VIII-16 Sulu-Celebes Sea: LME #37

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The Sulu-Celebes Sea LME is comprised of the Sulu and Celebes Seas, which are separated from each other by a deep trough and a chain of islands known as the Sulu Archipelago. The LME is bounded by northern Borneo (Malaysia), the southwest coast of the Philippines and Sulawesi Island (northern coast of Indonesia), but most of the LME falls within the archipelagic waters of either the Philippines or Indonesia. The LME covers an area of about one million km^2, of which 1.03% is protected, and contains 6.17% and 0.22% of the world's coral reefs and sea mounts, respectively (Sea Around Us 2007). A complex oceanography results from the Celebes' strong currents, deep sea trenches, seamounts and active volcanic islands. The LME's tropical climate is governed by the monsoon regime. During the southwest monsoon months, the northern and central parts of the region are affected by typhoons, which bring intense rains and destructive winds to coastal areas. There are more than 300 major watersheds and 14 major estuaries in the region. A report pertaining to this LME is UNEP (2005).

I. Productivity

The Sulu-Celebes Sea LME is considered a Class II, moderate productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$). The tropical climate, warm waters, ocean currents and upwellings make this LME one of the world's most biologically diverse marine environments. Located near the confluence of three major biogeographic zones and within the Indo-West Pacific centre of biodiversity, the region supports mega-diversity (Roberts *et al*. 2002, Cheung *et al*. 2002). A significant proportion of the total coral reef area of the Philippines (about 20,000 km^2) is located in this LME. This forms a part of the 'coral triangle', which has the highest coral diversity together with Indonesia and New Guinea (more than 500 reef-building species). In addition, 2,500 species of marine fishes, 400 species of algae, five species of sea turtles and 22 species of marine mammals are found in the LME (Chou 1997, Jacinto *et al*. 2000, Veron 2000).

Oceanic fronts (Belkin et al. 2009; Belkin and Cornillon, 2003): This semi-enclosed sea is connected to other seas of the Indonesian Archipelago via several straits. Flow constrictions within these straits are conducive to front formation (Figure VIII-16.1). The uniformly high surface temperature tends to mask salinity fronts caused by coastal upwelling, whose intensity sharply increases locally owing to orographic and bathymetric effects. Evaporative cooling also contributes to front formation since this process creates a colder and saltier water mass, which is substantially denser than ambient waters. Tidal currents and tidal mixing also play a significant role in front formation, especially off numerous coastal headlands and near straits. The most robust fronts are located in the eastern Celebes Sea.

Sulu-Celebes Sea SST (Belkin, 2009):
Linear SST trend since 1957: 0.62°C.
Linear SST trend since 1982: 0.23°C.

The steady warming of the Sulu-Celebes Sea was accentuated by two warm events, in 1988 and 1998, the latter being of the global scale (El Niño 1997-98). In many locales across this sea, the SST anomaly in 1998 exceeded 2°C; the extreme thermal stress has resulted in widespread restructuring of coral reef communities and numerous coral bleaching events (Vantier et al., 2005, p. 48, Figure 16; Goreau et al., 1997). The warm

