This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 4.

The results presented herein are supported wherever possible by published data. However, for some of the issues and concerns raised in this analysis, some publications are of a confidential nature, either in government or ‘commercial in confidence’ and thus were unavailable for inclusion in this report. Geo-political issues and sensitivities are of particular significance, notably in relation to foreign fishing, mineral extraction and related territorial/sovereignty disputes. The Transboundary Diagnostic Analysis for the South China Sea prepared for UNEP provides much useful data in support of the present analysis (Talaue-McManus 2000).

**Freshwater shortage**

The large range of climates in the region generates a variety of hydrological regimes. The South China Sea is host to some of the most humid climates (with annual precipitation above 10 000 mm in places) giving rise to major rivers, while in other parts it has a very arid climate, with closed hydrologic systems (FAO 1999). As a result, the region shows a very uneven distribution of its water resources and of its water use conditions. In the humid areas, water management concerns have mostly been dominated by considerations related to flood control. In
the arid areas, where water is scarce, hydrological studies have been oriented much more towards water resources assessment.

The hydrology of the region is dominated by the typical monsoon climate, which induces large inter-seasonal variations of river flows. In this situation, average annual values of river flows are poor indicators of the water resources available for use. In the absence of flow regulation, most of the water flows during a short season when it is usually less needed. A fair estimate of water resources available to a country for use should include figures of dry season low flow. However, such information is available only for a very limited number of countries. In view of the hydrological regime of the rivers in the region, run-off in Southeast Asia and the islands is not significantly affected by withdrawals, while the difference between natural and actual flow may be much more important in the arid regions (mostly China).

In terms of shared water resources, the region is characterised on the one hand by a series of insular, archipelagic countries among which no exchange is possible, and on the other hand by a littoral zone in which shared river basins play a critical role and make the computation of water resources relatively complex. In several cases, large inconsistencies were noted when comparing the flow at the border recorded by neighbouring countries. Indeed, compilation of information on water resources shows large methodological discrepancies between countries.

Agriculture is a major feature of the socio-economies of most South China Sea nations, and thus irrigation, drainage and water withdrawal are of significant relevance to the issues of freshwater shortage and pollution, as outlined for each nation in Annex VIII.

**Environmental impacts**

**Modification of stream flow**

Modification of stream flow, including that caused by water withdrawal, has moderate environmental impact in the region, with severe impacts in some areas. In Vietnam, the seasonal discharge of rivers has been altered, mostly as a consequence of loss of hinterland forests and riparian vegetation. In Thailand and Malaysia, stream flow has been affected by loss of riparian vegetation and dam construction, with significant saline intrusion in some areas. In Borneo, significant loss of riparian vegetation has occurred through effects of logging. In the Philippines, there has been saltwater intrusion to large freshwater lake systems and loss of riparian vegetation.

In Thailand, the capital city Bangkok faces problems of both over- and under-supply of water. Flooding occurs frequently in the wet season due to low average ground level, high tides and inadequate drainage (FAO 1999). The Metropolitan Waterworks Authority is unable to supply water to meet all domestic and industrial demand. As a result, in the outskirts of Bangkok, private and industrial abstraction of groundwater exceeds the safe yield of the aquifer. This accelerates the rate of land subsidence (5-10 cm/year), which in turn aggravates the problem of flooding. Indeed, subsidence has caused some parts of the drainage systems to be below the normal water level and has rendered them ineffective. The minimal discharge to maintain a water level of 1.7 m for navigation (this means 300 m³/s released in the navigation channel from Nakhon Sawan to the Chao Phraya Dam, and 80 m³/s downstream of the dam) cannot be maintained due to large amounts of water diverted from the rivers for dry season irrigation in the northern and central regions. This reduced the volume of inland waterway transport five-fold between 1978 and 1990. The volumes of water released by the Bhumipol and Sirikit dams are increasingly important to prevent saltwater intrusion, even if they do not meet the navigation demand (FAO 1999).

**Pollution of existing supplies**

Pollution of existing supplies has caused slight environmental impact across the region as a whole, but with moderate to severe localised impacts. Fish kills from various chemical inputs have been reported, and rivers close to urban centres in all countries (e.g. Bangkok, Thailand; Haiphong, Hanoi and Ho Chi Minh City, Vietnam; Manila, Philippines; Hong Kong, China) are usually polluted. There have also been significant increases in nutrient loads in many rivers and lakes from aquaculture activities, with likely increases in other inputs. In large parts of the region (e.g. Indonesia, Thailand, Cambodia, Vietnam), municipal and industrial wastewater is often discharged virtually untreated into the waterways causing rapid deterioration in the quality of river water (FAO 1999). In Thailand for example, approximately 833 million m³ of wastewater were produced in 1992. In 1995, only 35 million m³ of wastewater were treated (FAO AQUASTAT 2003). Numerous wastewater treatment projects are being developed in the Bangkok metropolitan area. There is little to no re-use of treated wastewater in Thailand, or indeed throughout most of the region. In Vietnam, no treatment facilities have been available in manufacturing plants, factories and sewer systems before wastes are discharged into water bodies. In Hanoi, 300 000 m³/day of wastewater are discharged into the rivers (FAO AQUASTAT 2003).

Virtually all urban streams in the region are highly polluted. Failure to provide adequate sanitation services not only translates to vulnerabilities to contagious and infectious diseases but also increases likelihood of sewage dumping-induced eutrophication in estuarine areas. More detail on sanitation data for individual countries is available from the
web sites of WHO’s Joint Monitoring Programme for Water Supply and Sanitation, and World Resources Institute’s EarthTrends Environmental Information Portal.

Changes in the water table
Changes in water tables have exerted moderate environmental impacts in the region, with severe impact in some areas, notably coastal Thailand (see also Annex VII). Wells have been deepened over hundreds of square kilometres, with major aquifer draw-down, saline intrusion, and there is little to no potable water available from some of the traditional coastal sources. In Cambodia, the quality of groundwater is generally satisfactory, although high iron concentrations and increased salinity levels have been encountered in some provinces (Svay Rieng, Prey Veng and Takeo). In Indonesia, overexploitation of groundwater has led to critical problems in some areas. For example, in Jakarta, excessive groundwater abstraction (32.6 million m³ in 1993) has caused saline groundwater to reach about 10 km inland from the coastline and led to land subsidence at a rate of 2-34 cm/year (FAO AQUASTAT 2003).

Socio-economic impacts
Overall socio-economic impacts ranged from slight (Health and Other social and community) to moderate (Economic). Economic impacts included insufficient water supply and irrigation, causing loss of agricultural and tourism uses and lowered productivity.

Economic impacts
There are numerous economic problems associated with freshwater shortage. These include growing water competition among users for potable water supply, industrial water supply, hydropower, environment, fishing, and watershed management, all competing with irrigation (FAO AQUASTAT 2003).

Erosion and siltation of canals have resulted in high costs for the operation and maintenance of irrigation schemes, and many are in need of frequent rehabilitation. The conversion of agricultural lands to industrial or residential use has significantly reduced the area equipped for irrigation that can actually be used for irrigated agriculture. Finally, the high cost of energy hampers the development of pump irrigation systems (see Annex VIII for detail). In most countries, fees collected from farmers to cover costs of irrigation and water supply do not meet the actual operational cost. Governments generally do not seek full cost recovery because the farming community is considered a low income group. For example, in Malaysia, fees cover only 10-12% of the actual operational cost (FAO AQUASTAT 2003). Further, about 32% of the water produced is lost in the distribution system due to pipe leakage, under-metering, and other unaccounted water losses. In many areas of the Philippines and elsewhere, there is insufficient water supply and irrigation, loss of agricultural and tourism uses, and low productivity.

Economic impacts
Drinking water across some parts of the region is of acceptable quality because of pollution management, although in many other areas surface water does not meet WHO drinking water criteria, because of the agricultural, industrial and human inputs. For example, many Filipinos, especially the poor, lack safe potable drinking water to meet even their basic survival needs. About one third of the population of Philippines, some 25 million people, devise their own ways of obtaining water because they have no access to formal sources such as deep wells or piped/reticulated water (FAO AQUASTAT 2003). Many poor people are required to buy water, with the daily consumption levels averaging just 15 litres per day, dangerously close to the survival minimum. Of the 25 million Filipinos whose water supply is self-provided, many are getting water from contaminated sources.

Thus, for millions of people in the region, and indeed the larger area of Southeast Asia as a whole, there is little to no access to wells or piped

### Table 5 Water-borne diseases in some countries of the region.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of inhabitants affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>500,000</td>
</tr>
<tr>
<td>Philippines</td>
<td>782,000</td>
</tr>
<tr>
<td>Thailand</td>
<td>1,040,000</td>
</tr>
</tbody>
</table>

(Source: FAO 1999)
supplies. Even in some areas with reticulated water, there are frequent interruptions to supply. Precise and comprehensive data on access to water supply are not available, and there are major differences in data quoted by different agencies (e.g. FAO and World Bank). FAO (1999) estimated that in Indonesia in 1990, just 35% of the urban population and 33% of the rural population had access to safe water supply. In Cambodia, some 1.75 million people (just 19% of the population) had access to clean drinking water in 1992, representing approximately 40% of the urban population and 15% of the rural population. At that time, only 7,000 of the 30,000 wells needed had been constructed by international organisations.

