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, Overexploitation 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 13. Detailed scoring information is provided in Annex II of this report.

The assessment of the GIWA concerns is based upon available data and the background information presented in the Regional definition. A number of data gaps and an imbalance in the availability of data exist, especially in terms of long-term trend data, which makes the assessment speculative in some cases. For example, the recent coral bleaching event in the region has resulted in a lot of information and data being published, whereas data on several threatened marine species are not available. In order to adequately address the concerns, empirical evidence from research elsewhere was used and applied to the regional context. This is indicated in the text where appropriate.

### Freshwater shortage

Analysis of meteorological records and other data indicates that the impacts of Freshwater shortage are most severe during the dry season. In the region, the dry season typically lasts about three to four months, with extreme conditions recurring every few years. Lack of data makes it difficult to provide an average for the region but recent records indicate that such extreme conditions occur much more frequently than before, placing much of the resource under pressure in terms of availability (Payet 2003). On the other hand, pollution impacts on...
freshwater resources are localised in areas of high urbanisation, and these impacts occur every day, with daily discharges of wastewater from domestic and industrial sources.

**Environmental impacts**

**Modification of stream flow**

Water resources in Madagascar, Mauritius and Seychelles are primarily extracted from rivers on the main inhabited islands through the construction of dams and reservoirs.

In Mauritius, 10 man-made reservoirs with a combined total gross storage capacity of 70 million m$^3$ yielding some 265 million m$^3$ per year have been built. Likewise, in Madagascar, several large dams have been built along the main rivers, thus not only affecting productivity of the flood plains but also the proper function of the numerous lakes present on this large island (World Bank 1998). In Seychelles, due to the topography of the Island it is not feasible to build any more dams along streams. Therefore, modification of stream flow occurs at a very low-scale. Water extraction from streams in Comoros is not a significant issue and does not pose a problem at this time (World Bank 2000a).

**Pollution of existing supplies**

Lack of consistent and long-term monitoring data prevents any sort of quantitative analysis of this issue. In fact, in Comoros data on water quality is not available but it is feared that there is contamination of existing supplies mainly from wastewater and solid waste disposal.

In Seychelles, the pollution load of major rivers ranges from 25.1 kg/day in rivers located within urban areas to 10.3 kg/day in areas located on the fringe of urban areas (Payet 1999). In remote areas, pollution loads are likely to be much lower.

In Madagascar, the lakes and rivers are threatened by generation of high levels of suspended solids resulting from continued deforestation. Intensive agriculture in some areas also leads to fertiliser and pesticide pollution of some water resources (Ranaivoson 1996).

Although samples of surface and groundwater meet the required physiochemical standards for drinking water in Mauritius and Seychelles, many samples from a number of hotspots have occasionally failed to meet the required bacteriological standards. In particular, wastewater contamination of potable water supply is an increasing problem in some areas. In Mauritius, intensive agriculture and industrialisation has led to pollution of existing water resources, especially within the coastal areas (ERM 1999).

**Changes in water table**

Comoros is heavily dependent upon groundwater resources, with over 44 wells, while Mauritius and Madagascar are less dependent. Data on changes of the water table on the Islands of Comoros were not readily available so the extent of the impact could not be assessed. However, the changes in the water table are likely to result from over-extraction during the dry season. In Madagascar, information describing the status of water tables is equally scant and not available to make any conclusions. However, in Mauritius, where more data is available, over-extraction of water tables does not seem to be a problem at present. Out of the 840 small wells/boreholes and 92 dug wells, 206 are presently in use mainly for domestic purposes (74 million m$^3$ per year), and agriculture (16 million m$^3$ per year). Total annual recharge is estimated at 390 million m$^3$ per year. However, since most of the boreholes are fed by superficial water bearing formations in the recent lava flow series, within a depth usually not exceeding 60 m, the yields of the exploited boreholes decrease to about 25 to 40 % during the dry season when the water table recedes to a range from 1 to 27 m depending on the location of the boreholes (WRU, 1997).

La Digue, which supports a population of 2,000, is the only island in the Seychelles that depends partly on groundwater. There are large changes in the water table during the dry season due to over-pumping to meet demand.

Due to the dependency of the Islands of Comoros on groundwater, and as a secondary source in Madagascar and Mauritius, impacts on the groundwater system were considered more severe than modification of stream flow in the region, particularly since groundwater treatment is very complex and costly. With changes in rainfall patterns in the region, groundwater as a potential resource is very important.

**Socio-economic impacts**

The impact on health varies across the region, mainly related to the availability of health services and differences in population. For example, Seychelles has the lowest population (~80,000), followed by Comoros (~600,000), Mauritius (~1.2 million) and Madagascar (~16 million). This problem of scale made the analysis of number of people affected biased towards the relative size of the country. Overall, the number of people whose health is affected is not very high considering that most of these people have access to water. However, in Madagascar and Comoros less than 50% of the population has access to treated water. The most serious health problem related to water is the occurrence of cholera outbreaks in Comoros and Madagascar, which leads to fatalities and disruptions in the economy of the countries (Table 14) (Bergeron 2001).
Occurrence of cholera in Madagascar is also responsible for stopping movement within 66 of the 111 districts in the country, with over 18,000 people infected and 1,070 deaths. So far there have been three epidemics of cholera in Comoros; in 1975, 1998 and 2001. The most recent outbreak of cholera lead to 1,246 declared deaths (Bergeron 2001). The recent outbreaks, two over a period of three years, were closely associated with poor sanitation and pollution of freshwater.

In Madagascar, occurrences of diarrhoea among children are common during the rainy season, affecting as many as 25% of children during a typical epidemic and leading to several deaths. This is directly related to the quality of water consumed, hygiene levels and sewage contamination (Bergeron 2001). In Mauritius and Seychelles, fewer cases of diarrhoea are reported and are probably linked to poor personal hygiene rather than poor water quality.

Lack of freshwater during the dry season impacts the local communities in all Island States in the region, in that they have to rely on water brought in by trucks. In many cases, especially in the rural areas, this service is not available and the local community resorts to untreated water sources, leading to unsanitary conditions and social disruption (World Bank 1998). In both Comoros and Madagascar, cholera epidemics affect community relations and also movement. This has impacts on schooling and performance in other economic sectors such as agriculture and fisheries. Produce from those regions affected cannot be sold to other regions, thereby aggravating the loss of revenue to the community. In the case of Madagascar, a cholera epidemic caused economic losses to the region and eventually the country. Over a period of three months, no goods from Madagascar could be sold or used (World Bank 1998). A cost estimate of these losses could not be made. In Mauritius, a link was found between decrease in fish catch and disposal of wastewater from three outfalls. The Government eventually awarded compensation to about 2,000 fishermen, and each received about 2,300 USD based upon loss in catch over a period of 10 years.

### Conclusions and future outlook

Due to Comoros dependency on groundwater, and as groundwater is the secondary source of freshwater in Madagascar and Mauritius, impacts on the groundwater system are considered more severe than modification of stream flow in the region. This is especially pertinent since groundwater treatment is very complex and costly. With changes in rainfall patterns in the region, groundwater as a potential resource is very important.

Disease outbreaks, especially malaria and cholera, are huge health problems in Madagascar and Comoros and are generally related to unsanitary conditions.