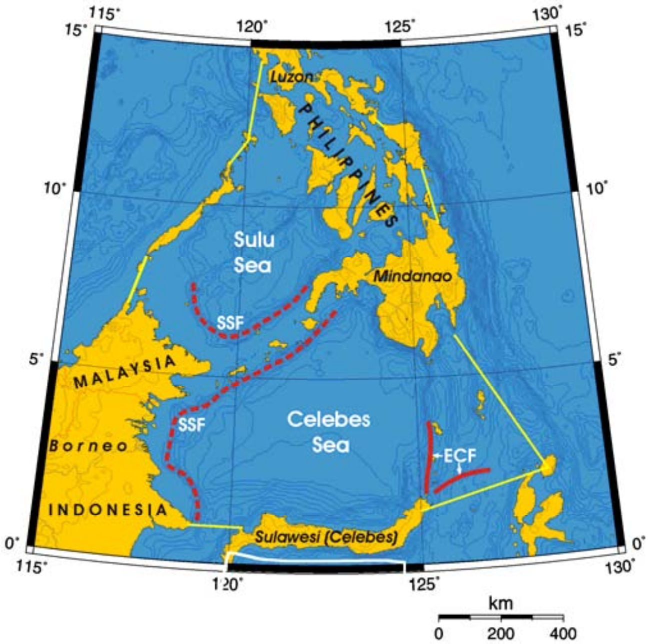

Figure VIII-16.1. Fronts of the Sulu-Celebes Seas LME. ECF, East Celebes fronts; SSF, Shelf-Slope Front (most probable location); Yellow line, LME boundary. After Belkin et al. (2009) and Belkin and Cornillon (2003).

event of 1988 occurred simultaneously in the Indonesian Sea LME, North Australian Shelf LME, West-Central Australian Shelf LME, and Northwest Australian Shelf LME; and only one year prior to the warm event of 1989 in the Southeast Australian Shelf LME. Apparently, the warm event of 1988 was caused by large-scale forcing. The all-time minimum of 1967 occurred simultaneously in the Indonesian Sea LME and, one year prior to the all-time minimum of 1968, in the West-Central Australian Shelf LME. The strong correlation between the Sulu-Celebes Sea's thermal history and adjacent seas could alternatively be explained by oceanic circulation, particularly, the Indonesian Throughflow that flows through this LME (NOAA Ocean Explorer, 2007).

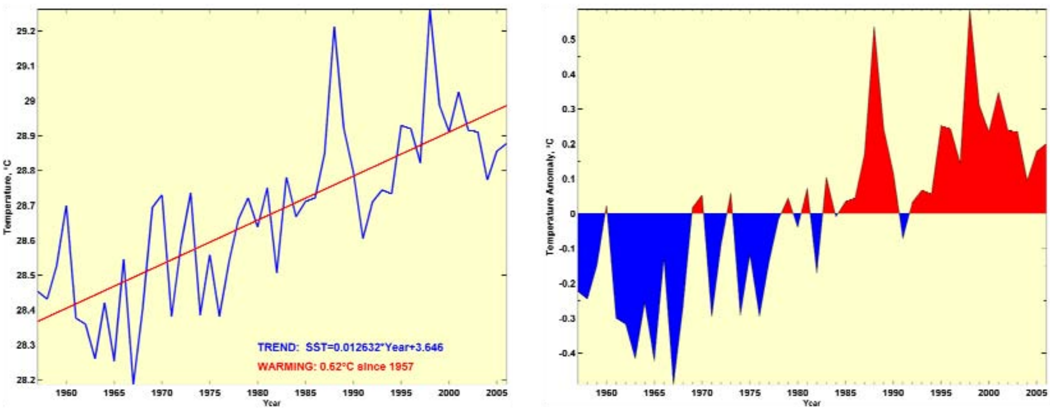

Figure VIII-16.2. Sulu-Celebes LME mean annual SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009) .

Sulu-Celebes Chlorophyll and Primary Productivity: The Sulu-Celebes Sea LME is considered a Class II, moderate productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$).

