VIII-12 Indonesian Sea: LME #38

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The Indonesian Sea LME is situated at the confluence of the Pacific and Indian Oceans, and is bordered by Indonesia and East Timor. It covers an area of 2.3 million km^2, of which 1.49% is protected, and contains 9.98% and 0.75% of the world's coral reefs and sea mounts, respectively (Sea Around Us 2007). Indonesia is one the world's largest archipelagic nations, with a coastline exceeding 84,000 km. The warm ocean acts as a 'heat engine' of global atmospheric circulation, with complex ocean-atmospheric dynamics, including the ENSO phenomenon. The convergence of three tectonic plates – the Eurasian, the Indo-Australian and the Pacific Plates – makes the region geologically as well as topographically diverse. Many of Indonesia's islands are subject to tectonic instability including volcanic activity. Seasonal monsoons, during which ocean currents reverse directions, exert a significant influence on the LME. The seas around Indonesia have complex and rapid currents owing to energetic tides over rough topography and also owing to the Indonesian Throughflow, which is the flow and exchange of oceanic water between the Pacific and Indian Oceans. Books, book chapters, articles and reports pertaining to this LME are Dalzell & Pauly (1989), Morgan (1989), Pauly & Martosubroto (1996), Pitcher *et al.* (2007), Zijlstra & Baars (1990) and UNEP (2005).

I. Productivity

The Indonesian Sea LME is considered a Class I ecosystem with high productivity (>300 $gCm^{-2}yr^{-1}$). The Banda Sea and the Aru Basin in particular, are areas of extensive seasonal upwelling and downwelling related to the monsoonal system. During upwelling periods, biomasses and productivity at all levels in the food chain are greatly enhanced (Zijlstra & Baars 1990). Stocks of small pelagic fish were also found to be considerably higher during the upwelling period. The changing oceanographic conditions in this LME also influence phytoplankton and zooplankton species composition.

The region is located in the Indo-West Pacific centre of biodiversity, supporting mega-diversity (Roberts *et al*. 2002). For example, more than 500 species of reef-building corals, 2,500 species of marine fish, 47 species of mangroves and 13 species of seagrasses are found in this region (Chou 1997, Tomascik *et al*. 1997, Veron 2000, Spalding *et al*. 2001). The pelagic realm is an important habitat, which supports high biodiversity of large and small migratory marine species, including a wide variety of cetaceans, including the blue, fin and humpback whales and other species that frequently migrate through the region (Kahn & Pet 2003).

Oceanic fronts Belkin et al. (2009): Straits connecting this LME with the other marginal seas are sites of front formation due to topographic effects caused by flow constrictions (Figure VIII-12.1). Internal tide interaction with sills in these straits is one of such front-genetic processes. Local (basin-scale) fronts are observed east of Borneo (EBSSF), northeast of Sulawesi (NESF), east of Halmahera (EHF), in the eastern parts of the Java Sea (EJSF) and Flores Sea (EFSF), across the Makassar Strait (MaSF), in the Molucca Sea (MoSF) and in the southern Banda Sea (SBSF).