The outlook for this concern is unfortunately not optimistic. With population growth, land use change and unpredictable rainfall patterns, the availability of water resources for the populations in the region does not appear to be secured. In fact, as seen in Seychelles and very soon in Mauritius, there has been a move towards desalination to meet demand. Construction of more dams is seen as having a greater impact on the environment when weighted against the economic cost of establishing desalination plants. However, desalination increases the country’s energy burden, and since all the energy is imported, it thus affects its economic performance in the long-term. No border conflicts are expected to arise due to the separate nature of the water systems; however internal conflicts with respect to uses of water may arise. This is pertinent in areas where there are multiple uses of water, such as for agriculture (irrigation), aquaculture (ponds), and hydropower (damping). Adequate planning and other mechanisms will be needed to address this concern.
Pollution

Pollution from land sources, especially from urban areas and agriculture, is of great concern to the region. Mauritius for example, cultivates almost 48% of its total land area and uses high amounts of fertilisers (ERM 1999). The Island uses on average 57,500 tonnes of chemical fertilisers per year representing around 600 kg/ha and three times that of Western Europe. Analysis of groundwater revealed nitrate concentrations as high as 45 mg/l, which is the maximum international accepted in potable water. The same applies to herbicides which also pose a threat to coral reefs and mangroves. Issues such as radioactive pollution were not treated, as these do not occur in the region.

Environmental impacts

Microbiological

No data was available for Comoros, although it was considered that the issue of microbiological contamination as a result of sewage is a growing problem. In Madagascar, statistics show that only 1.8% of the population have access to some form of sewage treatment, with over 50% of the population resorting to “natural” land disposal of sewage waste. At one particular beach, the total number of coliforms has been found to exceed 100,000 per 100 ml. Surveys of coliform levels in the Lagoon of Bain des Dames in Mauritius indicated that less than 80% of the samples met the guidelines for primary contact, i.e. swimming. As a result, swimming at this beach has not been recommended since 2001. The pollution source is a sewage outfall just outside the reef, some 200 m from the coast. Overall, the situation in Mauritius has improved with sewerage facilities provided for the main urban areas. Likewise, in Seychelles, at least 78% of the population have flushing toilets and septic tanks are the most common form of sewage treatment, although the most urbanised part of the Island (consisting of over 25% of the population) is now fully sewered (Payet 1999). Only 2% of the population is without proper sanitation facilities. Therefore, the microbiological and eutrophication problem is only significant in certain rural areas.

At the regional level, the issue of microbiological pollution has few transboundary implications since the amounts generated are relatively small. However, the impacts within the coastal and marine environment should not be ignored since many areas are still devoid of proper wastewater treatment facilities.

Eutrophication

Evaluation of eutrophication was challenged by the lack of data in particular countries. Eutrophication is primarily a result of improper wastewater treatment, over-application of fertilisers in agriculture, intensive animal husbandry and industrialisation. In Seychelles, a study of eutrophication along the east coast of Mahe revealed that nitrate, nitrite, and phosphate levels were elevated (according to Seychelles published water quality standards) throughout the area, with concentrations ranging from 0.4 to 0.5 mg/l, mean ammonia concentrations at 2.39 mg/l, and sulphide at 0.02 mg/l (Payet 1999). High ammonia concentrations were observed from samples collected close to river mouths and the main food processing areas, such as the tuna-canning factory. BOD$_5$ (5-day biochemical oxygen demand) and nitrate discharges for the city of Antananarivo (Madagascar) are approximately 10,368 tonnes and 2,608 tonnes per year respectively.

In Mauritius, preliminary surveys indicate damaging nutrient levels in numerous areas, which may have caused the development of six red tides in 1996 at the Trou aux-Biches area in the northern tourist zone of the Island. Likewise, within the tourist area of Beau Vallon Bay on Mahe, pollution loads (BOD$_5$) average about 72 tonnes per year. However, no nutrient-induced tides have ever been observed in the area.

Increased concentrations of harmful algae have been observed along the coast of Madagascar and have caused contamination in marine species such as shark (Carcharhinus leucas), Sardines, molluscs (Strombus gibberulus) and turtles (Ertmochelys imbricata, Chelonia mydas). This happens principally at the start of the rainy season (from October to April) in the southwest and northeast coast of Madagascar. High nutrient levels as a result of heavy use of inorganic fertilisers are also a serious problem in Madagascar, Mauritius and Comoros, all of which have a highly developed agricultural sector (Figure 12).

Chemical

Chemical pollution is restricted within areas of heavy industrialisation. Mauritius is the most heavily industrialised country in the region which explains the low regional score and weighting given to the issue. In 2011, the Island uses on average 57,500 tonnes of chemical fertilisers per year representing around 600 kg/ha and three times that of Western Europe. Analysis of groundwater revealed nitrate concentrations as high as 45 mg/l, which is the maximum international accepted in potable water. The same applies to herbicides which also pose a threat to coral reefs and mangroves. Issues such as radioactive pollution were not treated, as these do not occur in the region.
the Seychelles, industries are mainly oriented toward food processing. Madagascar is experiencing growth in its industrial sector, especially in the mineral processing area, with potential for significant chemical pollution in the near future. Chemical pollution from port activities was also considered an important issue for all countries in the region. Data on insecticide consumption was only obtained for Madagascar, Mauritius and Seychelles, showing a slow decline in use (Figure 13), although more data is needed to confirm this observation. It is not clear why there are large fluctuations in the imports of insecticides for Madagascar.

In Mauritius, there are over 896 large industrial operations with 48 industries producing textiles, 59 paper products, and 28 various chemical products. In contrast, Seychelles has no textile and paper industries and only two small industries producing chemical products. Nearly all the chemical factories (textile dyeing, soap, detergents, dry cleaning, etc.) in Mauritius are now found within sewered areas but in many areas reefs have been destroyed as a result of discharge of untreated industrial effluents. In Madagascar, effluents from a refinery constitute a major source of chromium, phenol and sulphate pollution in the coastal waters. In addition, it is estimated that metal processing plants dispose of over 1 274 tonnes of toxic sludge into the ocean every year.

The long-term persistence and migration of some trace metals and other contaminants such as PCBs will have transboundary implications for the region, but due to lack of any form of oceanic data on such pollutants, the conclusion is merely speculative.

Suspended solids

The issue of suspended solids is important in all countries in the region. The main source of suspended solids in Madagascar result from deforestation through slash-and-burn activities to convert land or agriculture and the subsequent surface run-off (Ranaivoson 1996). In Comoros, intensive agriculture in some areas is the primary source of suspended solids. In Seychelles and Mauritius, the primary sources of suspended solids are from construction and food processing activities (especially of fish products). In Madagascar, discharges of suspended solids from the Toliara region are estimated to be about 6 million tonnes per year. Data from other countries is lacking.

Solid wastes

The most critical issue for the States in the region is the growing problem of solid wastes. Whilst Seychelles and Mauritius have developed some organised forms of solid waste management, it still remains a problem for these two countries as well. In Comoros, waste collection and disposal is virtually non-existent, and wastes are often found scattered throughout the city and in both public and village areas. There is no treatment of solid waste; instead it is disposed of in open dumps which are expanding with the growth of the population.