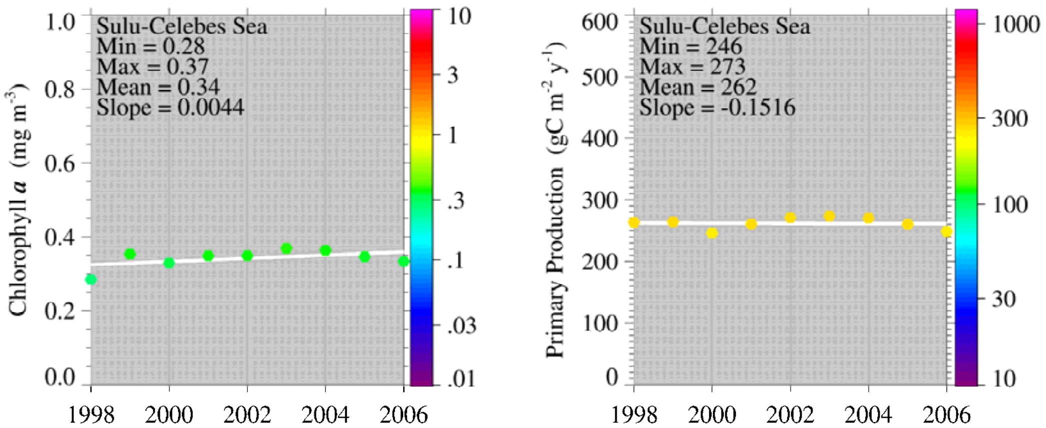

Figure VIII-16.3. Sulu-Celebes Sea: Trends in chlorophyll-*a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II Fish and Fisheries

The fisheries of the Sulu-Celebes Sea LME are multi-gear and multi-species. Reef fisheries provide essential sustenance to artisanal fishers and their families throughout the region while high value fish products are exported to expanding international, national and local markets. Live food and aquarium reef fish exports to Hong Kong and the Chinese mainland have burgeoned since the 1990s (Cesar *et al*. 2000). Aquaculture of prawns, oysters, mussels, fish, seaweeds and other species is an important industry in the three bordering countries (FAO 2000, BFAR 2004). The fisheries of the southwest coast of the Philippines are well-documented, relative to the fisheries from the other parts of this LME (see e.g., Ingles & Pauly 1984, Aprieto *et al.* 1986, Trinidad *et al.* 1993, DA-BFAR 2004). Total reported landings in the LME have increased steadily to one million tonnes in 2004 (Figure VIII-16.4), though a significant proportion of the landings is reported simply as unidentified fishes in the available statistics (included in 'mixed group' in Figure VIII-16.4).

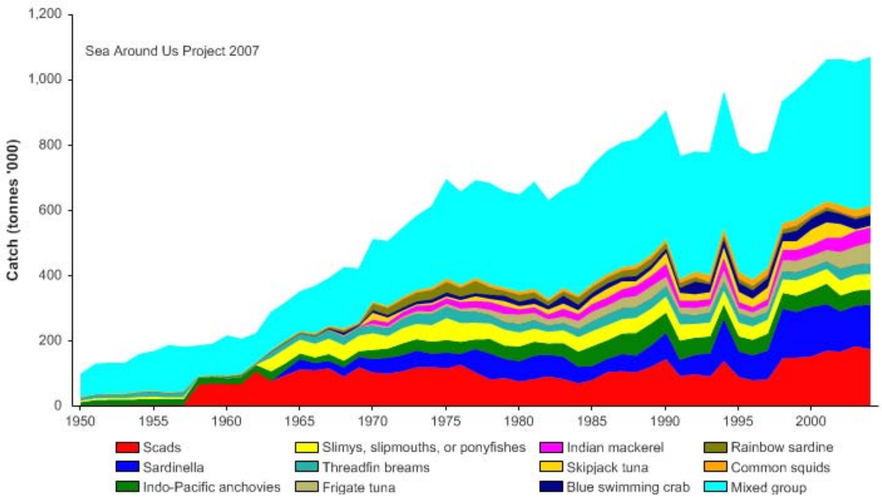

Figure VIII-16.4. Total reported landings in the Sulu-Celebes Sea LME by species (Sea Around Us 2007).