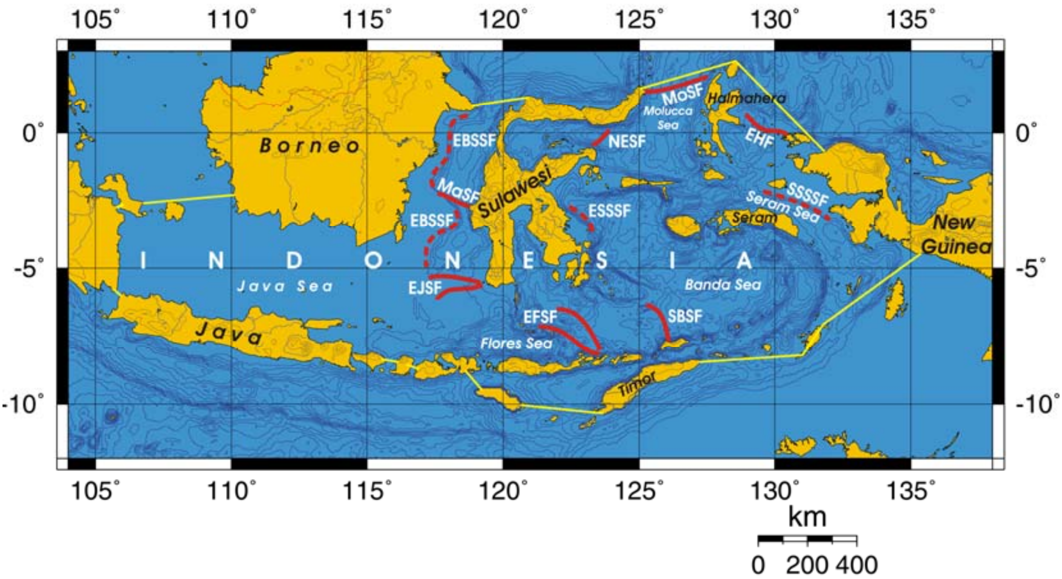

Figure VIII-12.1. Fronts of the Indonesian Sea LME. EBSSF, East Borneo Shelf-Slope Front; EFSF, East Flores Sea fronts; EHF, East Halmahera Front; EJSF, East Java Sea fronts; ESSSF, East Sulawesi Shelf-Slope Front; MaSF, Makassar Strait Front; MoSF, Molucca Sea Front; NESF, Northeast Sulawesi Front; SBSF, South Banda Sea Front; SSSSF, Seram Sea Shelf-Slope Front. Dashed lines show most probable locations of shelf-slope fronts. Yellow line, LME boundary. After Belkin et al. (2009) and Cornillon (2003).

Indonesian Sea SST (after Belkin 2009)
Linear SST trend since 1957: 0.53°C.
Linear SST trend since 1982: 0.24°C.

The thermal history of the Indonesian Sea since 1957 included brief cooling through 1967 and steady warming ever since (Figure VIII-12.2). The all-time minimum of 1967 occurred simultaneously with the all-time minimum in the Sulu-Celebes Sea LME and only a year prior to the all-time minimum of 1968 in the West-Central Australian Shelf LME and a minimum of 1968 in the North-West Australian Shelf LME.

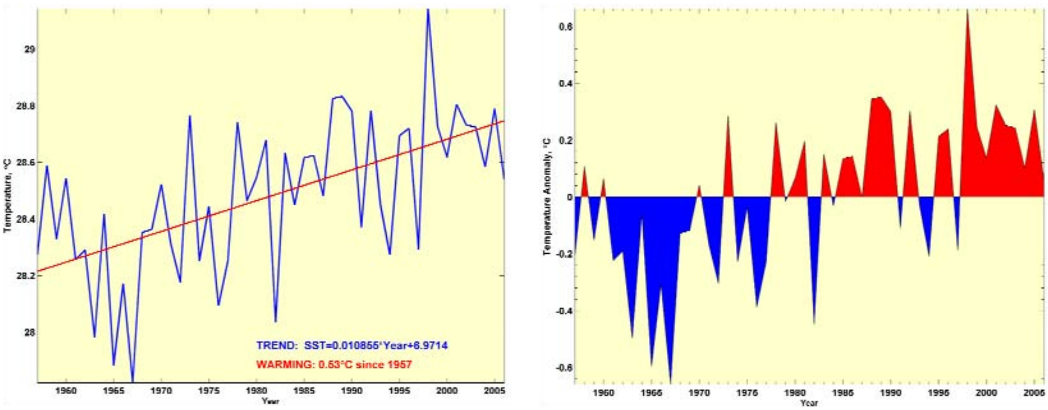

Figure VIII-12.2. Indonesian Sea LME mean annual SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

This sequence of events can be explained by advection of the low-temperature signal of 1967 from the Indonesian Sea toward Western Australia with the Indonesian Throughflow. The 1982 minimum occurred simultaneously in the North and Northeast Australian Shelf LMEs, but not off Western Australia; this can be explained by the long-time variability of the circulation pattern. The 1998 all-time maximum was likely caused by El Niño 1997-98. Despite the relatively uniform SST field, local anomalies up to 10°C are generated by the Indonesian Throughflow and tides, e.g. east of Bali in the Lombok Strait, where SST drops to 16°C vs. 28°C in adjacent waters (Vantier et al., 2005, p. 56).

Indonesian Sea LME trends in Chlorophyll and Primary Production: The Indonesian Sea LME is considered a Class I ecosystem with high productivity (>300 $gCm^{-2}yr^{-1}$).