Only 6% of solid waste generated in Madagascar is collected on a routine basis, with almost 52% of the population disposing of their waste anywhere convenient. Within the coastal areas, most of the wastes are disposed of, on or close to beaches and mangrove areas. Within Antananarivo alone, solid waste generation is estimated to be about 65 700 tonnes per year.

In Mauritius, all solid wastes are disposed in a sanitary landfill at Mare Chicose (ERM 1999). Old open dumps have now been converted into transfer stations where the solid wastes collected from different communities are compacted before being disposed of at the sanitary landfill. The estimated solid waste production increased from 243 360 tonnes per year in 1992 to 279 240 tonnes in 1995. It is estimated that by 2010, the amount of solid waste per year will increase to 477 360 tonnes. Similarly in Seychelles, a nationwide solid waste collection service is in operation and, upon completion of a sanitary landfill, the open dump located on the east coast of Mahe will be converted into a full transfer station (Hydroplan 2003). Composting of all the green (organic) wastes, which constitute more than 50% of the waste constituent, is also done on a commercial basis for both the local and export markets. In spite of these arrangements, littering and misuse of solid waste facilities is still evident in both Mauritius and Seychelles. Furthermore, with projected growth in solid waste generation and a lack of space to create new disposal areas, new problems will emerge.
A growing problem with important transboundary implications is disposal of solid wastes at sea, either formally or informally. Recent studies and observations indicate a growing amount of marine debris, which has an impact on marine life and also on distant islands. For example, Aldabra, a World Heritage Site (Figure 14) with no local population, receives considerable quantities of solid wastes in the form of marine debris, which washes up on the island every year. With no viable method to dispose of these wastes, this island sanctuary is threatened by this transboundary issue. Furthermore, there are no dedicated port waste reception facilities within the region.

Spills
Each of the four island states in the region is located within a region of high crude oil traffic between the Gulf States, Africa and Europe, but so far no major spills have been reported (GEF 1999). Tar balls deposited on beaches in Comoros, Madagascar and Seychelles have been reported on a yearly basis. There have also been various local spill events, especially related to refined petroleum products and, to a limited extent, other dangerous cargo. The extent and impacts of these spills are rarely assessed and documented. However, such spills can potentially have serious consequences on the natural coastal habitats and species, as well on the economies of the region.

Socio-economic impacts
The impacts of pollution in the region are felt in both the short-term and long-term and some pollutants also have a transboundary context. The tourism industry will be particularly affected by pollution and this already constitutes a problem in Comoros. In Seychelles, much money is spent on public education on solid waste disposal, as tourism is critical to the country. Investments in infrastructure to handle these problems are very low in some states. For example, in Madagascar, only 1 to 3% of public funds are spent on improving basic sanitation facilities. The cost of waste management in Seychelles is about 6 million USD, primarily due to the high cost of labour and fuel. The total cost of waste collection in Mauritius is about 78 million USD per year (ERM 1999). Disposal costs are also quite expensive at about 200 USD per tonne, but this is weighted against losses in tourism, which are likely to be much higher. The building and commissioning of a wastewater treatment plant with a capacity of 1 500 m$^3$, comprising of an activated sludge process and a clarifier, can cost between 50 000 and 100 000 USD.

The financial impact on industries and local government to invest in cleaner technologies in order to abide by existing standards for discharge of effluents is an important issue in Seychelles and Mauritius. For example, with the construction of every new hotel, a wastewater treatment plant that meets the stringent effluent discharge conditions must be built. The existing establishments are given time periods in which to make such investments. The costs of clean-up are also quite high. For example, in Mauritius, it cost a group of private sector operators over 200 000 USD to clean up a site (area 0.1 km$^2$) they had polluted.

The occurrence of red tides (toxic algal blooms) is currently associated with yearly seasonal patterns, but could become more pronounced if the issue remains unaddressed. Red tides have a direct impact on both fisheries, leading to loss of saleable fish catch, and tourism. The impact of oil spills can be catastrophic, especially since all states are located within this high-risk area.

Solid waste is the primary pollution issue in the region that affects a large number of the population, especially in those areas where solid waste management is non-existent. Improper disposal of solid waste creates breeding environments for vermin such as cats, dogs and rats which may, in turn, be vectors of deadly diseases such as the plague, leptospirosis, scabies and other tropical scourges. In some areas, particularly in Comoros and Madagascar, children also use such dumps as playgrounds. An emerging danger is the disposal of hospital contaminated wastes and industrial wastes within urban areas where children and human scavengers can have access to these wastes.

Disposal of solid wastes, especially containers, are also a source of mosquito population explosions in all four countries of the region. However, Madagascar and Comoros are worst affected, due to the presence of the malaria in those countries. In 2000, only 30.3% of children in Madagascar had access to a mosquito net, and only 0.8% of the nets are specially treated with pesticide. Countries like Seychelles...
and Mauritius, although not subject to the deadly disease, are at serious risk since the mosquito vector is present in both countries.

Disposal of human waste on the beaches in Madagascar also creates a serious respiratory ailment termed Acute Respiratory Infections (IRA) and frequent skin rashes. In Mauritius, two public beaches were closed for swimming as a result of high levels of coliform bacteria. These two beaches were located close to effluent outfalls.

In general, the social and community implications of these issues is both difficult to evaluate and adequately address. The majority of the population is affected by pollution. The universal habit of littering and disposal of domestic wastes in every drain is one of the largest problems to overcome in the area. The severity of the problem is therefore far-reaching and fundamental to any potential solution in the future.

According to traditions in Madagascar, it is not acceptable to place toilets within houses and instead they are built as separate constructions. Due to increases in population density, many of these dwellings do not have proper facilities and, as a result, dispose of their human wastes in other places on the beaches and in mangroves swamps. During high tides human faeces can be observed accumulating in several areas.

Conclusions and future outlook
Clearly, as indicated before, pollution in the region will probably increase as a function of the growth in population and the lack of appropriate infrastructure investments to treat the pollution to an acceptable standard. The analysis demonstrated clear linkages between the health of the population and the levels of pollution, so it is important that appropriate decisions are taken as this environmental issue is linked to the alleviation of poverty in these island states.

Although there seems to be an adequate legal framework, existing laws are not enforced, resulting in non-compliance. Besides legal mechanisms, economic incentives will need to be explored to encourage private sector and public contribution to pollution abatement in the respective countries.

The analysis also concluded that solid wastes and its related impacts constitute the biggest threat, in terms of social, environmental and economic well-being to the countries in the region. A strong transboundary link was also demonstrated as waste is routinely dumped into watercourses and the coastal environment where it can be carried thousands of kilometres in the ocean, affecting biodiversity, fisheries and tourism. However, the problem can be addressed through the development of appropriate mechanisms and adequate transfer of technology. Therefore, the future outlook appears positive provided there is political commitment. This issue is further investigated later in the report.

Habitat and community modification
Since there is significant human pressure on the main ecosystems described, it was concluded that the risk of species extinction is high. The risk of introduction of invasive species is also a concern, which may aggravate this situation. In many cases, it is very difficult to distinguish between loss and modification of habitats, given the data that is available. Thus, the most important biotopes are discussed separately without specifying loss versus modification.