Access to an improved water source refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection (Table 6). Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 litres per person per day from a source within 1 km of the dwelling (WHO/UNICEF 2000). These estimates show significant disparities with FAO estimates (e.g. Indonesia), in part because of different criteria.

Access to improved water sources in the region.

<table>
<thead>
<tr>
<th>Country</th>
<th>Access to improved water sources (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Cambodia</td>
<td>75</td>
</tr>
<tr>
<td>China</td>
<td>78</td>
</tr>
<tr>
<td>Indonesia</td>
<td>78</td>
</tr>
<tr>
<td>Malaysia</td>
<td>100</td>
</tr>
<tr>
<td>Philippines</td>
<td>86</td>
</tr>
<tr>
<td>Singapore</td>
<td>100</td>
</tr>
<tr>
<td>Thailand</td>
<td>84</td>
</tr>
<tr>
<td>Vietnam</td>
<td>77</td>
</tr>
</tbody>
</table>

(Source: UNDP 2001)

Precise and comprehensive data on the provision of environmental sanitation are not available for the region. In Cambodia, access to sanitation is limited to an estimated 1.24 million people (just 13% of the population), representing approximately 53% of the urban population (mostly in Phnom Penh) and 6% of the rural population (FAO 1999). A 1995 survey assessed the quality of water supply, wastewater and sanitation in the main towns of Cambodia. Most of the systems combined sewage and drainage water, and have not been maintained over the past two decades. As a result, they are now in poor condition and not functioning properly. Drainage water often mixes with drinking water with obvious health implications; floods are frequent during the rainy season as the sewers clog rapidly. According to FAO (1999), providing a safe water supply to 65% of the rural population in Cambodia during the period 1996-2000 would have required a capital investment of nearly 31 million USD.

Many local programmes are underway to address river pollution, as for example in Ho Chi Minh City, Vietnam, where polluted waterways are being cleaned as part of the World Bank-funded 'Urban Upgrading Project', including drainage, sewage systems and infrastructure. The once beautiful and clean waterways have been turned unintentionally into a dumping site. The project will work in 109 slums in Ho Chi Minh City, focusing on drainage and sewage networks, costing some 298 million USD over the period 2004-2012, and should benefit some 1.55 million residents). The project is based on the principle that active participation by communities in critical stages of preparation, design and implementation is a pre-requisite to effectively respond to the needs of these areas. This should ensure that numerous low-income communities will have clean water, better sanitation and sewage systems, and reduced flooding, pollution and water-borne diseases (Nhan pers. comm.).

Other social and community impacts

There are significant transboundary implications on the socio-economy of freshwater shortage, particularly in relation to the international nature of many of the river systems, and related potential for upstream/downstream conflicts. An example is Singapore which relies on the State of Johor in Malaysia for most of its water supply. This has been the focus of significant recent disputation between these two neighbouring nations. Singapore’s water supply from Malaysia is based on agreements made in 1961 and 1962. Malaysia has, for several years, wanted a major review of the price, which it regards as too low. However, the two agreements provided for price revisions after 25 years, in 1986 and 1987. Singapore’s stand is that since the 25-year period passed without review, Malaysia now has no legal basis to raise the price. Malaysia and Singapore continue to hold top-level meetings attempting to resolve this long-standing dispute.

In summary, major socio-economic impacts are spread widely across the region, and include:

- Loss/interruptions to human drinking water supplies (e.g. rural areas of Philippines);
- Increased potential for upstream/downstream conflicts (e.g. Malaysia, Singapore), or conflicts among urban and squatter groups (e.g. China). The water authorities in much of the region presently
Conclusions and future outlook

Despite its moderate impact for the region as a whole at present, freshwater shortage is a ‘food-security’ concern in some areas, and is the focus of national and international interventions (e.g. Philwater International Conference and Exhibition on Water Resources Management). Expanded programmes targeting both rural and urban water supplies, with the goal of delivering a reliable potable supply are beginning to be implemented, with the goal of achieving significant alleviation (see Annex VIII).

The overall environmental situation in regard to freshwater shortage in the South China Sea is expected to deteriorate slightly, remaining moderate by 2020. Socio-economic impacts are all expected to deteriorate, with health effects remaining as slight, other social and community impacts becoming moderate and economic impacts becoming severe. Although major improvements are expected in some locations (e.g. Singapore), many poorer areas in South China Sea do not have the resources or infrastructure to act, compounded by poverty and inadequate sources of water supply. In Indonesia for example, as the nation has started to implement development programmes to meet the sharply increasing needs for irrigation, safe drinking water, industrial water, energy, and other uses, the demand on water resources has increased rapidly. It is estimated that between 1990 and 2020, the demand will increase by about 220% (FAO 1999).

Thus major forcing factors include widespread increases in human populations, with a doubling expected by 2033, and industrialisation, with the compounding problem of increasing contamination. Although either directly or indirectly in all nations in the region, much legislation touches on water resources (Annexes IV and V), most of the existing laws are outdated. For example, in Malaysia, the Water Act of 1920 is inadequate for dealing with the current complex issues related to water abstraction, pollution and river basin management.

Water scarcity is a major issue in China and the Philippines, and increased competition for water between sectors already affects agriculture in China, Malaysia and Thailand. The trend is towards an intensification of the problem due mainly to the rapid growth of the domestic and industrial sectors in these countries. Major inter-basin transfer programmes are being developed in China and Thailand. Water scarcity and the interdependency between water use sectors are pushing countries to develop integrated water resources management programmes, as in Malaysia, Vietnam and Thailand. Water quality is also a growing concern in several countries where industrial development is important, including Malaysia and the Philippines. There is increased importance of water conservation and protection in the national programmes of Indonesia and the Philippines, while in Thailand, the transfer of populations from high density to low density areas has encountered serious socio-economic problems.

Although the Mekong River is considered as part of GIWA region 55 Mekong River, the 1995 agreement established by the four lower Mekong riparian countries provides a useful model for the larger region and new opportunities for regional collaboration in developing the Mekong Basin resources (water and related ecological resources). Some examples of promising collaboration are related to flood control in the Mekong Delta with Cambodia, and the possible importation of hydropower from upper riparian states. Importantly however, there are as yet no similar arrangements for other transboundary rivers.
Pollution

The health of the South China Sea Large Marine Ecosystem is in serious decline due mainly to coastal development. Around 270 million people live in the coastal areas of the South China Sea Large Marine Ecosystem, and this population is expected to double in the next three decades (LME 2004). The area’s rapid economic development and population growth are the cause of significant ecological damage in coastal and marine areas. The primary environmental threats by humans in the South China Sea are the destruction of mangrove forests, sewage pollution, exploitative fishing practices and overfishing, coral reef degradation, and damage to seagrasses and wetlands. Sewage pollution affects biodiversity and fisheries, and has health impacts on the downstream population. Pollution, overexploitation and destructive fishing practices are threatening 80% of the coral reefs in the region. Other pollution problems are increased river sedimentation and nutrients, plus destructive fishing practices, are being felt in the region’s other major habitat, seagrass communities, of which 20 to 50% were found to be degraded. Many fish nursery areas and breeding grounds are being degraded (LME 2004). Figure 7 shows urban development along Pasig River, Manila.

Industrial forms of water pollution are concentrated in the major urban centres. In much of the region, sewage treatment is superficial at best, with raw and/or primary treated sewage discharged directly into water courses (see Freshwater shortage). Agricultural pollution is also widespread, through leaching of fertilisers and pesticides into watercourses, massive loss of soils following land clearing and forestry and increasing aquaculture activities. Pollution from shipping and ports is also significant, as the South China Sea contains some of the world’s busiest international sea-lanes, with two of the busiest ports in the world, Singapore and Hong Kong (Coulter 1996).

The environmental impacts and threats from pollution in the South China Sea have been well documented in many reports (e.g. Gomez 1988, Johnston 1988, Chua & Pauly 1989, Soegiarto 1989, Piyakarnchana & Johnston 1990, Chua 1991, Chua & Scura 1991, Chua & Garces 1992, Coulter 1996, Low et al. 1996, Chua & Ross 1998, Johnston 1998, UNEP 1999). The degraded water quality of Ha Long Bay (Hai Phong province, Vietnam) is a typical example. Pollution of the Bay and man-made changes to the environment have threaten coral reefs, marine life and the livelihood of fishermen and hoteliers. In 10 years, 900 million tonnes of sediments polluted by the nearby coal mining, have been transported by the rivers into the Bay. Adding to this, close to 9 million m³ industrial wastewater contaminated by lead and petrol is discharged into the Bay every year (South China Morning Post in Naess 1999). The coral reefs suffer from the dynamite fishing by the Cat Ba Island fishermen, and untreated wastewater from Haiphong, Vietnam’s third-largest city with two million inhabitants, pollutes the Bay. It is also estimated that hundreds of visitor boats spill about 2 tonnes of oil each day. Similar levels of pollution occur at many locations in the South China Sea, although many are not as well documented as the latter World Heritage site.