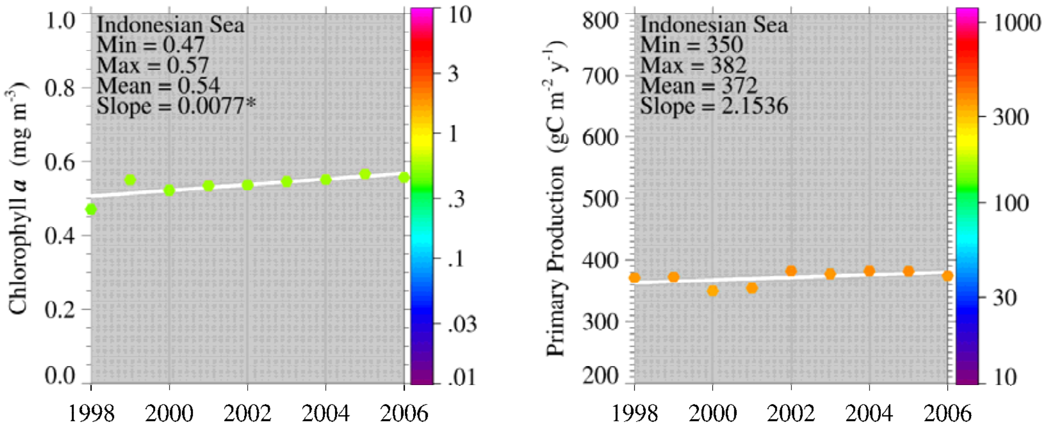

Figure VIII-12.3. Indonesian Sea LME annual trends in chlorophyll *a* (left) and primary productivity (right), 1998 – 2006. Values are color coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The fisheries of the Indonesian Sea LME are very complex and diverse, reflecting the region's extraordinarily heterogeneous geography and species variance (Pauly & Martosubroto 1996; FAO 2005). While most of the catch comes from its artisanal sector, industrial fisheries contribute considerably more in terms of value, since they target high-value shrimp and tuna stocks. Major species caught in the LME include tuna, sardines, anchovy, mackerel, as well as a range of reef fishes (Morgan 1989). Reef fisheries are vital to subsistence fishers and their families in the region but are also important in supplying high value products for expanding international, national and local markets (Cesar *et al*. 2000). Aquaculture of shrimps in coastal ponds has also increased rapidly during the last two decades in Indonesia.

As noted by Kahn & Fauzi (2001) for the adjacent Sulu-Celebes Sea, but also applicable in the Indonesian Sea, great uncertainties exist on the status of the local fish stocks due to serious discrepancies in fisheries data and a potentially significant level of Illegal, Unreported and Unregulated (IUU) catches. Total reported landings in the LME have increased steadily from the 1950s, with a sharp increase from less than half a million tonnes to over one million tonnes in the mid 1970s (Figure VIII-12.4). This distinct increase in the reported landings may be associated with developments related to the declaration of the EEZ. In 2004, the total reported landings reached 2.2 million tonnes and the value of the reported landings, showing a trend similar to landings, reached close to US$1.2 billion (in 2000 US dollars) in 2004 (Figure VIII-12.5)..

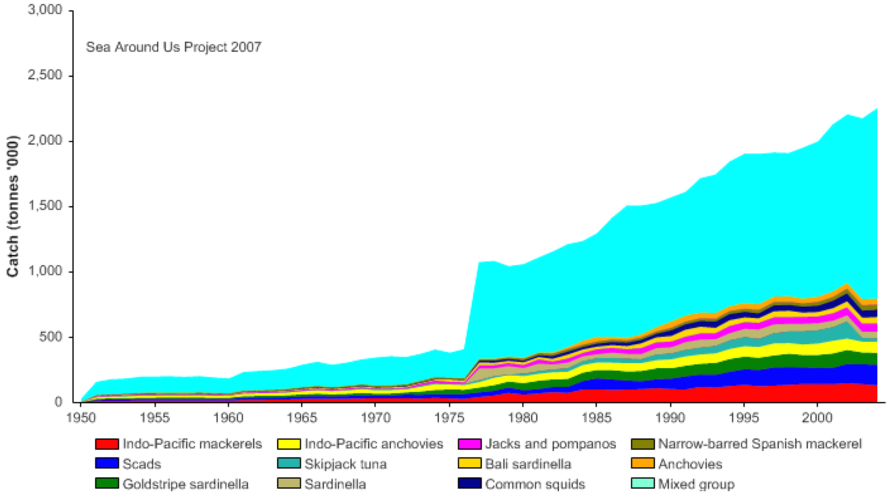

Figure VIII-12.4. Total reported landings in the Indonesian Sea LME by species (Sea Around Us 2007).