Environmental impacts
Coral reefs
Coral reefs, being important in both rural and national economies, are severely stressed as a result of human activities, compounded by the recent effects of the 1998 Indian Ocean mass coral bleaching event. A recent global survey (Bryant et al. 1998), indicated that at least 25% of the coral reefs in the region were at high risk of degradation from human activities (mainly within the Comoros area), 28% at medium risk (mainly within the Madagascar and Mauritius areas), and 47% at low risk (mainly within the Seychelles area) (Figure 15).
In Comoros, the skeletons of coral colonies are still used in construction of houses and sold to tourists as curios. It is estimated that a total of 1 200 tonnes of coral are extracted every year. Whilst the coral reef supports fisheries, reef-based tourism is also on the increase.

Madagascar has well developed reefs, covering over 20% of its extensive coastline. Surveys in 1996 identified 1 250 villages dependent upon the reefs for fish (FAO 1999). A total of 22 000 small boats were found to be in operation, landing over 70 551 tonnes of reef fish in 2001. Reefs face a number of threats in Madagascar such as high sedimentation levels from the rivers, pollution from agriculture and industries, sewage and solid waste discharges along the coast, pollution from commercial port operations, use of poison in fisheries, coral extraction for construction, and collection as tourist souvenirs (Cesar 2000).

The coral reefs in Mauritius are heavily used by the traditional fishing sector and increasingly by tourism. In particular, reefs close to tourist beaches are affected by trampling. Fishermen and tour operators also routinely damage reefs with anchors, traps or boat poles. Pollution from both urban, tourism and industrial sources also affect the health of the reefs.

Coral reefs in the Seychelles range from the inhabited granitic islands to the isolated coral atolls. Human pressures on the granitic islands include reclamation, reef damage by anchors, and in some areas impacts from tourism and urban sewage. However, most of the distant coral islands are still free from direct human pressure, and thus much of the corals were still in pristine state until the 1998 bleaching event. Bleaching occurred as a result of increased sea surface temperatures that persisted for several months in 1998. Comoros experienced over 55% coral mortality, Madagascar 30% and Mauritius 1 to 15%. Seychelles was perhaps the most severely affected, with live coral cover on the granitic islands reduced to less than 10% in some areas (Linden & Sporrong 1999).

On the basis of this analysis, coral reefs were deemed highly vulnerable ecosystems and continue to suffer from the devastating effect of human pressure on these reefs, and also the recent 1998 bleaching event (Linden et al. 2002).

Information on associated ecosystems such as seagrass beds is very sparse, and the ecological status in the region could not be determined (Gullström et al. 2002).

Wetlands (saline and freshwater)

Wetlands, including mangroves, are not very extensive in the region except in Madagascar. In Comoros, the mangroves are exploited for timber and other uses. Current mangrove stands exceed 3 000 ha. In Madagascar, mangroves cover an estimated area of 340 000 ha, especially on the western side of the Island. Mangroves provide the community with an important food and material source. For example, local people make use of its wood for cooking, construction, boats, its leaves for medicinal purposes and as fodder, and its bark for dyes. Freshwater aquaculture is an important activity in Madagascar, estimated to cover about 50 000 ha. However, these activities have not been sustainable. In Toliara, for example, of the 45 500 ha of wetlands that have been described, most have been destroyed as a result of over-harvesting for wood.

Figure 16 Land reclamation in Small Islands States such as Seychelles provides opportunity for housing, hotel and industry developments.

(Photo: Souter 2003)

In Seychelles, wetland areas, including mangroves cover only 150 ha. Apart from supporting important ecosystems, they also play a role in flood control on the flat coastal plains. However, wetlands have been reclaimed for agricultural use, and whilst this practice has stopped there is now increasing pressure for reclamation for housing and hotel development (Figure 16).

In view of these increasing pressures the ecosystem can be classified as highly threatened in the region.

Standing waters

Standing waters, such as lakes, are important ecosystems in Madagascar. These are exploited for freshwater fish with almost 40 000 tonnes harvested every year. Fringe vegetation is also harvested for construction. In view of these pressures and the constraints in water resources outlined in the assessment of Freshwater shortage, it is concluded that human pressure on this ecosystem is especially significant in Madagascar where it serves several uses.
Pelagic
The status of pelagic fish in the region is difficult to account for since they are usually highly mobile species. Research in Seychelles between 1989 and 1994 shows fluctuations in catch rates, but with a general trend indicating depletion of the resource (Mees et al. 1998). This is especially critical as the pelagic fish stock not only depends upon the national approach to management, but also upon the regional approach. This issue is investigated further in the assessment of Unsustainable exploitation of fish and other living resources.

Socio-economic impacts
In general, modification and loss of habitats results in economic losses in several areas, which is sometimes neither accounted for nor observed. Taking into consideration the relative size of the population and economy of each island, the economic impacts can be rather large, although the target of impacts is fairly specific in some areas, especially with respect to coastal ecosystem services. The frequencies of those impacts were determined to be continuous, but more intense during certain seasons of the year. Losses of habitats in the region would result in:
- Loss in tourism and related activities;
- Loss of food, medical and construction resources;
- Loss of foreign investment;
- Increase in conflicts between the communities;
- Loss of archaeological sites;
- Increase of other problems such as erosion;
- Reduced ability of habitats to recover.

Reef fisheries contribute about 43% of Madagascar’s total fish catch and are an important source of food and also foreign earnings (20% of total catch is exported). Therefore, a collapse of the reef ecosystem will have a huge impact on both domestic and foreign earnings from fisheries. Continued exploitation of current mangrove stands will lead to loss of several ecosystem services such as food, habitats for other species, construction materials and medicinal uses. It has been estimated that direct monetary losses from loss of mangrove habitats amounts to 600 USD per ha, or 204 million USD per year.

Both Mauritius and Seychelles depend heavily on the tourism sector for economic development and prosperity and, in turn, tourism depends on the quality of the environment. Degradation of the coral reefs would be especially detrimental to the diving industry. A study in the Seychelles quantified the economic benefits of biodiversity to Seychelles as being about 0.3 billion USD, compared with the economic costs of 40 million USD (Shah et al. 1997).

The impacts on health are not direct, but rather affect food availability, population pressures and nutrition. However, only a medium proportion of the population is affected, especially those living below the poverty line and children. The degree of severity is not deemed high, as other forms of substitute food sources are available and, in some cases, cheaper. For example, in Mauritius, 1 kg of fish costs 4 USD compared with 1 kg of poultry which is 2 USD. The frequency of health impacts are heightened during periods of drought or rough/colder seas, which increases fishery catch effort, pushing fish prices up, and subsequently affecting the daily diet of poor families. An unbalanced diet can lead to malnutrition.

Food security in the region (being geographically isolated) and the dependence of the communities on local sources of food, such as reef fisheries and mangrove products, implies a direct link of ecosystem health to human health. This is an important issue in the region as it affects economic performance in terms of productivity and also leakages due to increased food imports. For example, in 1998, Madagascar and Comoros obtained 26 000 and 3 600 tonnes of food aid, respectively.

Community impacts in the region are subtle and not very well documented. These impacts centre on social integrity, movement and competition/conflicts. Social values is affected as a result of loss of unique biodiversity in some areas. Loss in potential ecotourism services as well as medicinal value of certain species is also an significant impact.Degradation of ecosystems and habitats also leads to major population movements in the region, either to the coast, into other unaffected areas, or into urban areas. Social conflicts and competition increase with population growth, with erosion of the traditional values and most importantly reduction in output from the ecosystem.