Thermal pollution has only slight environmental impact in the region, being notable only in the immediate vicinity of the few power plants where ocean or riverine discharge of cooling waters occurs. Radionuclide pollution has no known environmental impact of at present; there are no nuclear power plants in the region, although there may be some episodic discharge from nuclear-powered ships navigating through the area.

Environmental impacts
Microbiological

Microbiological pollution has caused moderate environmental impact in the region. Many areas have high levels of faecal coliform bacteria (e.g. Manila Bay) from inadequate sewage disposal and treatment, with, at best, rudimentary sewage treatment for much of the region. The production of wastewater in the region of the Philippines national
capital and nearby provinces is estimated at 74 million m³, while the volume of treated wastewater reached just 10 million m³ in 1994 at the Ayala and Dagat-Dagatan pond (FAO AQUASTAT 2003). Sewage is mostly treated by settlement and primary treatment consists of screening, particularly in the urban areas. Disposal of wastewater is expected to increase as new sewer lines are being built every year. In Indonesia, municipal and industrial wastewater is discharged virtually untreated into the waterways causing rapid deterioration in the quality of river water.

Eutrophication

Eutrophication in the region as a whole has had slight impact, although with moderate impact in some estuarine and coastal areas of the Philippines and Thailand. Nevertheless, it is important to note that eutrophication may be more extensive than has so far been scientifically documented because of generally high nutrient loading from agricultural as well as domestic sewage sources (Talaue-McManus pers. comm.). Hotspots certainly occur in the vicinity of coastal cities, and estuarine areas in non-urban settings where sewage or industrial discharges are directly dumped because of the lack of sewer connections to centralised sewage treatment facilities. This is commonplace in Indonesia, Vietnam and the Philippines, all of which have high total population and population densities. Impacts are most significant in enclosed bays, harbours and lagoons with limited water circulation (e.g. Manila Bay). Use of fertilisers, particularly in plantation agriculture, contributes to eutrophication through leaching into watercourses, although by world standards use is low.

At present, scientific data are scarce to non-existent and the effects of the nutrients are uncertain, depending partly on rates of mineralisation and retention of the dissolved nutrients. There is little evidence of visible effects on the abundance and distributions of biota, or fish or zoobenthos mortality other than in some enclosed bays and in the immediate vicinity of river mouths. There are no indications that eutrophication from agricultural run-off is a significant problem at the scale of the region as a whole, although occurrences of hypoxia have been reported in areas crowded with fish pens and cages especially during extended periods of reduced trade winds and reduced water turbulence, such as during the 1997-1998 ENSO event (Talaue-McManus pers. comm.). Examples of blooms of toxic dinoflagellates that have caused paralytic shellfish poisoning have been reported in some parts of the region. Initial estimates of global nutrient loading can be found in Smith et al. (2003), and the environmental dataset is available from the Land-Ocean Interactions in the Coastal Zone (LOICZ) web site¹.

Chemical

Chemical pollution has had moderate environmental impact, with use of pesticides in agriculture being a significant problem in areas of Vietnam, Philippines, Thailand and Malaysia. Use of chemical defoliants by the United States military during the Vietnam War has caused long-term pollution of some catchments and sediments. Mostly localised water contamination also occurs from industry (manufacturing, metal fabrication, ship repair and agricultural and food processing industries such as oil milling, sugar refining and meat and fish processing) and from mining, with contaminant loads concentrated near the discharges. Releases of chemical and other forms of pollution from shipping in harbours also commonly occurs, as regulations and controls relating to ship-derived pollution are rarely enforced. Much industrial waste, a result of economic activity along the coast, also goes straight into the ocean without treatment.

Overall emissions of organic water pollutants, measured by biochemical oxygen demand (BOD), vary widely among nations (Table 7). In the Philippines, emissions appear to have remained relatively steady from 1980 to 1993 with an average input per worker of 0.19 kg/day (World Bank 1999). The industrial sector’s share of organic water pollution was mostly contributed by food. In Indonesia by contrast, there appears to have been a rapid increase in emissions, during the same period. Here food is the major industrial contributor. Similarly in Malaysia, emissions of organic water pollution have increased, again with food being the major industrial contributor (Table 7). Pargal et al. (1997) note that in the case of Indonesia, the industrial sectors of textiles, leather tanning, food products, and pulp and paper are more BOD-intensive than other manufacturing sectors. Pulp and paper is significantly more intensive in organic water pollution than food products, although textiles and leather tanning are also relatively BOD-intensive; metals and machinery are least BOD-intensive. Pulp and paper and miscellaneous manufacturing are most intensive in total suspended solids (TSS), while

Table 7  Emissions of organic water pollutants in the South China Sea region.

<table>
<thead>
<tr>
<th>Country</th>
<th>1980 BOD load (kg/day)</th>
<th>1993 BOD load (kg/day)</th>
<th>Food industry contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>ND</td>
<td>12 078</td>
<td>ND</td>
</tr>
<tr>
<td>China</td>
<td>ND</td>
<td>6 500 000</td>
<td>ND</td>
</tr>
<tr>
<td>Indonesia</td>
<td>214 010</td>
<td>357 000</td>
<td>59</td>
</tr>
<tr>
<td>Malaysia</td>
<td>77 215</td>
<td>136 055</td>
<td>12</td>
</tr>
<tr>
<td>Philippines</td>
<td>182 052</td>
<td>181 714</td>
<td>53</td>
</tr>
<tr>
<td>Singapore</td>
<td>ND</td>
<td>33 331</td>
<td>ND</td>
</tr>
<tr>
<td>Thailand</td>
<td>ND</td>
<td>355 000</td>
<td>ND</td>
</tr>
</tbody>
</table>

¹ www.loicz.org

Note: ND = No Data.
(Source: World Bank 1999)
Machinery is least intensive. In the other South China Sea nations, total BOD emissions range across several orders of magnitude.

**Suspended solids**
Suspended solids have had severe environmental impact in coastal waters throughout most of the region. This has resulted from land use practices causing extensive deforestation in many watersheds, logging and mining, and urban development, compounded by high rates of erosion and siltation. Erosion is a major problem throughout the region (Naess 1999). Logging and ‘slash and burn’ agriculture create millions of tonnes of sediments that are transported through the rivers to coastal areas and river deltas. Sediments smother coral reef, mangrove and coastal ecosystems, and consequently destroy the productive breeding grounds for fish. There have been major changes in turbidity and levels of suspended sediments in Malaysia, Vietnam, Philippines, Indonesia (Sumatra and Kalimantan) and Thailand. These impacts, with extensive dredging and land reclamation, have caused major changes in biodiversity of affected benthic communities.

In the Philippines, of the order of 1 billion m³ of sediment is discharged into coastal waters annually, carrying high loads of particle-bound nutrients. This is of particular concern given that the timber industry has traditionally suffered from mismanagement and corruption, although there have been some recent improvements. Nonetheless, implementation of ‘best-practice’ forestry management, such as the retention of buffer zones along watercourses, is rarely enforced and violations are common. One exception to this is Palawan (Philippines), where logging was halted through effective implementation of legislation in the early 1990s, providing a major reduction in sediment loss from the catchments and much needed protection for the fringing coral reefs and other coastal and marine habitats (Hodgson & Dixon 1992). As noted above, in Vietnam’s Halong Bay, 900 million tonnes of polluted earth has been carried into the sea by rivers that traverse nearby coal-mining zones (South China Morning Post in Naess 1999). Underwater ‘hills of mud’ up to 30 m high have been created.

**Solid wastes**
Solid wastes have caused moderate environmental impact in the region but with severe impact locally, particularly around towns and villages where waste management is poor or non-existent. There is widespread litter on beaches giving rise to public concerns regarding recreational use, and impacting the tourism industry (e.g. many areas of Thailand, Vietnam, Philippines, Malaysia, Indonesia). There are high frequencies of benthic litter recovery and interference with trawling activities (e.g. Manila Bay and some other near-shore areas where half the trawls may be filled with solid wastes). Most cities, towns and villages are situated on the banks of rivers, and cannot manage their waste. The rivers are therefore used as deposits for solid waste (Naess 1999).

**Spills**
Spills have had moderate environmental impact at present. The South China Sea forms part of the major oil tanker routes between the Indian and Pacific Oceans (Figure 8), with episodic discharges from shipping (tankers, fishing boats, bulk carriers, ferries etc.), and occasional spills from oil exploration and production.

![Figure 8 Major shipping lanes in the South China Sea region.](https://via.placeholder.com/150)

Ship ballast discharges and ‘ballast-washing’ also regularly occur, impacting on all littoral countries to varying degrees. Etkin (1997) reported that over 800 million litres of oil had spilled into East Asian seas, including South China Sea, since 1965. International trade is expected to triple by 2020, and much of this trade will be transported by sea (Chua pers. comm.). Most of the countries in the region have ratified the UN Convention on the Law of the Sea (UNCLOS) and the International Convention on Prevention of Marine Pollution from ships (MARPOL), and have taken some steps towards developing oil spill contingency plans. Yet little spill control equipment is in place and implementation of emergency procedures is not well developed.