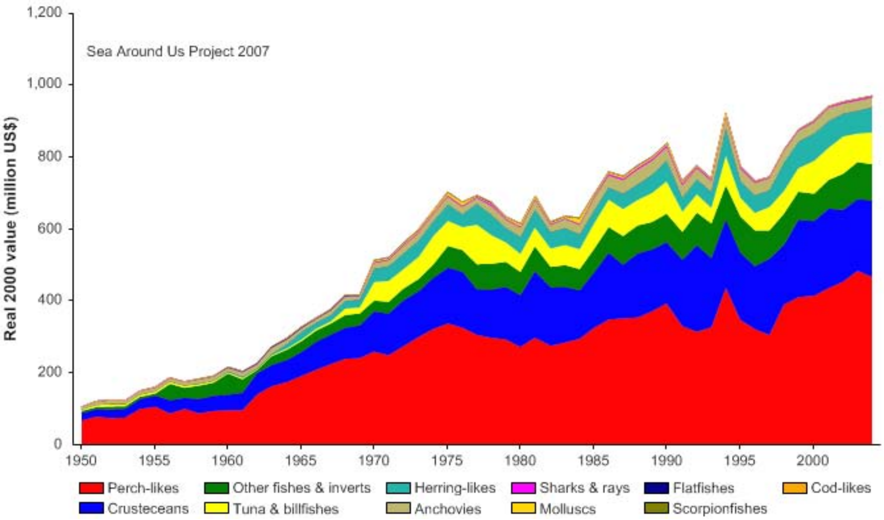

Figure VIII-16.5. Value of reported landings in the Sulu-Celebes Sea LME by commercial groups (Sea Around Us 2007).

The value of the reported landings has also increased, exceeding US$900 million (in 2000 real US dollars) in recent years (Figure VIII-16.5).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is increasing, and has reached 40% of the observed primary productivity in recent years (Figure VIII-16.6), a very high level that is possibly skewed by the large proportion of unidentified fishes in the reported landings. The Philippines account for the largest share of the ecological footprint in the LME.

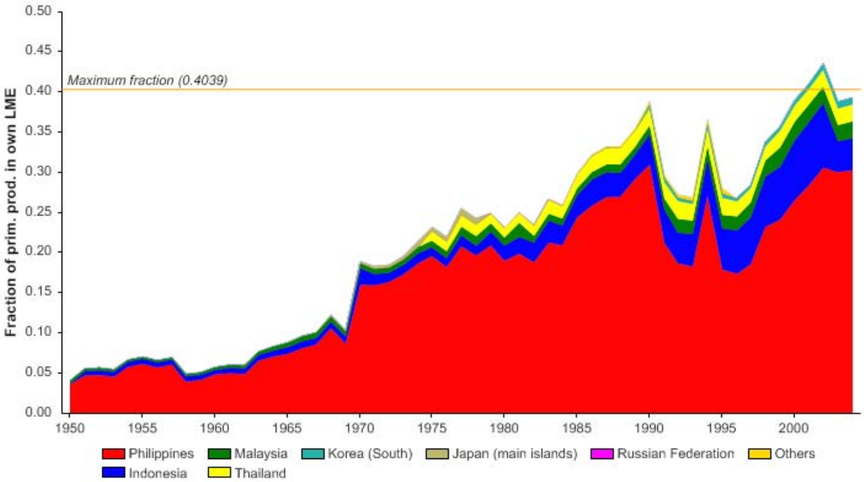

Figure VIII-16.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Sulu-Celebes Sea LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The trend in the mean trophic level (i.e., the MTI; Pauly & Watson 2005) and the FiB is not conclusive, likely due to the poor quality of the underlying landings statistics (Figure VIII-16.7). However, a decline in the MTI can be seen from 1950 to 1974, a period in which the proportion of unidentified fish in the landings statistics was relatively small, an indication that a 'fishing down' of the food web (Pauly *et al.* 1998) is perhaps occurring in the LME, only to be drowned out by the high level of taxonomically aggregated catches in recent years.