In Comoros, more than 70% of the population uses forest wood for cooking, mangroves for construction and boat building, coral for construction, fish as a staple food, and plants for medicinal use. In Madagascar, migrations of small communities to more productive areas are often the cause of social conflicts, such as access to living areas and resources to sustain their livelihood. Social integration is a concern especially with regard to custom and norms, and access to coastal resources. This has an overall effect on the GDP per capita, as almost 40% of the population depends directly on coastal resources in Madagascar. The purchasing power decreased by 15% between 1993 and 1997 among the rural people, who are heavily dependent upon those ecological resources.
The main areas of community conflicts are:
- Between local people (e.g. fishermen) and migrants;
- Between local (small-scale) and industrial (large-scale) operators;
- Between traditional land access rights and new land owners/users.

Costs for loss of ecosystems are not placed upon local communities, but upon the local government or the private sector. For example, in Mauritius, fishermen have in many instances won compensation for loss of fisheries as a result of decrease in productivity which the fishermen claim was a result of other developments such as tourism.

Conclusions and future outlook
The impacts of human activities on ecosystems are very high and increasing in the region as demands are placed upon these ecosystems. In Madagascar and Comoros, poverty has kept the dependency of the population on the natural resources very high, whereas in other states, other options for food, construction materials and energy exist.

Whilst fishery demands increase, growth in tourism also places additional pressure on these sensitive ecosystems. The region has a high biodiversity, but human intervention at all levels (including the catchment area and the marine environment) has pushed such ecosystems into isolated pockets of fragmented habitats. A growing network of protected areas may alleviate the problem in the short-term.

Existing ecosystems are also threatened by invasive species and increasingly by changes in the Earth’s climate. Recent mass coral bleaching events have left most reefs in the region in a dilapidated state. There is increasing evidence which indicates that such events may occur more frequently in the future (Hoegh-Guldberg 1999).

Unsustainable exploitation of fish and other living resources
This concern is probably the most variable and has the most transboundary implications across the region, which is indicated by the overall score for the concern which is the regional average rather than a regional consensus (Table 13). For example, in Comoros, overexploitation is a severe issue whereas excessive by-catch is more or less non-existent, in contrast to Seychelles, where overexploitation is not a major issue but excessive by-catch is.

Environmental impacts
Overexploitation
Existing trends in catch and demand for fish resources indicate a continuously increasing pressure in the region. With catches declining in some areas, fishermen are moving into other areas. The number of fishermen relative to length of the coastline is also high in some countries; Madagascar 17 per km, Comoros 26 per km, Mauritius 53 per km, and Seychelles 3 per km. Products from high value fisheries, such as tuna and shrimps, are exported and there is a growing trade in sea cucumber and shark fin to East Asia which is increasing existing pressure and also affecting the functioning of the entire marine ecosystem. The inability to monitor movement of fishermen makes it difficult to determine the level of exploitation of a resource in a particular area, but fishing effort/movement as a proxy indicator can give an indication on the status of the fishery resource within the region.

Overexploitation is common for high value species, such as shrimps, sea cucumber and some demersal species. For example, along the west coast of Madagascar, the Maximum Sustainable Yield (MSY) determined for the shrimp fishery is 12 000 tonnes (2000), but a total of 11 959 tonnes was harvested in 2001, implying that the fishery is most likely being exploited beyond its MSY, assuming there is under-reporting. Total fishing effort increased by up to five times during the period between 1977 and 1994. In Seychelles, the reef fishery is currently fully exploited in the granitic islands, although present catch levels are well below the MSY. Mauritius recorded a decline in fish catch per fisherman day (FCPFD) from 5.2 kg in 1986 to 3.6 kg in 1989. The current average FCPFD for reef fish is 4 kg.

In Comoros, export of live fish has increased to about 750 fish per week and is growing. Overexploitation of certain species e.g. turtles, results in a decrease in the population and may lead to a complete extinction of the species.

Excessive by-catch and discards
By-catch is not a serious issue in Comoros, but in Madagascar, it is estimated that at least 75% of the by-catch is not landed but disposed of at sea. In Seychelles, by-catch and discards are most common in the industrial tuna fishery where as much as 25 to 30% of the catch is by-catch. The domestic fishery does not generate by-catch or discards. A growing concern in the region is the discarding of shark carcasses after finning. Shark flesh has little market value and is therefore often discarded at sea. The issue of by-catch is therefore associated with more industrial forms of fishing and shark finning, all of which may become important fisheries in the region.
Destructive fishing practices

Destructive fishing practices are causing severe impacts in some countries (Comoros) and much less severe in others (Seychelles). Thus, an average score was assigned to the issue as no regional consensus can be made (Table 13).

Destructive fishing is a common practice in Comoros despite awareness campaigns. Fishing with dynamite constitutes a danger to coastal ecosystems. Fishing at low tide also increases trampling of coral reefs. Cloth and net fishing are a threat to biodiversity as small fish are also captured. In Madagascar, destructive fishing principally occurs in the mangroves using mosquito nets, and in shallow reef areas through trampling, dynamite and poison, overturning of corals, and gear entangling and destroying the corals. In Mauritius, the only mode of destructive fishing practices is through seine netting, whereas in Seychelles, destructive fishing practices are isolated to a few cases of fishermen using gill nets on coral reefs.

Decreased variability of stock

Information linking the health of aquatic organisms and sources of pollution is virtually non-existent in the region. However, it is a relatively important cause of collapsing fish stocks in the region. Recent studies on the impacts of coral bleaching showed no significant decrease in reef fish abundance soon after a bleaching event, but this may affect fish stocks in the long-term.

Impact on biological and genetic diversity

The impact of fishing practice on biological and genetic diversity is manifested in two main areas: complete extinction of a species or complete destruction of the habitat for the species. Whilst the former is unlikely to occur on a more longer term (except maybe in the case of some species of turtles, sea cumbers, and crustaceans, which are heavily exploited and have unique life cycles), modification of habitats that support the fishery critically undermines the viability of present fisheries, including the fish reproduction and food sources. Pollution, which also affects organisms at the bottom of the food web, and physical destruction, which destroys the habitats, is the major source of this impact. However, when considering the overall picture, only some areas are affected, with potential for restoration and re-introduction of lost species.

Transboundary impacts on the biological and genetic diversity include introduction of invasive marine species, primarily from tanker ballast water.

Socio-economic impacts

Artisanal fishing in the nearshore coastal waters and shallow shelf seas employs 80% of all people involved in fisheries, and is an essential and conservative component of coastal communities. Estuarine and lagoon fisheries in particular, have a major socio-economic importance.
Damaging fishing practices (bleaching, poison or dynamite) are still being used in Mauritius and Madagascar. In addition, the increasing demands for wood for fuel and housing has placed pressures on mangrove forest in the region, mainly in Madagascar (Lebigre 1997) and Comoros. All these factors have caused diminishing returns from these shallow seas. The severe El Niño event of 1998 resulted in numerous coral reef areas bleached with little prospects of regeneration. These events raise alarming concerns for the future of the coral reefs and the many communities that depend on these reefs to sustain their livelihood. Some recovery of coral communities has been observed and no decreases in fish catch have been reported (Linden et al. 2002).