**Socio-economic impacts**
Socio-economic impacts of pollution in the South China Sea are all moderate. Most impacts are related to poverty and are concentrated in...
the major urban centres. There have been losses in fisheries (e.g. off the Malaysian Sarawak coast), economic losses to aquaculture facilities and shellfish industry through regular advisories of high levels of toxicity (e.g. Philippines, Vietnam, Indonesia, Thailand). There have also been losses in wildlife and recreational value in parts of the Philippines, and conflicts of land use in Philippines, Thailand and Malaysia. Health issues include harmful algal blooms and cases of mercury poisoning. There have also been costs associated with clean-ups and coastal restoration. There is a lack of data in the region to support these statements, however, the key impacts include:

- Increased risks to human health;
- Increased costs of human health protection;
- Loss of water supplies (e.g. potable water);
- Increased costs of water treatment;
- Costs of preventive medicine;
- Costs of medical treatment;
- Costs of clean-up;
- Loss in fisheries;
- Change in fisheries value;
- Costs of reduced fish marketability due to aesthetic perceptions;
- Reduction in options of other uses of freshwater;
- Potential for international conflicts;
- Damage to equipment (e.g. particle impacts);
- Avoidance of amenities and products due to perceptions of effects of contamination;
- Costs of preventative measures;
- Costs of contingency measures.

**Conclusions and future outlook**

For the Pollution concern as a whole, the present level of environmental impact is moderate. However, environmental impact of suspended solids is already severe, primarily resulting from deforestation over the past 150 years. To 2020, environmental impacts from pollution are likely to deteriorate, but remaining as moderate, primarily because of the predicted increases in forestry and agriculture, and a major increase in population overriding the improvements in infrastructure. Regulations and laws governing the sources of pollution have not been sufficiently developed or followed up by local and national governments as economic growth and industrial development are more highly valued than protection and management of the marine environment.

Although most of the countries have signed and ratified relevant conventions and treaties, many are unable to implement regulations effectively. There is seldom one ministry or department that coordinates the implementation and enforcement of anti-pollution laws. Further, policy makers generally view pollution mitigation or control projects as irrecoverable and unproductive investments (Naess 1999). Consequently, these have a very low rating when government funds are allocated to various sectors. The general lack of expertise and experience in implementing and conducting integrated and sustainable management of marine related pollution problems are a serious obstacle to their effectiveness. Data management and methodologies also vary from country to country, making it difficult to compare and synthesise data (Low et al. 1996, Naess 1999).

However, in some areas of most nations, efforts are now beginning to be made to clean up local pollution sources and impact sites, and implementation of regulations is improving. An early example was the establishment in February 1981 of the Memorandum of Understanding between Indonesia, Malaysia, Singapore and Japan of the Malacca Strait Council, when a Revolving Fund was set up to combat oil pollution from vessels in the Straits of Malacca and Singapore.

Nevertheless, the overall socio-economic prognosis for the future is for deterioration causing severe impact to the economies. By contrast, there is expected to be an improvement in health issues (becoming slight), and both improvement and deterioration in other social and community aspects (remaining moderate), mostly because of an increase in projects for pollution mitigation and control (e.g. sewage treatment). There are expected to be marked differences in the magnitude and success of such interventions among the different South China Sea nations, and both the direction of change and the rates of deterioration and/or improvement will depend on the success of ongoing and planned interventions. In the latter regard, an important recent initiative is the GEF funded UNDP/GEF/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas. The project focuses on four activities:

- Demonstration sites;
- Promotion of ratification of international conventions;
- Development of sustainable financing mechanisms;
- Capacity building.

This regional programme has been successful in bringing national and local governments, industry, donor agencies, NGOs and organisations in the international community together in environmental management projects in three selected sites. Ten countries are members of the programme, established in 1994. Detailed recommendations and strategies for implementing effective pollution management strategies in the region are contained in reports by Chua (1991), Chua & Pauly (1989), Chua & Scura (1991), Chua & Garces (1992) and Chua & Ross (1998) among many others.
Habitat and community modification

The South China Sea region lies within the global centre of biodiversity for marine species. The region supports some of the world’s most diverse seagrass beds and mangrove forests, as well as more than 2,500 species of marine fishes and 500 species of reef-building corals (Chou 1997, Veron 2000). Extensive cutting for timber, conversion for aquaculture (Figure 9), other forms of coastal development and sedimentation have caused major fragmentation and reduction in the area of these habitats (Talaue-McManus 2000). Only one-third of the original mangrove forests remain, while seagrass beds have been reduced or degraded by 20-50% through increased sediments, nutrients and destructive fishing. Key aspects of the ecosystems, habitats and biodiversity of the South China Sea are further discussed in the Regional definition.

Environmental impacts

Loss of ecosystems or ecotones

Loss of ecosystems has already caused severe environmental impacts, with permanent destruction having reduced the surface area of mangroves, seagrass beds, coral reefs, and riparian vegetation by more than 30% in the past several decades, from siltation, development and destructive fishing practices. Development of ports has resulted in foreshore reclamation and channel dredging, while muro-ami, blasting and poison fishing has damaged or destroyed large areas of coral reef. Seagrass beds, muddy and sand-gravel bottoms and fringing coral reefs are also impacted by trawling and siltation. For marshes, swamps, riparian belts, fast flowing stony bottomed streams and slow flowing sandy/muddy floodplain rivers the combined effects of human impacts, including agricultural expansion and, in the case of Vietnam, widespread military use of defoliants, have caused extensive habitat loss and fragmentation in many parts of the region.

Figure 9  Newly excavated aquaculture ponds north of Merang, Malaysia.
(Photo: J. Oliver, ReefBase)
The original area of mangroves in the South China Sea has decreased by 70% during the last 70 years. With a continuation of the current trend all mangroves will have been lost by the year 2030 (UNEP 1999), with millions of hectares of land, mostly mangrove forests, having already been converted for shrimp hatcheries and mariculture. In Singapore, more than 95% of mangroves and 60% of coral reefs have been lost (Figure 10). In Thailand, there has been major loss of mangroves and marshlands through changing land use patterns, loss of coral reefs through siltation, pollution and destructive fishing exacerbated by the lack of protection, and loss of seagrasses through coastal construction. In Malaysia, loss of mangroves is continuing through coastal development. In Indonesia, of the estimated 39 million ha of coastal and inland swamps, some 7.5 million ha have been identified as potentially convertible to arable land (FAO 1999). In Vietnam, by contrast, the loss of mangroves is being addressed through a major rehabilitation project at Can Gio (43 000 ha). Despite the continuing destruction, significant areas supporting good quality coastal and marine habitats still remain (e.g. Spratly and Paracel Islands; western Palawan, Philippines; and Con Dao Islands, Vietnam), both within and outside MPAs.

Figure 10 Coastal development near a mangrove estuary, Singapore.
(Photo: J. Oliver, ReefBase)

Modification of habitats or ecotones
Modification of habitats is also severe, with changes in species compliment/community structure (e.g. coral reefs), changes in population structures and/or functional group composition (e.g. coral reef fishes) and major changes in ecosystem services (e.g. reef fisheries, mangrove resources). For example, the important fisheries ‘nursery-ground’ roles of large sections of mangroves and seagrass beds have been seriously depleted, while about 80% of coral reefs have been degraded or are under severe threat from destructive and overfishing, siltation, pollution and development (Bryant et al. 1998, Burke et al. 2002). Freshwater habitats have also been impacted from introductions for example Tilapia and African catfish. There have been local extinctions in some areas for example loss of mud crabs in Rayong, loss of turtles and dugongs in many parts of Philippines and Vietnam through habitat loss and exploitation, and loss of freshwater fishes.

Socio-economic impacts
Coastal ecosystems
Loss of riparian and coastal vegetation, including mangroves and seagrasses, has had enormous socio-economic implications.
Mangroves of the South China Sea cover 4 million ha of the coastal areas, representing 28% of the world’s mangrove forest and have enormous economic (and environmental) value (UNEP 2004). Products and ecological services provided by these systems are estimated to be worth about 16 billion USD per year (Low et al.1996, Naess 1999, UNEP 1999). Further, the estimated value of seagrass and coastal swamp areas in the South China Sea region is 191 billion USD per year (UNEP 1999). As noted above, the original area of mangroves has decreased by 70% during the last 70 years. With a continuation of the current trend all mangroves will have been lost by the year 2030 (UNEP 1999). Subsequently, many of the shrimp farms had been abandoned, because the operators found them unsustainable due to the high concentrations of chemicals and the destruction of the mangrove habitat. Local NGOs claim that the donor agencies (including the World Bank) should be held accountable for environmental destruction caused by shrimp farming, and that the government should establish and implement clear criteria for sustainable shrimp farming and ways to rehabilitate damaged mangroves.