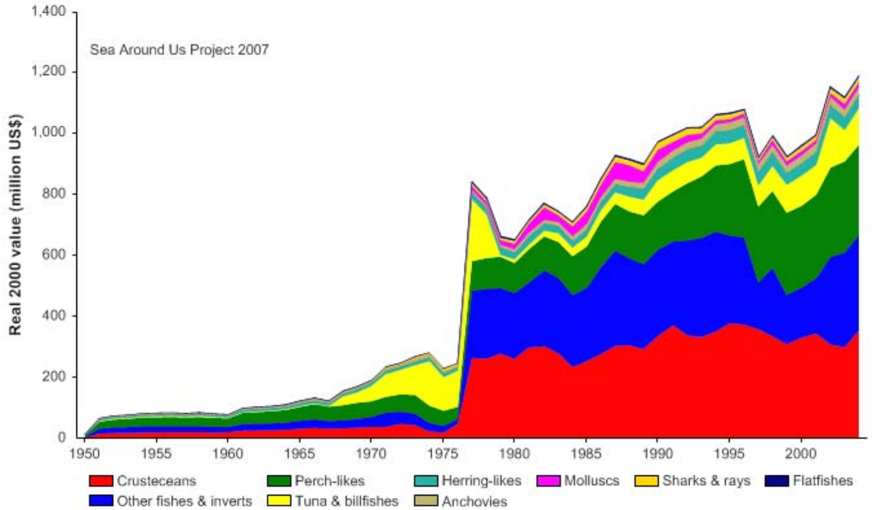

Figure VIII-12.5. Value of reported landings in the Indonesian Sea LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is increasing, and is currently at 30% of the observed primary production (Figure VIII-12.6). Indonesia and Thailand account for the largest shares of the ecological footprint in the LME.

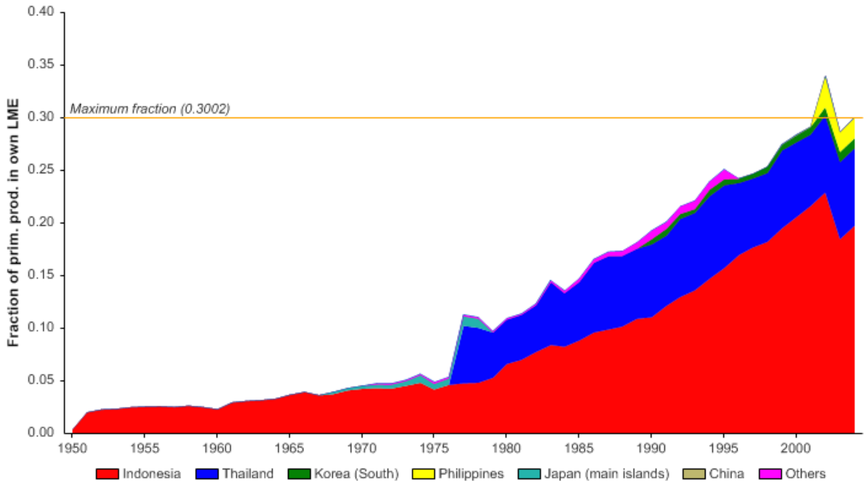

Figure VIII-12.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Indonesian Sea LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of fisheries landings (i.e. the MTI; Pauly & Watson 2005) shows an increase from the early 1980s, an indication of increased reported landings of high trophic species such as tuna (Figure VIII-12.7 top). Such interpretation is also inferred by the increase in the FiB index during the same period (Figure VIII-12.7 bottom) denoting a steady expansion of the fisheries in the region. It must, however, be noted that these indices may be skewed by the high level of unidentified fishes in the underlying landings statistics.