The economic impacts of overexploitation of fish in the region are significant since the region depends on these fishery resources for basic food supply, for export and also an increasing tourism activity (for fishing and for diving/snorkelling). Although cost and revenue figures are not available for many of the uses, the size of the economic sector and also the community that is affected is large and continuous. Price indices indicate that the cost of fishing is increasing which may be related to the fishing effort and limited supply of fish resources. In Comoros, the main fishery is artisanal and 72% of the catch is comprised of pelagic species. In addition, the cost of fish is 0.3-0.8 USD/kg which is low as compared to meat, which is about 2 USD/kg. Revenue from fisheries in 1995 was about 2 million USD.

In Madagascar, 20% of the fish is exported. This includes high value fisheries such as tuna and shrimp which are exported and earned the country 90 million USD in foreign exchange in 2001. However, shrimp trawling poses a big threat to this type of fishery, thus undermining the future sustainability of this revenue source. In both Seychelles and Mauritius, fishermen receive special concessions such as no license fees, cheap fuel and soft loans. However, the price of fish has increased over the last 10 years, primarily reflecting the increase in fishing effort. In Seychelles, fish costs about 2-8 USD/kg, and in Mauritius, 2-5 USD/kg, depending on the species.

The direct health impacts of fisheries include the health benefits of fish consumption, and the assumed saving in medical costs that would arise from consumption of other less healthy meat products. However, fish, particularly pelagic species, are also known to have trace pollutants, such as DDT, and also harbour heavy metals such as mercury. Diseases arising from fish consumption are not very common, except for the toxicity in fish caused by a dinoflagellate, ciguatera. Ciguatera is known to occur throughout the region, but is more common in Mauritius and Madagascar (Quod et al. 2000).

Fishing is still a community-based activity throughout the region, so a negative impact on fish stocks will affect the families involved and also increase conflicts and fishing pressure. It is observed that many communities resort to destructive fishing practices, contrary to their traditional practices to reduce catching effort and also amount of catch. Through loss of fisheries, the fishery community will also lack the necessary funds to purchase other goods and services, and once again turn to other habitats for exploitation. Changes in government policy, with respect to access in its attempt to control exploitation, may also lead to increased conflicts.

**Conclusions and future outlook**

Fisheries are probably the most critical and complex transboundary concern in the region but, due to a consistent output of the fisheries, in contrast to the collapses observed in the Atlantic, it is not viewed as being highly critical. Whilst some stocks appear to be healthy, it is clear that, in the majority of the fisheries, especially the reef fisheries, there is serious overexploitation.

Fisheries support the region from an economic perspective and any collapse in the fisheries will seriously affect the quality of life. Efforts to eliminate destructive fishing practices should increase.

The future of the fisheries in the region is unknown and more studies are required to understand the viability of existing stocks and how they can be managed sustainably. Without these options, it is likely that fisheries in the Indian Ocean will suffer the same fate as those in other parts of the world.

**Global change**

The impacts of global change under present conditions are often very difficult to qualify, much less quantify. Since global change superimposes itself on current variability, it takes sufficient data and information to evaluate the real impacts of global change under present conditions.

**Environmental impacts**

**Changes in the hydrological cycle**

Current data are inadequate to determine whether there is a change in the hydrological cycle. However, the region has experienced several abnormal and extended periods of drought and weather extremes over the last five years, leading many to believe that there is indeed a change in the hydrological cycle.
Paleo-climatic conditions of the Indian Ocean point to the fact that during the late Triassic, the Inter-Tropical Convergence Zone also had an influence on climatic conditions. Furthermore, sedimentological evidence supports the hypothesis that drier rather than wetter conditions prevailed during the late Pleistocene period. Recent coral reef core samples indicate a strong relationship between the El Niño phenomenon and the Indian Ocean. Historically, occurrence of drought in this region of the world also coincided with La Niña years. These events have now been correlated to reduced agricultural output and scarcity in water resources, i.e. rivers exhibiting significantly reduced flows compared with long-term averages. Consequently, it was concluded that a change in the hydrological cycle would indeed have a marked impact on the agriculture and water supply sector.

**Sea level change**

Likewise, lack of appropriate long-term sea level monitoring stations in the region precludes making any informed conclusions about sea level change under present conditions. However, considering increases in coastal erosion and morphological changes to the coast, which can be associated with natural processes, an evaluation of how sea level rise would impact the region could be made.

Sea level rise projections of 0.5, 1.0, 1.5 and 2.0 m have been used in case studies for Mauritius (IPCC 2001). The major impacts of sea level rise in Mauritius are land loss, erosion of beaches, damage to coastal infrastructure, degradation of coral reefs and loss of wetlands. In Madagascar, the effects of sea level rise are not observed, but in Comoros and Seychelles, several beaches have been eroded as a result of increased wave intensity and abnormal tidal ranges. In many situations, the effect of sea level rise is to accelerate the degradation of coastal environments that are already affected. This is likely to be the most serious impact since a large proportion of the population and the economic sectors are located on the coastal plains and therefore will be worst affected by sea level rise. Table 15 provides an indication of the expected changes in temperature and precipitation, essential indicators of changes in weather and wave patterns.

**Changes in ocean CO$_2$**

No information was available on CO$_2$ flux and fate in the region, or even the Indian Ocean. However, based upon theoretical evidence, increases in atmospheric CO$_2$ concentrations will have implications for coral reef stability and will also disrupt fisheries and climatic patterns in the region. The rate of calcification in corals and, as a consequence, reef growth will decrease because of the decreasing availability of carbonate in sea water resulting from increasing levels of CO$_2$ in the atmosphere (Souter & Linden 2000). This is expected to further compromise the structural integrity of coral reefs and cause further impacts along the coast.

**Socio-economic impacts**

Since the island nations of the region are geographically isolated, any shortage in water will need to be met either by transport of water from another location or production of water within the country. As a result of the recent droughts, both Seychelles and Mauritius have invested in desalination plants to meet demand during the dry season. Changes in the hydrological cycle will also affect agricultural productivity.

In August 1998, Mahe (Seychelles) recorded the highest rainfall in 26 years, when 694.1 mm of rain fell within a 24-hour period. Two young men lost their lives in the rainstorm and the extent of the damage was estimated between 3 to 4 million USD. The highest previous record for August was 371.6 mm in 1985 when, again, torrential rain created widespread damage. Whilst such changes are often described as one-off events, they indicate how catastrophic changes in the hydrological cycles can be.

Except in Madagascar, the majority of the population in the region lives on the coastal plateau, which is not more than 2 m above mean sea level. The main economic effects of sea level rise will be loss of infrastructure, services, and use of the property, which has been eroded or flooded.

In Madagascar, the number of sites and frequency of beach erosion has increased considerably over the last decade (Toradec 2000). After the passage of cyclone Dina in January 2002, five more sites have

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**Table 15** Summary of projected changes in temperature and precipitation for Small Island States in the Indian Ocean over the next 50 to 100 years as inferred from AOGCMs.