**Marine ecosystems**

Major economic costs are accruing from loss and modification of coral reef habitats, which are also of immense economic value. The reefs provide nursery and breeding grounds for 12% of the world’s total fish catch; contributing some 30% of East Malaysia’s total catch and 25% in the Philippines (Gomez 1988, Brookfield & Byron 1993, Low et al. 1996). In Southeast Asia, reefs are estimated to be worth more than 2.4 billion USD per year, based on their value in food security, employment, tourism, pharmaceutical research and shoreline protection (Burke et al. 2002). The reefs of Indonesia provide annual economic benefits of 1.6 billion USD per year in 2002, however over the next 20 years, human impacts, notably overfishing, destructive fishing and sedimentation could cost Indonesia some 2.6 billion USD (Burke et al. 2002). Figure 11 shows the reefs at risk in the South China Sea region.

**Fishing**

In the case of destructive fishing, the bombs, usually constructed from bottles stuffed with explosive potassium nitrate, detonate underwater, killing or stunning fish so that they are easy to net. There is considerable collateral damage to reef communities, with localised death and injury to all incident species, and coral mortality rates of 50 to 80% (Hopley & Suharsono 2000). For the fisherman, the short-term gains from bombing may be impressive, with a 1-2 USD investment returning up to 15-40 USD in profit on the local market. Moreover, given the ease with which fish bombs are assembled (potassium nitrate is a common component of fertiliser), fishermen seldom want to make the switch to more sustainable, but time-consuming, technology like spears and hooks. As a result, in many coastal areas, bombed reef fish often dominate local markets. But the practice has a devastating effect on coral reefs, which may take more than 50 years to recover.

Cyanide use can be nearly as destructive as blast fishing, but its focus is often the international market, rather than local supply. Prized reef fish like grouper (Serranidae) and Napoleon wrasse (*Cheilinus undulatus*) are chased into corals, where the diver uses cyanide-filled squirt bottles to stun the fish for capture and sale on the live reef fish market. These fish are usually shipped aboard large cargo ships to discerning diners in Hong Kong, Singapore, and Taiwan, where the fish are picked out of aquariums just prior to cooking. The cyanide does more than stun the fish, though, as coral is killed as well, particularly since the divers often have to tear apart the coral structure with crowbars to pull the fish out.

**Tourism**

Although often considered a relatively benign ‘non-extractive’ industry, additional socio-economic impacts can accrue from tourism, usually at...
two stages in the development of the industry (Hopley & Suharsono 2000). The early construction phase may employ damaging techniques of land clearing and quarrying of the coastline and fringing reefs for resort construction. After the resort is occupied, damage may result from sewage disposal, anchor damage at dive sites (mooring facilities are not normally installed) and breakage of corals by inexperienced divers and snorkelers (particularly where operators are not trained to give environmental advice to the tourists). Tourism may also create conflict with the local communities (e.g. Djohani 1995).

Thus present socio-economic impacts of habitat and community modification range from slight (Health) to severe (Economic and Other social and community impacts), primarily because of:

- Reduced capacity to meet basic human needs (food, fuel) for local populations (many areas of South China Sea);
- Changes in employment opportunities for local populations and associated changes in social structures (e.g. Thailand, Vietnam, Philippines);
- Loss or reduction of existing income and foreign exchange from fisheries, tourism, and other uses (many areas, but also attributable to factors additional to habitat loss);
- Human conflicts, national and international (e.g. territorial disputes over exploitation of Spratly Islands reefs);
- Injury and death to fishermen using destructive fishing methods (e.g. blast fishing in many areas);
- Loss of future opportunity for investment income and foreign exchange, and increased risks to capital investment (e.g. failure of coastal aquaculture projects in many parts of the region);
- Costs of controlling invasive species (e.g. Tilapia);
- Costs of restoration of modified ecosystems (e.g. coral reef and mangrove forest restoration programmes are already being undertaken);
- Inter-generational inequity.

There are particularly serious economic issues in fishing communities, where local fishermen are unable to catch sufficient fish for sustenance.

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**Figure 12**  Cora reefs: Left: Lemon damsel (*Pomacentrus mollucensis*) and mixed coral species, Pulau Perhentian, Malaysia. Right: Crown of thorns starfish, north of Pulau Gut off Pulau Tioman, Malaysia. (Photo: B. Huzaimi, ReefBase)
There are also economic conflicts between investors and local users, and also from loss of mangrove habitats, loss of charcoal production and costs of rehabilitation, and failures in aquaculture. There are also health (loss of traditional medicines, pharmaceuticals, potential increases in mosquito-borne diseases), educational and scientific issues arising from habitat loss. Other social and community impacts include relocation of villages and conflicts among different user groups (e.g. among shallow and deep water fisheries). Progress in managing human use of habitats is not expected to be sufficient to fully mitigate the damaging effects of population growth.

Conclusions and future outlook

As with the neighbouring regions of Sulu-Sulawesi Sea and Indonesian Seas, the major causes of loss and modification of the freshwater, coastal and marine habitats include:

- Siltation, conversion for aquaculture, agriculture, industrial development affecting marshes, swamps, rice paddies and riparian belts;
- Deforestation, siltation, damming and waste disposal affecting rice paddies and rivers;
- Silica mining and solid wastes affecting sandy foreshores;
- Aquaculture conversion and timber collecting affecting mangroves;
- Sediment run-off, siltation and dredging affecting seagrass beds and coral reefs;
- Destructive fishing affecting coral reefs;
- Trawling affecting soft-bottom habitats;
- Mid-water trawling, drift netting and other forms of pelagic fisheries, oil and gas exploration and pipelines affecting oceanic habitats.

For the Habitat and community modification concern as a whole, present level of environmental impact is already severe, although there are some positive steps. These include mangrove rehabilitation programmes, notably in Vietnam, and the protection of forests, watersheds and reefs in some areas (e.g. Palawan, Philippines). UNEP has undertaken the Coastal Marine Environment Management Information System (COMEMIS), to help improve the region’s capacity to make sound environmental assessments through GIS. Even some habitat modifications, such as a coastal reclamation project in Singapore, have had positive effects, providing a nesting site for turtles and birds.

At present, most habitats are only poorly represented in protected areas and of those, many are poorly managed. For example, approximately 4% of Philippine coral reefs are listed as being protected, although most of these are being degraded at increasing rates from destructive fishing, sedimentation and pollution, and a lack of enforcement. There are only two international protected areas conserving coral reef habitats in the region (Figure 13). Approximately 125 other marine protected areas have already been gazetted, although there are insufficient resources for management and enforcement of fisheries and other regulations in many MPAs at present, which limit their effectiveness. By contrast, several small community-based management initiatives have proven very successful at protecting coral reefs and facilitating replenishment of reef-based fisheries (e.g. Apo Island in the neighbouring Sulu-Celebes (Sulawesi) Sea region) (Russ 1985, Russ & Alcala 1996a, b).

Future levels of environmental impact are expected to remain as severe, with both some improvement and some deterioration to 2020. Future socio-economic scenarios are also for significant deterioration by 2020, with severe economic and other social and community impacts, and both deterioration and improvement in the health situation, which should remain as slight.

Given that the region lies at the centre of global biodiversity, with adjacent regions of Indonesian Seas and Sulu-Sulawesi Sea, the present situation and future prognosis indicate that more extensive and intensive intervention is required, including (PEMSEA pers. comm.):

- Direct on-the-ground community-based conservation programmes, including further development of protected areas;
- Training programmes to build additional long-term capacity among governments, NGOs, and communities;

![Figure 13 International and national protected areas in the South China Sea region.](Source: UNEP/WCMC 2003)
Assessment programmes for identification of critical areas for biodiversity (e.g., through government agencies and NGOs such as WWF, IUCN, The Nature Conservancy and Conservation International); Multilateral integration to maximise effectiveness of obligations under international conventions and treaties (e.g., the Convention on Biodiversity, UNCLOS, MARPOL, Ramsar Wetland Convention).

Conservation of representative habitats through continued development of protected areas is a regional priority of global importance. Nations bordering the South China Sea already have many legally designated protected areas including coastal and marine habitats, and some multilateral conservation agreements have been established. Of the more than 125 coastal and marine protected areas in the region, many contain coral reefs (Spalding et al. 2001, and see Cheung et al. 2002 for comprehensive lists and tables). There are also two World Heritage sites (Halong Bay, Vietnam and Puerto Princesa Subterranean River National Park, Philippines), although their inscription on the World Heritage Register was primarily for geomorphological and cultural features, rather than habitats. The effectiveness of many MPAs is limited at present by insufficient resources for management and enforcement of regulations, with just 10-20% considered as effectively managed (Box 3) (Cheung et al. 2002).

Recommendations for priority actions in regard to improving MPAs in the region include (Cheung et al. 2002):

- Implement legislative reforms;
- Incorporate planning and management into an Integrated Coastal Management framework;
- Develop/enhance sustainable financing to continue adaptive management including co-management;
- Fill gaps in establishment of representative MPAs in underrepresented biogeographic zones;
- Establish/improve joint research and cooperative management areas.

Many lessons have already been learned from the few successful MPA models, and the future successful development of protected areas will include extensive community and stakeholder consultation, education and regulations offering real protection, with agreement and strong support from the customary resource owners and users. In collaboration with the respective governments, national to local, several international NGOs, including WWF, IUCN and The Nature Conservancy, are presently working towards assessment and management of critical biodiversity sites in the region.