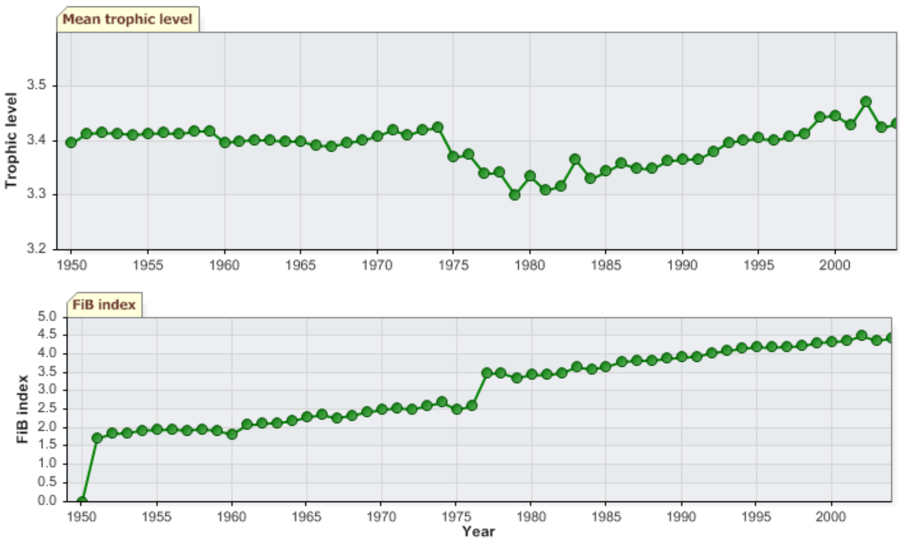

Figure VIII-12.7. Mean trohpic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Indonesian Sea LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that only a small number of the stocks in the LME are either overexploited or have collapsed (Figure VIII-12.8, top) with 80% of the catch from fully exploited stocks. Again, the high level of taxonomic aggregation in the underlying landings statistics must be noted here.

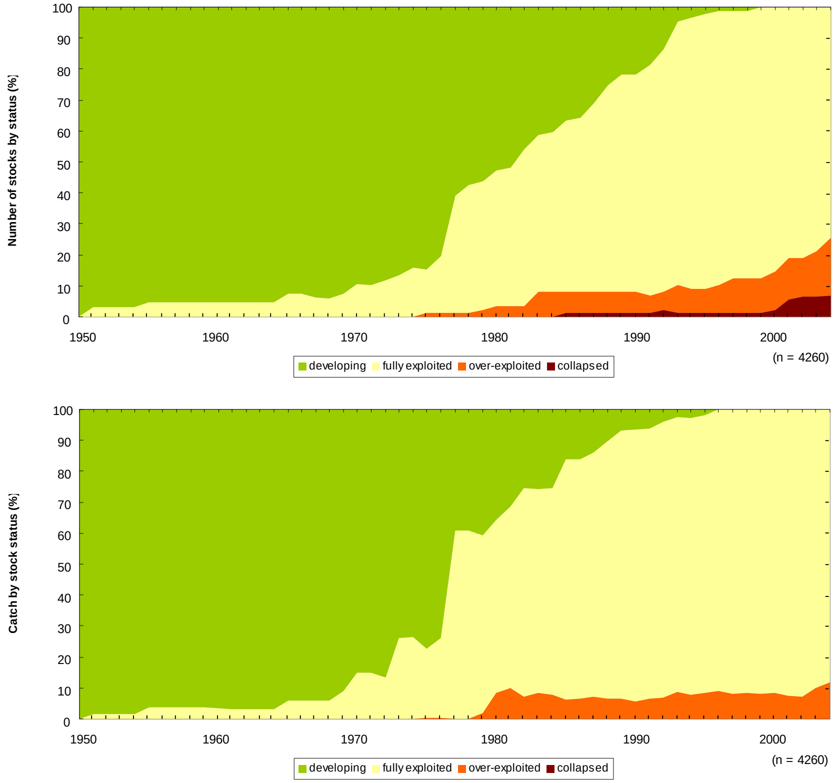

Figure VIII-12.8. Stock-Catch Status Plots for the Indonesian Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of '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).