<table>
<thead>
<tr>
<th>Period</th>
<th>Annual mean temperature change (°C)</th>
<th>Annual mean precipitation change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GHG*</td>
<td>GHG+A**</td>
</tr>
<tr>
<td>2050s</td>
<td>2.10 (±0.43)</td>
<td>1.64 (±0.22)</td>
</tr>
<tr>
<td>2080s</td>
<td>3.16 (±0.89)</td>
<td>2.61 (±0.65)</td>
</tr>
</tbody>
</table>

been added to the list. Erosion up to 2 m has been recorded and, in some areas, whole beaches have been lost. Protection works currently being undertaken cost approximately 0.1 to 0.2 million USD per km depending on the works required and remediation works are likely to be even more costly.

Global change will have several levels of impact on the region. Under present conditions, it is very difficult to relate health impacts to global change, as the relationship is likely to be indirect, except for the case of extreme weather conditions which destroy life or cause propagation of water-related diseases. Evidence from other case studies indicate that global change issues will cause human population displacement as a result of the loss of coastal land, loss of jobs and economic opportunities, loss of private and public property, loss of traditional sites and memorial grounds, loss of biodiversity critical to community support, and loss of livelihood (IPCC 2001). In fact, the sea already threatens some towns in Comoros, and coastal protection works are being undertaken. In addition, some cultural and archaeological sites have also disappeared.

The social impacts of sea level rise will cause migration and displacement of the population. Those that can afford it will be able to leave the country but many will have to seek alternative housing further inland. Since most of the economic activities are located on the coast, sea level rise will cause loss of jobs and economic opportunity leading to serious social problems within the communities. Loss of property will also probably cause an increase in the value of property as available land becomes more scarce. Beach loss will have a significant impact on jobs in the tourism sector.

**Conclusions and future outlook**

Global change is indeed very complex and much more research is required before conclusive statements can be made. However, as concluded by IPPC (2001), there is now clear and discernible evidence of changes in the climate which are likely to cause serious modifications to the Earths functioning over the next 50 to 100 years. The report concludes that the areas most affected will be island states and countries which are least developed. This includes all countries comprising the Indian Ocean Islands region.

Because coral reefs are extremely vulnerable to increases in sea temperature, as illustrated by recent mass bleaching events, mounting research evidence points to these complex ecosystems as the litmus test for global change. Since they are among the most diverse and productive biological systems on Earth, the effects will be catastrophic to many coastal states.

In the future, global change will have severe impacts, if current trends are not curbed by rapid and expedient interventions. Substantial attention is needed to address this issue.

**Priority concerns**

Based upon the analysis of the main issues, it was concluded that the most severe concern for the region was Pollution. The concerns were ranked in descending order of severity:

1. Pollution
2. Global change
3. Habitat and community modification
4. Unsustainable exploitation of fish and other living resources
5. Freshwater shortage

Supporting evidence was obtained from the African Environment Outlook (AEO) assessment (UNEP 2002), the GEF MSP Sub-Saharan African Project: Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa (which include reports for Seychelles and Mauritius only by Dulyamamode et al. 2002 and Jones et al. 2002, respectively), and the Nairobi Convention Transboundary Analysis Assessments (UNEP 1998). All these reports conclude that pollution is one of the priority areas in the region. These reports also single out the issue of solid wastes as a common problem in the region, but no in-depth analyses or policy option analyses have been conducted. Below, the impacts of the two priority concerns (Pollution and Global change) are summarised followed by a comprehensive overview of the solid waste issue in the region.

**Pollution**

The regional assessment concluded that pollution is a priority that should be addressed in the context of transboundary waters assessment. Among all of the issues considered, the problem of solid wastes (both land-based and marine-based) was considered to be most critical in the Indian Ocean Islands region, with important transboundary implications.

The issue of microbiological pollution is also important at national level, especially in non-urbanised and coastal areas, which tend to be devoid of proper wastewater treatment facilities. Linked to these issues is the problem of eutrophication caused by both raw sewage and over-application of fertiliser in agriculture, intensive animal
husbandry and industrialisation. Chemical pollution is relatively low and restricted within areas of heavy industrialisation. However, the long-term persistence and migration of some trace metals and other contaminants such as PCBs will have transboundary implications for the region. The sources of suspended solids vary between countries within the region, but it was concluded that they are linked to improper agricultural activities, slash-and-burn activities, improper construction and effluent discharge. The risk of an oil spill was considered very high, although no major spills have yet been reported.

The region will continue to be economically affected by pollution, especially in areas that are important for tourism. The financial impact on industries and local government to invest in cleaner technologies in order to abide by existing standards for discharge of effluents is also an important socio-economic issue that needs to be addressed if the problem is to be solved.

Pollution also has significant impact on human health in the region, primarily through the propagation of vermin such as cats, dogs and rats, which may in turn be carriers of deadly diseases such as bubonic plague, leptospirosis, scabies and other tropical scourges.

At the community level, the majority of the population is already affected by pollution, but it seems that the social perception of the problem is not far-reaching (i.e. people continue to litter despite being provided with waste collection facilities) and fundamental to any potential solution in the future.

Global change

Prioritisation of Global Change occurred primarily because of concerns that existing anthropogenic pressures would change the world’s climate to the detriment of vulnerable states such as those comprising the region. Further studies are required to indicate how islands will be affected by this global phenomenon. This includes a change in the hydrological cycle, which in turn will have a marked impact on the agricultural productivity, the water supply sector and with floods causing destruction to habitats and infrastructure. The impacts of sea level rise will also be pronounced resulting in land loss, erosion of beaches, damage to coastal infrastructure, degradation of coral reefs and loss of wetlands. Whilst there is considerable lack of data for those issues, there is general agreement that this issue should not be taken lightly, as some of its effects are already being observed in the region.

The impact of global change on the socio-economic development of the countries in the region has not been calculated but is estimated to be high, with losses in infrastructure and services the most severe. Furthermore, there are large concentrations of population along the coastline that would be affected by global change.

Under present conditions it is very difficult to assess the health impacts of global change, as the effects are likely to be indirect, except for the case of extreme weather conditions which destroy life or cause propagation of water-related diseases.

The social impacts of sea level rise will cause migration and displacement of the population. The prognosis for this environmental concern is strongly negative, especially in view of the uncertainty and the lack of adequate response by developing countries, which are responsible for the generation of a considerable proportion of greenhouse gases, one of the primary drivers of global climate change.

Solid wastes: Context and system description

If solid wastes are not managed properly, there are many negative impacts that may result. These impacts are not only restricted to where the wastes are generated or deposited but can have far-reaching consequences beyond national and ecosystem boundaries. For example, waste improperly deposited on land can find its way into the ocean and be transported for thousands of kilometres with impacts...
on marine life. Secondly, the degradation components of wastes, such as those coming from landfill leachates, can also seep into the marine environment allowing toxic substances to accumulate in marine life, for example whales.

The AEO (UNEP 2002) reports that the growing populations in urban centres in the Western Indian Ocean Islands, together with the growing number of tourists and patterns of increased consumption, are producing greater and greater volumes of solid waste.

**Geographical aspects**

In addition to domestic waste, which is common to each country in the region, the types of commercial waste generated is determined by the types of economic sectors present in each country. The sources are usually restricted geographically within urban centres, industrial zones, ports, fisheries areas and tourism areas such as beaches and dive sites. In most cases, these wastes are disposed of in open dumps due to lack of funds for properly engineered landfills. Furthermore, many of these dumps are located close to the coastal areas, and through leakage, runoff and wind-transport pollute the adjacent marine environment. With the increase in consumption patterns and industrial use, as well as tourism (cruise tourism), the amount of wastes entering the marine environment, without concomitant action on the ground, can only get worse.