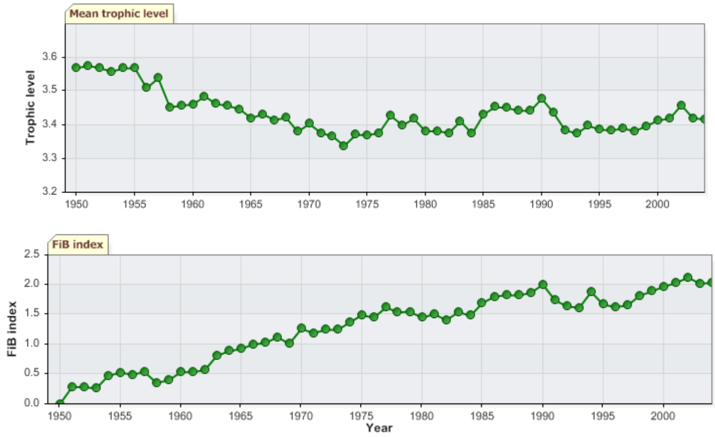

Figure VIII-16.7. Marine Trophic Index (top) and Fishing in Balance Index (bottom) in the Sulu-Celebes Sea LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that about half of the stocks in the LME have collapsed or are currently overexploited (Figure VIII-16.8, top), and that the reported landings are largely supplied by fully exploited stocks (Figure VIII-16.8, bottom). Such diagnosis is probably a result of the high degree of taxonomical aggregation in the underlying statistics.

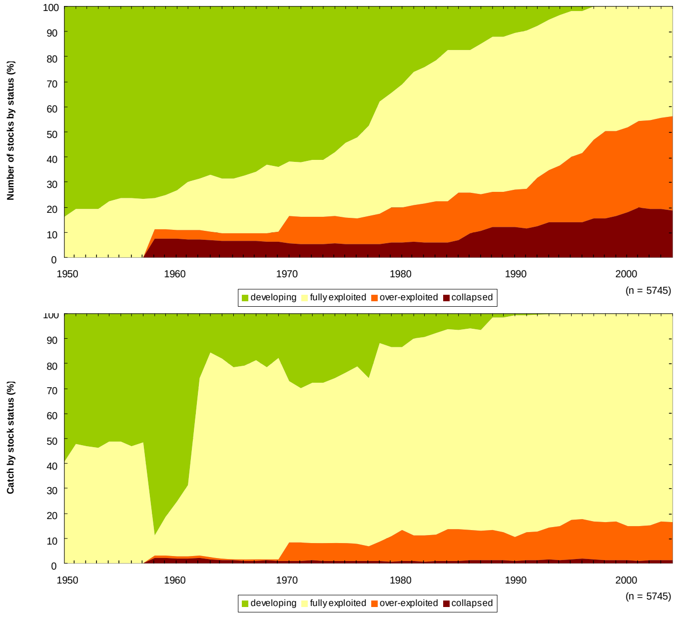

Figure VIII-16.8. Stock-Catch Status Plots for the Sulu-Celebes Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

Beyond the archipelagic waters of the Philippines, neither the status nor the future viability of the fisheries in the Sulu-Celebes Sea LME is understood. Great uncertainty exists because of serious discrepancies in fisheries data, which may also be missing a significant quantity of Illegal, Unreported and Unregulated (IUU) catches, possibly as high as 50% of the total catch (Kahn & Fauzi 2001). Unreported catches are high, as has been shown for Northern Sabah (Teh *et al.* 2007). The LME is an attractive fishing ground for illegal fishers, including commercial fishers from throughout Southeast Asia and beyond. Consequently, accurate data on the extent, number of vessels and their mode of operations are rare, despite the likelihood that such illegal activities may have significant environmental and socioeconomic impacts.