Overexploitation is widespread in this LME, with many fish stocks exploited well beyond the biological limits (Dwippongo *et al.* 1987), especially in the coastal zone, which is exploited by 85% of Indonesian fishers (Hopley & Suharsono 2000). In addition, foreign fleets continue to threaten Indonesia's fisheries, but again, accurate data on the extent, the number of vessels and their mode of operations are inadequate (Kahn & Fauzi 2001, Perrin *et al*. 2002). Coral reefs have been exploited for a long time, even in the more remote areas of Eastern Indonesia (Palomares & Heymans 2006), and are now considered to be under severe fishing pressure. Of particular concern is the live reef fish trade in the Southeast Asian region, including in the Indonesian Sea LME. The use of fish poisons to catch aquarium and food fishes is a serious problem in many Pacific countries, but more so in Indonesia and the Philippines (Johannes & Riepen 1995). Use of explosives is also of a grave concern throughout the region (see Pollution and Ecosystem Health).

About 85% of aquarium fish traded internationally has been caught using cyanide, targeting about 380 species from a few families such as Labridae, Pomacentridae, Chaetodontidae, Pomacanthidae and Scaridae (Pratt *et al*. 2000). The live food fish trade primarily targets groupers (especially *Epinephelus* spp. and *Plectropomus leopardus*), Napolean wrasse (*Cheilinus undulates*) and barramundi cod (*Cromileptes altivelis*) (Pet & Pet-Soede 1999). Because of their particular life-history attributes, groupers are highly susceptible to overexploitation and the targeting of their spawning aggregations is a serious concern (Licuanan & Gomez 2000). In addition to taking adult groupers for direct food consumption, the live reef fish food trade also involves capture of wild fry and fingerlings supplying the grouper mariculture industry in Southeast Asia, predominantly in Taiwan and Thailand (Sadovy & Pet 1998).

Over the past several centuries many of Indonesia's coral reefs have been heavily and chronically overfished, with a major loss of productivity and cascading effects to other components of the ecosystem. Overexploited stocks include many species of reef fish such as groupers and threatened and endangered species such as sea turtle and dugong. Benthic invertebrate species such as sea cucumbers, trochus and clams are also overexploited, particularly around major coastal population centres. Overexploitation of pelagic species such as shark, tuna and billfish is also evident. Catch per unit effort for these fisheries has declined sharply, as has the size of fishes caught. There have also been local extinctions and reductions in market availability (UNEP 2005). Of major importance in this context has to be the realization that much of the true catch may not be accounted for by official landings statistics, e.g., as shown for northern Sabah, Malaysia (Teh et al. 2007). While these examples pertain to other LME areas, the same problem applies to the Indonesian Sea LME.

The problem of excessive bycatch was assessed as severe (UNEP 2005). However, there are little or no discards because virtually all of the bycatches, except those produced by distant waters fleets and through the use of blast fishing and poisons, are consumed. Sharks are also caught as bycatch in trawl as well as tuna long-line fisheries. Perrin *et al*. (2002) noted that bycatch is a major threat to all marine mammals in Indonesian waters, especially to cetaceans and dugong, and can lead to major losses in biodiversity. Impacts of destructive fishing on fisheries resources and marine habitats are increasingly becoming a problem, even within national parks (Pet-Soede & Erdmann 1999, UNEP 2005). There is a widespread habitat destruction of coral reefs from blast and poison fishing including extensive damages to soft-bottom communities from trawling (see Pollution and Ecosystem Health). The impacts of destructive fishing have major transboundary implications, both in terms of target species population dynamics and in terms of international market demand. Although these practices are illegal, regulations are difficult to enforce, especially in remote areas.

III. Pollution and Ecosystem Health

Pollution: Urban expansion and industrialisation have resulted in coastal pollution from domestic, agricultural and industrial wastes in the Indonesian Sea LME. Industrial forms of water pollution are concentrated in the major urban centres, primarily the large cities of northern Java. Oil spills, slowly degrading toxic wastes from chemical as well as non-chemical industries, agricultural runoff and heavy metals threaten coastal waters. This has resulted in severe pollution in some areas, such as Sunda (UNEP 2005). Because of inadequate sewage disposal and treatment throughout the region, microbiological pollution is severe, especially around urban centres. Eutrophication is also severe around urban centres, particularly in areas with limited water circulation and where sewage, agricultural and/or industrial discharges are present.