Box 3 Marine Protected Areas in Southeast Asia.

The ASEAN countries have developed several models for the management of MPAs:

- Centralised or top-down whereby they are managed by a single authority, normally the government. This often applies in Indonesia, Malaysia, Thailand and Vietnam.
- Local, bottom-up level, such as the predominantly community-based management projects in Indonesia, Thailand or the Philippines.
- Shared between several stakeholders. This usually involves the community and government, but could also include NGOs, IGOs and universities, thereby constituting collaborative or co-management strategies.

There are numerous case studies of successful management of MPAs in Southeast Asia, with the collaborative and community-based management strategies being especially fruitful, demonstrating that the paradigms for sustainable management of coastal and marine resources in the region have already been developed. However, these examples appear to be the exception, as the statistics illustrate that marine resources are failing to get the adequate attention that they require. Only 7% of the total number of MPAs in the region are effectively managed, while 68% have poor or unknown management. Thus, most MPAs, while they look good on paper, can be regarded as ‘paper parks’. They have been declared as MPAs, but they are protected only in theory and not in practice, as there are no management plans and only weak attempts at implementing effective control of national regulations. For many, the management effectiveness rating is ‘unknown’ (48.6% of the MPAs in the region), which probably indicates that there is no management. Alternatively, this lack of information may be partly explained by the political and security sensitivities in Southeast Asia with some areas inaccessible for research and monitoring. This status is largely due to a lack of field knowledge, experience, and political will from the governments.

(Source: Wilkinson et al. in press)

Unsustainable exploitation of fish and other living resources

The South China Sea ranks fourth among the world’s 19 fishing zones in terms of total annual marine production. Southeast Asian Seas annually yield approximately 7 million tonnes of fishery resources (McManus 1994). The annual value of this catch exceeds 6.5 billion USD. The ASEAN nations export nearly 1 billion USD worth of fish products annually. More significantly, fisheries contribute approximately 65% of the animal protein consumed in countries such as the Philippines, Malaysia, and Indonesia, with the highest dependencies being found among the poorest coastal people (McManus 1994).

Areas adjacent to the Spratly Islands are particularly productive, such that the annual catch from the reef-studded waters of the Sabah-Palawan area is about 10,000 tonnes, valued at approximately 15 million USD. The local fish stocks in most of these areas are heavily fished. Adult fish are very difficult to find on some reefs in the region (McManus 1994).

Figure 14 shows catches in the South China Sea LME by country. For more information on the South China Sea LME see Box 4.

As with neighbouring regions, neither status nor future viability of the fish stocks are well understood, and for many fisheries, their status may be summarised as being illegal, unreported and unregulated (IUU). There are significant gaps in data on population dynamics for some
fisheries. Data issues affecting significant areas of the region include (Alban pers. comm.):

- No village statistics, with little or no capacity to collect fisheries statistics at village level;
- No data on reef and other fisheries;
- For artisanal fisherman, a resistance to collect or understand/use data, rather traditional judgements/knowledge prevail;
- Lack of data on fishing grounds, their location, extent, seasonality, productivity;
- Lack of integration, appropriate use of data in management, with urgent need for better coordination;
- Data often not management-related, having been collected for science, not for fisheries management;
- Data reliability issues;
- Field data reporting systems and standardisation varies across fisheries and countries (e.g. log books), with significant effort needed to define what is unique and what is shared, what works and does not;
- Funding difficulties in developing standard data collection and reporting for shared fisheries - relevant to management of the South China Sea as a whole (e.g. PISCES genetic project to define relations among stocks in South China Sea).

Scale of the different fisheries is another major issue, with substantial differences among different fisheries; commercial inshore/offshore/ international foreign offshore, in terms of boat numbers, sizes, catch capacity, area sizes fished and gear types. This leads to increasingly complicated management strategies related to multi-species fisheries.

Environmental impacts

Overexploitation

Overexploitation in the South China Sea region has already had severe environmental impacts (Box 5). Many stocks, including demersal reef fish, holothurians, molluscs and crustacean stocks, are considered to be exploited beyond Maximum Sustainable Yield (MSY), partly through overinvestment and with encroachment of large-scale commercial operations, including incursions by foreign vessels using long drift nets into traditional/artisanal fishing areas. There is also overexploitation of sharks, tuna, bill-fish and other pelagic species. Sharks are also caught as

Box 5 Overexploitation in the South China Sea region.

The GIWA regional Task team raised concerns about the GIWA definition of overexploitation: “Overexploitation refers to the capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock.”

The concepts of Maximum Sustainable Yield (MSY) are outdated, see e.g. Jackson et al. (2001) and Pauly et al. (2002). More appropriate criteria would include proportions of spawning biomass for individual species and a ‘whole of ecosystem’ approach to multi-species fisheries. In particular, there are significant differences between tropical multi-species and multiple trophic level fisheries versus temperate single-few species and trophic level fisheries, in relation to:

- Multiple gear selection, adaptation, modification in response to fisheries diversity and level of poverty of fishermen (some fishermen cannot afford to diversify into specialised gear);
- Increasing coastal populations, initially target common species (e.g. mullet), but overexploitation leads to diversification to non-target species;
- Fish meal/oil production encourages fishermen to take everything;
- Targeted by catch e.g. turtles.

Given the above, the four defined categories of overfishing; recruitment, growth, target and malthusian, all occur in the region and have different impacts in the different fisheries/nations, in relation to natural fluctuations in stock population sizes from:

- Recruitment variability, large annual fluctuations in recruitment, cohorts, size/year classes, differences in susceptibility to overfishing among year classes, climate effects on recruitment and distribution;
- Differences in life history characteristics across species, degree of aggregation, spawning sites susceptibility to overfishing.

These natural fluctuations produce significant inter-annual variability in stock sizes that in turn affect productivity and the socio-economics of the different fisheries, be they subsistence or industrial. Subsistence fisheries are largely limited to shallow coastal waters because of lack of equipment and/or knowledge. This can lead to tension with foreign fishermen who have broader options.
by-catch of the trawl fisheries and the tuna long-line fishery. Additionally, the benthic invertebrate fisheries, particularly for sedentary species of holothurian sea cucumbers (Trepang or Beche-de-mer), trochus, green snails and clams, are overfished, particularly around the major coastal population centres. Spiny lobsters are also targeted in oceanic waters, sandy reef lagoons and flats and mangrove areas.

Poison fishing for demersal reef fish is also widespread having burgeoned in the 1990s to supply the live fish food trade in Hong Kong and China, and also the aquarium trade, with prices increasing but catch per unit effort (CPUE) declining sharply (Cesar et al. 2000). Existing fisheries for endangered species (turtles and dugong) are continuing, and there have been localised species extinctions.

There has also been a significant recent increase in effort in the pelagic fisheries. For example, data from the Philippines Department of Agriculture suggest that yields of some pelagic species have continued to increase, but that catch per unit effort has declined steadily, suggestive of ‘ecosystem overfishing’. In Malaysia, Sabah’s fishery stocks have declined by 70% since 1995. In Thailand, the Gulf of Thailand provides a classic case-study of a collapsed fishery (Pimoljinda & Boonraksa 1999).

Further, around 70% of coral reefs in the broader region (including Sulu-Sulawesi Sea and Indonesian Seas) are heavily overfished, producing less than 5 tonnes/km²/year, with clear indications of ‘trophic overfishing’, in comparison with the remaining 30% of reefs which produce of the order of 15-20 tonnes/km²/year (DeVantier et al. 2004). Data from reefs of the Philippines indicate that carnivorous families of reef fish will not fully recover their pre-fished levels of biomass for 20-40 years after effective protection has been implemented, when 20-25 kg of catch may be taken from 1 000 m² of reef area annually (equivalent to 20-25 tonnes/km²) (Alcala pers. comm.).

At present, neither status nor future viability of some fisheries are well understood in parts of the region, and their status may be summarised as being illegal, unreported and unregulated.

Excessive by-catch and discards

Environmental impacts of excessive by-catch and discards are also severe, although some of the assessment criteria are largely irrelevant to the situation in the region. Here, there is little to no by-catch or discards, as virtually all of the much-diminished catch - including turtles, sharks and even whales - is kept and eaten, with massive overexploitation of species regarded as by-catch in other regions.

There is however widespread capture, either intentional or accidental, of rare, threatened and endangered species in traditional and commercial fisheries. These are usually kept as part of the catch. Smaller ‘trash’ fish taken in trawls are used as feed in aquaculture. Further, substantial, though unquantified, levels of by-catch are produced by distant waters fleets, through use of blast fishing and poison methods, and in the milkfish and shrimp fry fisheries, where juveniles of all other species are discarded. There is also considerable targeted and incidental capture of endangered species of turtles and dugong. The Philippines and Malaysia have developed a bi-national agreement for conservation of marine turtles, but this is not observed in remote areas. In many areas there are few biological regulations in fisheries, or enforcement.

