. and Chanphengxay, S. (2004). Undervalued and Overlooked: Sustaining Rural Livelihoods through Better Governance of Wetlands. *WorldFish Center Studies and Reviews* 28.
- Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/SummaryInfo.aspx?LME=35
- SEAFDEC (2003). Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Fisheries Management. Southeast Asian Fisheries Development Centre. MFRDMD/SP/3.
- Sherman, K. (2003). Physical, Biological and Human Forcing of Biomass Yields in Large Marine Ecosystems. *ICES CM* 2003/P: 12.
- Silvestre, G.T., Garces, L.R., Stobutzki, I., Ahmed, M., Santos, R.A.V., Luna, C.Z. and Zhou, W. (2003). South and South-East Asian coastal fisheries: Their status and directions for improved management. Conference synopsis and recommendations, p 1- 40 in: Silvestre, G., Garces, L., Stobutzki, I., Ahmed, M., Santos, R.A.V., Luna, C., Lachica-Aliño, L., Christensen, V., Pauly, D. and Munro, P. (eds), Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67.
- Stobutzki, I.C., Silvestre, G.T., Talib, A. Abu, Krongprom, A., Supongpan, M., Khemakorn, P., Armada, N., Garces, L.R. (2006). *Fisheries Research* 78:130-142.
- Sudara, S. and Yeemin, T. (1997). Status of Coral Reefs in Thailand, p 135-144 in: Grigg, R.W. and Birkeland, C. (eds), Status of Coral Reefs in the Pacific. Sea Grant College Program, School of Ocean and Earth Science and Technology, University of Hawaii, U.S.
- Sudara, S., Sanitwongs, A., Yeemin, T., Moordee, R., Panutrakune, S., Suthanaluk, P. and Natekanjanalarp, S. (1991). Study of the Impact of Sediment on Growth of the Coral *Porites lutea* in the Gulf of Thailand, p 107-112 in: Alcalá, A.C. (ed), Proceedings of the Regional Symposium on Living Resources in Coastal Areas. Marine Science Institute, University of the Philippines.
- Talaue-McManus, L. (2000). Transboundary Diagnostic Analysis for the South China Sea. East Asian Seas Regional Coordination Unit Technical Report Series 14, United Nations Environment Programme, Bangkok, Thailand.
- UNEP (2004a). Mangroves in the South China Sea. UNEP/GEF/SCS Technical Publication 1.
- UNEP (2004b). Coral Reefs in the South China Sea. UNEP/GEF/SCS Technical Publication 2.
- UNEP (2004c). Seagrass in the South China Sea. UNEP/GEF/SCS Technical Publication 3.
- UNEP (2005). Wilkinson, C., DeVantier, L., Talaue-McManus, L., Lawrence, D. and Souter D. South China Sea, GIWA Regional Assessment 54. University of Kalmar, Kalmar, Sweden. www.giwa.net/publications/r54.phtml

- UNEP SCS (2008) Establishing a regional system of fisheries refugia in the Gulf of Thailand and South China Sea. Report available online at:http://refugia.unepscs.org/Fisheries_Refugia_Information/About_Fisheries_Refugia/About_Fisheries_Refugia.html
- Wyrski, K. (1961). Dynamics of the Demersal Fish Resources in the Sunda Shelf Area of the South China Sea. Ph.D. Dissertation, University of Washington, Seattle, U.S.
- Yanagi T., Sachoemar, S.I., Takao, T. and Fujiwara S. (2001) Seasonal variation of stratification in the Gulf of Thailand, *Journal of Oceanography*, **57**(4), 461-470.
- Yeemin, T. (2004) Status of coral reefs in the Gulf of Thailand and the Andaman Sea, poster presented at the 10th ICRS, Okinawa, Japan, 28 June - 2 July 2004.