Siltation rates in this LME are among the highest in the world (Hodgson & Dixon 1992). Pollution by suspended solids is severe in coastal waters, particularly in north Java and Sumatra, with high turbidity over wide areas. Close to the major urban centres, the affected zone extends up to 50 km offshore (Hopley & Suharsono 2000). This has mostly resulted from extensive deforestation in many watersheds, compounded by high rates of erosion as well as industrial mining. Solid waste is a severe problem locally, particularly in the Java Sea and around the cities, towns and villages where waste management is inadequate.

Chemical pollution from agricultural pesticides and industries is severe in localised areas. Mercury contamination from gold mining is widespread and is generating serious health as well as environmental risks in Indonesia (Limbong *et al*. 2003). Studies conducted by Kambey *et al*. (2001) showed that mercury levels in the tissue of fish near gold mines were higher than levels recommended by the WHO for total restriction on fish consumption. The disposal of toxic materials from mines via submarine tailings placement is of special relevance to Indonesian marine life (Perrin *et al*. 2002). In the next decade, the world's biggest copper and gold mine situated in Indonesia will discharge more than one billion tonnes of tailings over a wide area. This LME forms part of both the main and Ultra Large Crude Carrier oil tanker routes between the Indian and Pacific Oceans. Furthermore, there is regular discharge of ship ballast waters in this LME. In addition to spills, chronic pollution from oil production facilities and refineries is evident in some areas such as Sunda (Hopley & Suharsono 2000).

Habitat and community modification: The Indonesian Sea LME has a large diversity of coastal habitats, including extensive mangroves, coral reefs and seagrass beds. The area of Indonesia's mangroves has been estimated to range from 24,000 km^2 (Tomascik *et al*. 1997) to 42,500 km^2 (Wilkinson *et al*. 1994), representing over two thirds of the area of mangroves in Southeast Asia. Seagrass beds are even more extensive (30,000 km^2 according to Tomascik *et al*. 1997). Estimated coral reef areas range from 50,000 to 90,000 km^2 (Spalding *et al*. 2001) to 85,707 km^2 (Tomascik *et al*. 1997). Overall, habitat and community modification was assessed as severe in the Sunda and Wallacea sub-regions, and moderate in the Sahul (UNEP 2005). Extensive cutting for timber, conversion for aquaculture and other forms of coastal development, heavy siltation, pollution and destructive fishing have caused major fragmentation and reduction in mangrove area. For example, more than 30% of the mangroves in north Java disappeared during the last 150 years. About 80% of the reefs are at extremely high risk of further damage from human activities (Bryant *et al*. 1998, Burke *et al*. 2002). In the last 50 years, the proportion of degraded reefs has increased from 10% to 50% (Hopley & Suharsono 2000). In central Indonesia, 40% of coral reefs are currently classified as being in poor condition and only 6% in excellent condition (Hopley & Suharsono 2000).

Damage to coral reefs from the use of explosives and poisons is catastrophic. Johannes & Riepen (1995) forecast the collapse of the live fish industry in Indonesia and this does appear to be happening in many areas (Bentley 1999). On regularly bombed reefs, coral mortality can range from 50% to 80%, even in National Parks (Pet-Soede & Erdmann 1999). The effects of cyanide fishing are multiple. In addition to being broken to retrieve stunned fish, corals are also bleached by the cyanide (Johannes & Riepen 1995) and recovery may take up to half a century (Cesar 1996). As reefs become damaged and unproductive, they are abandoned by fishers who move to new reefs to continue this pattern of destruction. Indonesian coral reefs are also impacted by pollution. Reefs subject to land-based pollution (sewage, sedimentation and/or industrial pollution) show 30% to 50% reduced diversity at 3 m and 40% to 60% reduced diversity at 10 m depth relative to unpolluted reefs (Edinger *et al*. 1998). This implies a dramatic, rapid decrease in Indonesian reef-based fisheries resources. Mining and quarrying of coral is another significant threat to the LME's coral reefs and is widespread at both subsistence and commercial levels, despite being banned by various provincial governments (Hopley & Suharsono 2000). Indonesia's reefs have also been impacted by the 1997-1998 El Niño event that triggered widespread bleaching, with western and west-central Indonesia most affected.

Modification of coastal habitats has resulted in major changes in population structure as well as functional group composition, notably on coral reefs, and massive changes in ecosystem services of coral reefs and mangroves (DeVantier *et al*. 1999). For instance, the important nursery and feeding ground role of mangroves as well as seagrass beds for fish and marine mammals have been lost over extensive areas. Habitat modification and loss have also contributed to the decline in populations of marine mammals such as dugong (Marsh *et al*. 2001). Habitat degradation has significant transboundary implications in terms of reduced fish recruitment and impacts on migratory species as well as on biodiversity throughout the region.