Destructive fishing practices

Destructive fishing is also having severe environmental impacts. Massive habitat destruction and fragmentation, and changes in population and community structure are occurring from trawling and mechanised ‘push-netting’ (with minimal use of by-catch exclusion devices), widespread use of explosives (reef bombing), electric fishing, ‘muro-ami’ and use of poisons for fishing. Widespread reef bombing has been attributed to increasing competition among fishers and corresponding declines in catches. Many reefs in the region have also been targeted with poison fishing for the live fish food trade in Hong Kong and mainland China, initially using potassium cyanide or sodium cyanide and more recently also using poisons derived locally from plants. Poison fishing has also been used in collection of ornamental reef fishes for the international aquarium trade. Figure 15 shows a fish trap off the coast of Sharp Island, Hong Kong.

Decreased viability of stocks through contamination and disease

Decreased viability of stocks has no known environmental impact at present. However, there are some developing problems arising from...
the increased occurrence of ‘red tides’, diseases in pilchards and diseases spreading from aquaculture farms. In areas adjacent to the region, there has been a marked decline in aquaculture production in some lakes, with Tilapia culturing affected in approximately 10% of lakes in the Philippines. In the Java Sea, part of GIWA region 57 Indonesian Seas, major loss of maricultured prawns has occurred, with disease spreading into wild stocks.

**Biological and genetic diversity**

Biological and genetic diversity has moderate environmental impact in the region, but with severe local impacts. There have been extinctions of native species and local stocks as a result of introductions and a clear decrease in heterozygosity in cultured fish stocks (e.g. Tilapia). The introduced fishes are eating and displacing endemic fishes in the Philippines, Vietnam and other areas, with corresponding changes in community structure and diversity. There is also evidence of reduction in genetic diversity in milkfish stocks in the Philippines due to repeated spawning of cultured offspring, and release of cultured broodstock into the wild.

**Socio-economic impacts**

Socio-economic impacts related to unsustainable exploitation of fish are severe from economic and other social and community aspects, with moderate health effects. There has been widespread loss of income from fisheries collapse and loss of productivity (e.g. Gulf of Thailand), with concomitant shifts in target species. Fishing ‘down the food-chain’ is widespread in most, if not all, countries of the South China Sea. There have also been increasing levels of competition for fisheries resources among traditional artisanal fishermen and commercial and foreign fleets.

In the Philippines and elsewhere, the fishing sector has the highest birth rate and highest levels of poverty. In many areas, fisher families’ children are malnourished as most fish are sold and fish consumption has declined from approximately 36 kg/person/year to 24 kg/person/year, with consequent high levels of malnutrition (DeVantier et al. 2004). There are few alternative options, and the levels of poverty are such that many children are ‘trapped’ into fishing. Injuries and deaths from blast fishing and diving are common, with frequent deaths of children during muro-ami fishing. There are also conflicts among different fishing groups, influx of foreign nationals to the fisheries, with conflicts on the fishing grounds. It is estimated that a 50% reduction in fishing effort will be needed to restore many fisheries to sustainable levels, particularly in the municipal coastal fisheries which, at present, are 90% artisanal and 10% commercial (DeVantier et al. 2004). It is also predicted that there will be a major deficit in wild-caught fish production by 2010, to be supplemented by aquaculture. Figure 16 shows fish pens in Manilia Bay, Philippines.

Disputes over sovereignty of the Spratly Islands have resulted in significant levels of multilateral tension in recent years. Some of the states have even used arms to prevent other nations from occupying islands or reefs (Naess 1999). Examples include an incident in 1988 when a Vietnamese attempt to stop the Chinese occupation forces led to the sinking of Vietnamese ships and drowning of more than 70 men. Subsequently, tensions have developed between the Philippines and China.

Given the above, the key socio-economic impacts of unsustainable exploitation of living resources in the South China Sea region include:

- Reduced economic returns and loss of employment/livelihood (e.g. from overexploitation causing fishery collapse in the Gulf of Thailand and elsewhere);
- Conflict between user groups for shared resources (e.g. between local and outside/foreign fishermen, Vietnam and elsewhere);
- Loss of food sources (e.g. sources of protein) for human and animal consumption (e.g. reduction in consumption among poor fisher families in Philippines and elsewhere);
- Reduced earnings in one area by destruction of breeding populations and/or juveniles in other areas (migrating populations, widespread throughout the region);
- Loss of protected species (e.g. turtles, dugongs, whales, which is widespread throughout the region);
- Reduced commercial value resulting from tainting (particularly in areas adjacent to major population centres);
Box 6  
**Fisheries status and prognosis for South China Sea.**

In the South China Sea, the fisheries situation resembles malignant and incongruent problem. Fishing fleets of individual countries are depleting the common resources of the sea, thereby causing long-term costs (loss of future fishing opportunities) to all, and reaping short-term benefits at the cost of others. Although there are bilateral attempts at improving the current situation (e.g., China’s fishing ban), regulation of fisheries is dependent on a regional approach to the problem where all littoral (states) have to commit themselves to agree upon a limit to annual catches. The long-term effect of this development might lead to the break down of the ecosystem. Scientists of the region have published widely on the current situation of important ecosystems and of fisheries, they have attended numerous regional conferences, and they participate in government funded projects, but as the political will to pursue environmental policies, based on this knowledge, remains limited, as protection and management of South China Sea ecosystems is left to the individual state. Consequently, no political space is left for non-state actors, such as marine scientists, to influence in practice the development of the marine environment of the region.

(Source: Excerpted from Naess 1999)

- Increased risks of disease in commercially valuable stocks (aquaculture diseases affecting productivity and also infecting wild stocks are all widespread throughout the region);
- Inter-generational equity issues (access to resources);
- Human health impacts (child malnutrition, direct risks to blast fishermen, diving injuries to dive fishermen are all widespread throughout the region).

**Conclusions and future outlook**

For the GIWA concern of Unsustainable exploitation of living resources, the present level of environmental impact is severe. Because of the increasing coastal population, greater commercialisation, decline in resources, lack of effective regulation and poor to non-existent enforcement, there is expected to be a significant environmental deterioration. This will be manifested mostly through overexploitation, lack of by-catch and discards, destructive fishing and changes in diversity, and with the potential for decreased viability of stocks, such that the level of environmental impact in 2020 is expected to remain as severe, and get worse than the current situation (Box 6).

Furthermore, all the socio-economic indicators are expected to deteriorate, with severe economic and social and community impacts and moderate health impacts associated with overexploitation of fish by 2020. This prediction may be ameliorated to some degree by improved enforcement of regulations (e.g. Philippines Fisheries Code, Chinese fishing bans in some areas) and through successful interventions by government and NGOs.

Most South China Sea nations recognise that fisheries are resources that are threatened if the current trend continues, but they also need the fishery products to feed their populations and to uphold industries based on fishery production (Naess 1999). East Asia was the fastest growing economic region in the world in the 1980s and 1990s, and also one of the most heavily populated. The governments have to provide food for their people, and seafood is the main source of animal protein for most Asians (two-thirds of the animal protein consumed in Asia comes from fish and crustaceans) (Coulter 1996). Thus, there is constant competition between socio-economic and environmental concerns, where the socio-economic concerns often win as food and economic income are more important to the individual and the government than sustainable use of coastal resources (Naess 1999).

It was the unanimous view of the GIWA Task team that the region’s fisheries stocks, as with stocks in neighbouring Sulu-Celebes (Sulawesi) Sea and Indonesian Seas, are in urgent need of careful stewardship if their sustainable future utilisation is to be assured. This will primarily require a high degree of local intervention and community-based support, and effective enforcement of fisheries regulations. There also needs to be more reliable stock assessment and monitoring, founded in improved understanding of the population biology of the target species and issues of ecological scale and connectivity in relation to replenishment. There is strong potential for well-planned mariculture of some ornamental and food species, with the need for development of appropriate policy and legislation.

**Global change**

The southern part of the marine region, with adjacent Indonesian Seas and Sulu-Sulawesi Sea, forms part of the “heat engine” of global atmospheric circulation, with complex ocean-atmospheric dynamics. The northern and central parts of the region are affected by typhoons during the southwest monsoon months, bringing destructive winds as well as intense rains in excess of 1 000 mm of rain in less than 1 week (Figure 17). The warm ocean and its links to the atmosphere contribute to the El Niño Southern Oscillation (ENSO) phenomenon. The influence of El Niño, La Niña and the Australian and Asian monsoons contribute to the unique climate conditions in this region, an object of global climatology research. The region also has complex oceanography and current flow (see Regional definition).

The GIWA Task team identified the need to include an additional issue with major implications for coral reefs in the region: Changes in sea surface temperature (SST). Criteria used for scoring this issue are appended in Annex VI. At the time of the assessment in 2001, there were no known environmental impacts associated with sea level change, increased UV-B radiation and changes in ocean CO₂ source/sink function in the region.
Environmental impacts
Changes in hydrological cycle and ocean circulation
Changes in the local/regional water balance in recent decades and increased variability of current regimes (including those caused by changes in ENSO events) have had slight environmental impacts. There is anecdotal evidence for changes in coastal currents and erosion patterns in Thailand and in oceanographic upwelling patterns following ENSO (e.g. Philippines) and hydrological evidence of changes in rainfall and storm patterns (e.g. Sabah).