Excessive fishing effort and destructive fishing have led to severe overexploitation of fisheries and considerable threat to coral reefs in this LME, with declining catches, particularly in coastal areas (FAO 2000). Statistics from the Philippines (BFAR 1997, DA-BFAR 2004) and Indonesia suggest that, despite increasing catch of some species, CPUE has declined steadily. Over the past few decades, many of the fringing coral reefs have been depleted, with a major loss of productivity and adverse effects to other components of the ecosystem (Licuanan & Gomez 2000). About 70% of the coral reefs in the Philippines are heavily exploited, producing less than five tonnes per km^2 per year, while the remaining 30% produces between 15-20 tonnes per km^2 per year (Licuanan & Gomez 2000). Overfishing has also led to severe depletion of market-sized fishes as well as reduction in population sizes and in some cases, local extinction. This also includes large piscivorous species such as groupers, barracudas, jacks and sharks (Werner & Allen 2000). Bycatch is produced by distant-waters fleets as well as through the use of blast fishing and poisons. Rare and endangered species of turtles as well as marine mammals are also caught incidentally. There are little or no discards in the region’s inshore fisheries, however, since virtually all of the bycatch is utilised by local fishers.

Destructive fishing practices (e.g., dynamite and cyanide fishing on reefs) have severe impacts in coastal areas (Pilcher & Cabanban 2000). Live coral reef fish trade is of particular concern. Use of fish poisons to catch aquarium and food fishes is a rapidly growing problem in many Pacific nations, but is most serious in the Philippines and Indonesia (Johannes & Riepen 1995) with about 85% of the aquarium fish traded caught using cyanide, targeting 379 species from a few families (e.g., Labridae, Pomacentridae, Chaetodontidae, Pomacanthidae and Scaridae) (Pratt *et al*. 2000). The live food fish trade primarily targets groupers (especially *Epinephelus* spp. and *Plectropomus leopardus*) and Napolean wrasse (*Cheilinus undulates*). Because of their particular life-history attributes, groupers are easily overexploited and targeting of their spawning aggregations is of a serious concern (Licuanan & Gomez 2000). In addition to taking adult groupers for direct food consumption, the live reef fish food trade also involves the capture of wild fry and fingerlings supplying the grouper mariculture industry in Southeast Asia, predominantly in Taiwan and Thailand (Sadovy & Pet 1998).

Because of Indonesia’s increasing coastal population, greater commercialisation, continued use of destructive fishing practices and lack of effective regulation and enforcement, depletion of fisheries resources is expected to continue in the LME. However, such a grim outlook on the future of fisheries in the LME may be ameliorated to some degree by improved enforcement of national regulations (e.g., Philippines Fisheries Code) and through successful interventions by government and NGOs.

II. Pollution and Ecosystem Health

Pollution: Rapid industrialisation and economic growth have taken a heavy toll on the environment of the seas of East Asia. Most of the pollutants entering the marine environment come from land-based sources, and have changed virtually every dimension of the coastal and marine environments (Fortes 2006). Pollution in the Sulu-Celebes Sea LME is of particular concern around the major urban centres (UNEP 2005). Major sources of pollution include sewage, industries, agriculture, aquaculture and shipping. Throughout the region, sewage treatment is rudimentary, with raw or primary treated sewage discharged directly into water courses. Microbial pollution is of local significance near to the major urban centres. Eutrophication is most significant in enclosed bays, harbours and lagoons with limited water circulation, particularly where sewage or industrial discharges are present. Pollution is a locally significant problem in areas such as Batangas Bay (heavy metals), urban areas of Mindanao, the Visayan Islands and other industrial and urban areas, with contaminant loads concentrated near discharge points. While pollution from agricultural run-off is not a major problem at the scale of the LME, localised agricultural pollution is widespread. Releases of chemical and, to a lesser extent, microbiological pollution from shipping in harbours, are also common. The Makassar Strait and Celebes Sea LME is a major oil tanker route between Japan and the greater Pacific Ocean, the Indian Ocean, West Asia and Europe, with associated risks of collisions and spills (MPP-EAS 1998).