Unless there are improvements in regulation and expansion and improved management of protected areas, the health of the LME is likely to deteriorate further primarily because of the predicted increases in fisheries, deforestation, agriculture, aquaculture, mining and industrialisation as well as a major increase in population without the required improvements in infrastructure.

IV. Socioeconomic Conditions

The population of Indonesia as a whole is about 222 million in 2006 (Indonesian Central Statistics Bureau, 2006), with some 200 million people living in the LME region. The total population is expected to double to 400 million by 2035. Subsistence farming and fishing are the major activities of large numbers of people outside the main urban centres. Most of the approximately 6,000 coastal communities are directly dependent on the sea as their primary source of food and income (Dahuri & Dutton 2000). Coastal and marine industries, including oil and gas production, transportation, fisheries and tourism, account for 25% of the nation's GDP, in addition to employing a significant percentage of Indonesia's workforce (Dahuri & Dutton 2000).

The socioeconomic impacts of overexploitation of fisheries include reduced economic returns as well as loss of employment of fisher families, conflicts between user groups, loss of food sources for human and animals and injury or loss of human life from diving accidents (Johannes & Djohani 1997). Losses in revenue to the Indonesian economy as a result of poaching by foreign boats may top four billion US dollars (Perrin *et al*. 2002). The reefs of Indonesia provided annual economic benefits of US$1.6 billion per year in 2002, based on their value in food security, employment, tourism, pharmaceutical research and shoreline protection. However, over the next 20 years, human impacts, notably overfishing, destructive fishing and sedimentation, could cost Indonesia some US$2.6 billion (Burke *et al*. 2002). The cost from fish bombing alone over the next 20 years will be at least US$570 million (Cesar 1996, Pet-Soede *et al*.2000), while the economic loss from cyanide fishing is estimated to be US$46 million annually (Hopley & Suharsono 2000).

Pollution has severe socioeconomic impacts, especially around major urban centres and coastal villages (UNEP 2005). Water pollution is found in virtually all populated and/or highly industrialised areas of Indonesia and is known to cause massive fish kills, harvest failure from aquaculture and threats to human health (Dahuri 1999, Hopley & Suharsono 2000). Habitat and community modification impact local fisheries, cause increased beach erosion and have adverse consequences for tourism, due to loss of aesthetic value and the cost of mitigation measures.

V. Governance

The Indonesian Sea LME is governed by Indonesia and the recently independent state of East Timor. Indonesia uses the ‘Archipelagic Doctrine’ to define its territorial waters;

most of this LME is within archipelagic waters. Marine governance in Indonesia is very complex as there are three levels of government – district, provincial and national – with marine jurisdiction. The government has sponsored the Coral Reef Rehabilitation and Management Programme, a 15-year initiative aimed at strengthening the management of the country's coastal resources while considering the needs of coastal communities. Since the 1980s, there have been major advances in the regional capacity for development of policy and legislation based on sound science. For example, a 'critical mass' of regional expertise now resides in government, inter-governmental agencies, academic institutions and NGOs. There is also an extensive literature on the marine environment in Indonesia that is published locally in the Indonesian language.

An urgent priority regarding the management of the country's coastal and marine living resources is the development of a functional, integrated network of MPAs (UNEP 2005). This must be accompanied by the establishment of substantial no-take zones as well as the development of appropriate policy and legal frameworks. The National Parks Service manages six National Marine Parks and several other Terrestrial National Parks with marine areas. These parks cover a total sea space of 41,129 km^2, equivalent to 1.3% of the country's territorial and archipelagic seas (Putra & Mulyana 2003). Indonesia is developing co-management strategies for improving the management of these parks.

The LME falls within the UNEP-administered East Asian Regional Seas Programme (see Gulf of Thailand LME). Indonesia participated in the GEF-supported project 'Regional Programme for Marine Pollution Prevention and Management in the East Asian Seas region' from 1994 to 1999. This country is also participating in the GEF-supported PEMSEA (see Gulf of Thailand LME) and Bay of Bengal LME projects (see Bay of Bengal LME and www.fao.org/).

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