Changes in sea surface temperature
Changes in the sea surface temperature has also had a slight impact already, with changes in the structure of coral reef communities from elevated SSTs during various coral reef bleaching events since 1983, notably during mid-1998. There has been good recovery of most bleached areas and, on average, none of the bleaching events appear to have been as severe as those from some other countries, with the caveat that most data are anecdotal (Wilkinson 2000, 2002).

Socio-economic impacts
The socio-economic impacts associated with Global change, as they relate specifically to international waters, are negligible to slight, with a major degree of uncertainty remaining. There have been some economic and health effects associated with drought and linkages to habitat loss (clearing and forest fires) and freshwater shortage, particularly overextraction of freshwaters and salination of wells. Health effects include potential links to dengue and haemorrhagic fever and respiratory illnesses from haze and forest fires, with some displacement of communities due to fires and floods.

The following key socio-economic indicators are likely to be adversely affected to greater or lesser degree:
- Freshwater availability;
- Food security;
- Employment security;
- Changes in productivity of agriculture, fisheries and forestry;
- Changes in resources distribution and political jurisdiction;
- Response costs for extreme events;
- Loss of income and employment;
- Loss of incomes and foreign exchange from fisheries;
- Loss of opportunity for investments (both domestic and foreign);
- Increased costs of human health care.

Conclusions and future outlook
According to Talaue-McManus (2000 and pers. comm.) there is sufficient evidence of major environmental changes resulting from global climate change in the region. While the socio-economic impacts are yet to be evaluated, their signature on SSTs as well as long term changes in air temperatures and on atmospheric chemistry are unequivocal. Nevertheless, assessing the impacts of Global change using the GIWA scoring criteria determined that this concern had only slight overall environmental impacts at the time of the assessment. Environmental impacts are expected to deteriorate, but remain slight by 2020. There are increasing per capita releases of CO₂ and the increasing population will increase local production of greenhouse gases. However, there is considerable uncertainty in climate model predictions of changes in temperature and sea level, and also in the capacity for acclimation and adaptation of species and ecosystems. Corresponding socio-economic aspects are also expected to deteriorate, with moderate levels of economic impact and other social and community impacts and slight health impacts by 2020.
Priority concerns for further analysis

Future scenarios suggest a rapid human population increase, with increasing urbanisation and increasing reliance on industrialisation and extractive industries. This population explosion is driven primarily by socio-cultural and religious attitudes, and influenced by factors as diverse as world trade, tourism, industrialisation, fisheries, and oil exploration and exploitation. The region’s rapid economic development and population growth are the cause of significant ecological damage in coastal and marine areas. The primary environmental threats by humans in the South China Sea are the destruction of mangrove forests, sewage pollution, exploitative fishing practices and overfishing, coral reef degradation, and damage to seagrasses and wetlands (LME 2004).

There are likely to be significant increases in industrial fishing and aquaculture (shrimps, seaweeds) in the region. Exploitation of commercial pelagic fisheries for tuna and billfish is expected to increase by 2020. The increasing reliance on motorised fishing craft and major increase in industrial fishing is expected to cause severe overexploitation with decreasing production from coastal and reef fisheries, and concomitant food shortages. Regulating fishing pressure provides a complex management challenge, with important linkages to the application of Marine Protected Areas (MPAs) in stock replenishment. Future protection of coastal and coral reef areas will be important if these key habitats at the global centre of biodiversity are to be sustained.

There are trends of increasingly large-scale forestry, by both national and international commercial operators. Large areas of the ‘loggable forests’ have already been logged and other areas have been assigned for logging, contributing to severe soil erosion in many areas. Large-scale sediment mobilisation from unregulated forestry and agriculture has already impacted on water quality of streams and rivers and ultimately on estuarine and coastal habitats (e.g. fringing reefs) and processes in much of the region.

There is potential for expanded offshore oil and mineral exploration, and increased tanker traffic through South China Sea between Japan and the greater Pacific Ocean and the Indian Ocean - west Asia-Europe, with attendant risks of collisions and spills (Etkin 1997, MPP/EAS 1998, Chua pers. comm.).

Expansion of fisheries, mining, various forms of plantation agriculture and forestry, increasing urbanisation and manufacturing will further increase pressures on catchments and rivers, and increasing water shortages are likely to impact on a large proportion of the population. There will be limits on other sectors from freshwater shortage and other concerns. Thus, total pressures on international water resources are likely to increase moderately, causing significant deterioration in both the environment and socio-economic structures, despite improved regulation.

The worst affected areas face moderate to severe environmental impacts causing severe socio-economic hardship by 2020. Despite recent improvements in national and regional capacity, there remains insufficient capacity for effective policing or enforcement of regulations or for developing measures for alleviation of existing water-related problems, primarily because of low finance and a relatively small taxation base. There are already serious health issues arising from episodic freshwater shortage. The rate of deterioration can be minimised by ongoing and future planned interventions, including those at multilateral, national, provincial and local government levels and through the concerted efforts of several international NGOs. Nonetheless, continuing international assistance will be required in the short term for major improvement in international waters-related issues.

For the present, six of the 23 environmental GIWA issues are already having severe impacts:

- Suspended solids;
- Loss of ecosystems;
- Modification of ecosystems;
- Overexploitation of fish;
- Excessive by-catch and discards;
- Destructive fishing practices.

There was an unambiguous overall prioritisation of the five GIWA concerns, when assigning equal weight to environmental, economic, human health and social and community impacts:

1. Unsustainable exploitation of fish and other living resources is of highest priority, with severe present levels of environmental, economic and other social and community concerns and moderate health impacts.
2. Habitat loss and community modification is of equal priority from environmental, economic and other social and community impacts, but of slightly less priority in terms of health impacts.
3. Pollution is of third priority, with moderate levels of environmental and socio-economic impact.
4. Freshwater shortage is of fourth priority, with moderate levels of environmental and economic impact, but only slight health and other social and community impacts at present.
5. Global change is of fifth priority, with only slight present environmental and socio-economic impacts.
These findings are consistent with those of the UNEP Transboundary Diagnostic Analysis (TDA), which rated habitats (mangroves, coral reefs, seagrasses and estuaries) and marine and freshwater fisheries as the highest priority concerns, followed closely by pollution (sewage and freshwater contamination) and freshwater concerns (Talaue-McManus 2000). Thus, these two large-scale analyses (TDA and GIWA), using different approaches, have concurred on the key international waters concerns in the region. Both analyses confirm that the international waters environment and socio-economy of much of the South China Sea are already under severe impact, requiring continued concerted national and international intervention for any chance of amelioration in the short to medium-term.

There is expected to be deterioration in the environmental and economic impacts of most GIWA concerns, but with some stabilisation and even improvement in others, notably for health and other social and community aspects. There is also expected to be widening gaps in both implementation and success of interventions among different countries.

With equal weighting applied to the four indicators, there was little overall change in scores or ranking for the future:
1. Unsustainable exploitation of living resources.
2. Habitat loss and community modification remain jointly of primary concern and are expected to have severe environmental and mostly moderate to severe socio-economic impacts.
3. Freshwater shortage ranked third and is expected to have moderate environmental and socio-economic impacts.
4. Pollution is also expected to have moderate environmental and socio-economic impacts and is ranked fourth because there will be an increase in pollution-mitigation projects in the region.
5. Global change, with slight to moderate impact, ranked fifth.

Future impacts from Global change were sufficiently uncertain for it to rank as the least of the GIWA concerns for 2020, although potentially strong linkages with freshwater shortage and habitat loss and community modification were identified, complicating the prioritisation analysis.

Global change is expected to impact on freshwater shortage and oceanography and on habitat loss. Other two-way linkages with high potential for ‘feedback’ will occur between freshwater shortage, pollution and habitat loss and between habitat loss and overexploitation of fish. Global change effects on freshwater shortage are likely to be manifested through changes in the frequency and intensity of ENSO events. ENSO during the 1990s caused water shortages in some parts of the region and flooding in others. Future predicted increases in both the frequency and intensity of ENSO events are likely to have major environmental and socio-economic impacts, particularly given that the human population is expected to double by 2033. Global change effects on habitats are predicted to be manifested through both freshwater shortages and flooding, particularly in lowland stream, river, marshland and riparian communities. Potentially severe global change effects are also expected for coral reef habitats, through the synergistic effects of changes in ocean alkalinity affecting reef calcification processes (Kleypas et al. 1999) and through elevated SSTs causing widespread reef bleaching and death (Hoegh-Guldberg 1999, Wilkinson 2000, 2002). There are also expected to be severe consequences from complex linkages between habitat loss and fisheries, and pollution and fisheries. It is expected that environmental and socio-economic impacts of climate change will increase after 2020.

The following causal chain analysis will focus on the linkages between Habitat and community modification and Unsustainable exploitation of living resources, particularly the environmental and socio-economic impacts and causes of overfishing and destructive fishing practices.