Suspended solids pose a severe problem in the coastal waters of the Philippines, as a result of extensive deforestation in the region's watersheds (e.g., Hodgson & Dickson 1992, Chia & Kirkman 2000, Burke *et al*. 2002). This is compounded by erosion and siltation rates that are among the highest on Earth. For example, in the Philippines, it is estimated that approximately one billion m^3 of sediment are lost to coastal waters annually (Burke *et al*. 2002)***,*** carrying high loads of particle-bound nutrients. The transboundary impacts of this phenomenon are compounded by sediment-laden waters flowing seasonally into the region around the northern coast of Sabah and to the south of Palawan from the South China Sea LME (Bate 1999). Pollution by solid waste is severe around the larger cities, towns and villages where waste management is generally poor or non-existent.

Habitat and community modification: The Sulu-Celebes Sea LME includes diverse habitats such as estuaries, sandy foreshores, mangroves, seagrass meadows, coral reefs and deep sea. Major causes of modification of these habitats are conversion for aquaculture, destructive fishing practices, agriculture (pollution) and industrial development (dredging, siltation and oil and gas exploration). Overfishing has caused changes in population structures and/or functional group composition (e.g., coral reef fishes). The important fish nursery ground function of large sections of mangroves and seagrass beds has been seriously impaired.

Overall, habitat degradation in the Sulu-Celebes Sea LME was assessed as severe, with extensive degradation particularly of mangroves and coral reefs (UNEP 2005). An estimated 60% - 80% or more of the mangrove resources in the Philippines have been lost (Atmadja & Mann 1994). In 1967, the Philippines Bureau of Fisheries and Aquatic Resources (BFAR) reports showed the existence of 4,200 km^2 of mangrove areas, of which about 1,400 km^2 remains (FAO 2000). The loss of mangroves can be attributed primarily to the illegal conversion into fishponds, indiscriminate cutting for firewood and construction purposes, and reclamation. In Indonesia, up to 10,000 km^2 of land, mostly mangrove forests, were allocated by the government to shrimp farms. By 2001, about 70% of these farms had become unsustainable and were subsequently abandoned (UNEP 2005).

Development of most ports has resulted in foreshore reclamation and channel dredging, while muro-ami[1] (Hopley & Suharsono 2000, Pilcher & Cabanban 2000), blasting (Cabanban 1998) and poison fishing (Pratt 1996) have damaged or destroyed more than 70% of coral reefs throughout the region. According to Burke *et al*. (2002), up to 50% of Indonesia's 51,000 km^2 of reef has already been degraded and 85% is threatened by human activities. Destructive fishing practices are the single largest threat to the region's reefs (Burke *et al*. 2002). BFAR reports have indicated that up to 70% of reefs in the Philippines have been destroyed by rampant dynamite fishing as well as by accumulation of silt from the watershed areas (FAO 2000). Coral cover and fish density on the reefs are decreasing at an alarming rate, even within some protected areas.

Changes in sea surface temperature have also affected the structure of coral reef communities during various coral bleaching events since 1983. For example, in the Philippines Tubbataha National Park, mean live coral cover decreased by about 19% after bleaching in 1998, then remained stable from 1999 to 2001 (Chou *et al*. 2002). There was good recovery of most other bleached areas and, on average, the bleaching events appear to have been less severe than in some other countries (Chou *et al*. 2002, Wilkinson 2002).

Environmental impacts are likely to deteriorate further, primarily because of the predicted increases in forestry, mining and agriculture as well as a major increase in population, without accompanying improvements in infrastructure. The impacts of habitat degradation are likely to deteriorate further or remain stable. In the Sahul area an improvement is expected due to strengthened regulations as well as management of protected areas.

III. Socioeconomic Conditions

National statistics suggest that the total population of the Sulu-Celebes Sea LME region is approximately 33 million (WWF 2001). The region has diverse economic activities, with the major export earners including fisheries, mariculture, agriculture and mining. Service industries, including coastal tourism, also make a substantial contribution to GDP. There is significant offshore oil and mineral exploration, with a potential for substantial expansion in the coming decades. Subsistence farming and fishing are major activities of large numbers of people outside of the main urban centres. The Sulu-Celebes Sea LME's fisheries are an important source of foreign exchange earnings for the three countries (FAO 2000, BFAR 2004). In addition, the countries obtain a significant percentage (up to 70%) of their animal protein from marine fishes (FAO 2000, BFAR 2004). Marine fisheries including fish farming are also an important source of employment in the region (FAO 2000, BFAR 2004).

The socioeconomic impacts of overfishing are severe, with reduced subsistence livelihood and food supply as well as reduced economic returns to small-scale fishers throughout the Philippines and Indonesia. These impacts include loss of employment, conflict between user groups for shared resources, reduced earnings in one area by destruction of juveniles and reproductive stock in other areas (migratory as well as shared stocks) and loss of protected species (e.g., local extinction of dugong in the Philippines).

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[1] Muro-ami involves setting a net over a coral reef into which a group of 10-30 swimmers drive the fish. The swimmers are equipped with weighted lines that are bounced up and down on the reef in an effort to drive out the fish.

The socioeconomic impacts of pollution were assessed as moderate, and include increased risks to human health, increased costs of human health protection, preventive medicine, medical treatment and of clean-up, as well as economic loss in fisheries and reduced fish marketability. Most of these impacts are concentrated around the major urban centres, where there have been significant health issues including cases of mercury poisoning.

The socioeconomic impacts of habitat and community modification were considered to range from moderate to severe (UNEP 2005). Increasing habitat fragmentation on the region's coasts has depleted the wide variety of resources that used to be the main source of sustenance and survival of coastal inhabitants (Fortes 2006). Major economic costs are also accruing from destruction of coral reef habitats. In 2001, the reefs of Indonesia and the Philippines provided annual economic benefits of US$1.6 billion and US$1.1 billion per year, respectively (Burke *et al*. 2002). Over the next 20 years, human impacts on the reefs could cost Indonesia and the Philippines some US$2.5 billion each (Burke *et al*. 2002). Habitat destruction has resulted in loss of income from tourism, loss of opportunity for investment, increased risks to capital investment, and costs of controlling invasive species and of restoration of modified ecosystems (UNEP 2005). Other socioeconomic costs of habitat modification are related to its impacts on fisheries.

V. Governance

Marine resource management and exploitation are, in theory, already controlled by extensive policy and regulatory frameworks. Both the Philippines and Indonesia have moved to decentralised management of marine resources (FAO 2000). The establishment of MPAs is one of the measures taken to address habitat degradation and unsustainable fisheries exploitation in the region. Several hundred protected areas have already been designated (Spalding *et al*. 2001, Cheung *et al*. 2002) and over one hundred more are currently being gazetted. Most protected areas are situated in the Philippines, especially in the Tubbutaha Marine Park. Several small community-based management initiatives have proven to be very successful at protecting coral reefs as well as facilitating replenishment of reef-based fisheries (Russ & Alcala 1996, Sherwood 2002). These successes are not common, however, as only 7% of the total number of MPAs in the Southeast Asian region are effectively managed, while 68% have poor or unknown management (Kelleher *et al*. 1995, Burke *et al*. 2002).

One of the greatest challenges in this LME is non-compliance with existing laws and regulations, which is exacerbated by weak institutional capability for enforcement. In addition, the information base is limited in these countries. However, steps are being taken to address the information gap, with several research initiatives in various agencies (including universities) in the respective countries. An extensive literature exists in the region, much of which is published in the national language, for example, in Indonesia. The Sulu-Celebes Sea LME is included in the UNEP-administered East Asian Regional Seas Programme (See the Gulf of Thailand LME). International agencies such as the UNEP, WWF, Conservation International and GEF have initiated some projects in the region. GEF is supporting several projects in the region (see the Gulf of Thailand LME). GEF has also provided support for the development of a TDA as well as the preliminary framework of a SAP for this LME.

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