In Comoros, the main sources are mainly on Grand Comores, within its capital Moroni, but also along its coastal areas where solid wastes are practically dumped onto the beaches (Figure 18) (UNEP 1998). Moroni generates both municipal solid wastes, litter, and wastes from the port and fishing vessels. The coastal marine environment is also littered with solid waste. No estimates of the extent of the problem have been made, although studies done in South Africa indicate that this is a problem throughout the entire Indian Ocean (Madzena & Lasiak 1997). In other rural areas, the same problem persists. Discharge of solid wastes from the major rivers is also an important source of accumulation of solid waste within the coastal zone.

In Madagascar, the problem is most pronounced in the cities, for example in Antananarivo (in the high lands) and Toamasina (the most important port city on the east coast). Littering is a big problem along the main roads and in the coastal regions. When the heavy rains come, the litter is swept to the coast and emptied into the sea, with a huge amount becoming stuck in the mangroves. Solid wastes are also generated in the industrial zones on the east coast, in particular within the vicinity of Toamasina. It is estimated that only 25% of solid waste is collected (UNEP 1999).

Solid waste in Mauritius is found mainly in the capital and its port, but also in other urban areas as well as villages. Although there is an efficient solid waste collection service, illegal disposal of rubbish and littering remains the main source of solid waste that ends up in the coastal environment. Waste from the fisheries trans-shipment port is also a problem. These amounts are not very high but no exact information is available.

In Seychelles, whilst there is an efficient service for collection of solid waste on the main inhabited islands, the problem arising from illegal dumping and littering causes some impact on the environment. The main areas affected are the beaches, rivers, ravines, drains and public areas. Since Seychelles also has an important fishing industry, wastes from this activity is also becoming a serious problem (Payet 1998).

Solid wastes that end up in the coastal marine environment not only affect the immediate environment, but are transported off the coast, into the open seas, and end up in remote areas where there is no significant human presence. For example, the Masaola Marine Park in Madagascar, and the Ste Anne Marine Park in Seychelles (both within the vicinity of major commercial ports and urban centres) suffer from the deposition of huge amounts of solid wastes transported by coastal currents (Payet 1996). A clean-up exercise in April 2003 by the Ste Anne Marine Park rangers in Seychelles resulted in the collection of over 5 m$^3$ of plastic debris on the small islands within the marine park. Remote islands, such as Aldabra and Cosmoledo Atolls (within the Seychelles EEZ), are also affected by solid wastes in the form of marine debris (Figure 19). It is estimated that more than 10 m$^3$ of wastes end up in the lagoons and beaches of these distant uninhabited islands. The impact...
on wildlife within the region is unfortunately not known, although the likely impacts can be inferred from studies done elsewhere (Coe & Rodgers 1997).

Another important geographical problem is waste from mobile sources within the Indian Ocean such as commercial transport ships, fishing boats and cruise ships. Wastes from commercial vessels may include packaging and domestic debris, which is discarded in the open sea. Secondly, fishing vessels also have a bad reputation of discarding empty salt (plastic) bags, large amounts of nets and other fishing gear, including marker buoys (Payet 1996). Waste sources from cruise vessels include solid wastes (e.g. plastic, paper, wood, cardboard, food waste, cans, and glass) and even hazardous ones such as fluorescent light bulbs, spent oil/lubricant cans and batteries. It has been estimated that a 3 000-passenger cruise ship (considered an average size, some carry 5 000 or more passengers) generates on a typical one-week voyage about 50 tonnes of garbage and solid wastes (Coe & Rodgers 1997). An emerging problem is that of small yachts chartered for tourism purposes. As they usually have a lack of space on board, rubbish is often thrown overboard or dumped on nearby islands. Figures on the amounts involved for each of these sources are not known, although for cruise ships this implications could be estimated.

The transboundary implications of solid wastes is exemplified in a report where a buoy travelled over two years from South Africa to Tasmania, a distance of over several thousand miles (CSIRO 1998).

The environmental impacts of solid wastes within the region can be divided into three main areas: impacts from uncollected solid wastes, impacts from improper disposal, and impacts from natural movement of solid waste.

Impacts from uncollected solid wastes

This is most prominent in Comoros and Madagascar, where there are no proper sanitary landfills and no collection service, except in the cities, but even there the service is not consistent. For example, in Antananarivo, about 240 tonnes of garbage remains uncollected every day. Piles of rubbish placed by the roadside or on the beach are a common sight. In Mauritius and Seychelles, littering is common in urban areas and illegal dumping is limited to rural areas and in ravines where they are not seen from the roadsides. In those cases, uncollected and illegal stacks of waste often end up in drains, causing blockages, which result in flooding and unsanitary conditions. Stray dogs, cats, rats, flies and other insects (especially mosquitoes) breed in stocks of solid wastes, and these animals are often very effective disease vectors. Foul

Table 16  Estimated annual amount of solid waste.

<table>
<thead>
<tr>
<th></th>
<th>Comoros (tonnes/year)</th>
<th>Madagascar (tonnes/year)</th>
<th>Mauritius (tonnes/year)</th>
<th>Seychelles (tonnes/year)</th>
<th>Total (tonnes/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic waste collected</td>
<td>27 090</td>
<td>219 000</td>
<td>370 369</td>
<td>44 400</td>
<td>1 095 000</td>
</tr>
<tr>
<td>Ship generated waste collected</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>1.3</td>
</tr>
<tr>
<td>Domestic waste not collected</td>
<td>104 000</td>
<td>1 095 000</td>
<td>60 000</td>
<td>2 500</td>
<td>1 266 500</td>
</tr>
<tr>
<td>Waste collected from rivers and drains</td>
<td>ND</td>
<td>9 000</td>
<td>4</td>
<td>ND</td>
<td>9 000</td>
</tr>
<tr>
<td>Waste collected in clean-up campaigns</td>
<td>ND</td>
<td>ND</td>
<td>73</td>
<td>271</td>
<td>344</td>
</tr>
<tr>
<td>Waste collected on beaches</td>
<td>ND</td>
<td>40 000</td>
<td>520</td>
<td>120</td>
<td>40 640</td>
</tr>
<tr>
<td>Total waste likely to end up in the sea (estimated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 316 484</td>
</tr>
<tr>
<td>Area used for waste disposal (ha)</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>2.5</td>
<td>2</td>
</tr>
</tbody>
</table>

ND = No Data. (Source: GIWA task team calculations 2003)

Consequently, the discharge of wastes into the coastal and marine areas, either through direct discharge or transport via rivers and drains is an increasing problem. For instance, surveys carried out in South African beaches five years apart, showed that the densities of all plastic debris have increased substantially (Ryan & Moloney 1990). Increases in the population of vermin have drastic consequences on the flora and fauna as well. For example, increases in rat populations can have an impact on important bird areas, affecting nesting and feeding patterns. Coastal bird populations may also be affected through ingestion of marine debris (Walker et al. 1997).

Open burning of wastes is also quite common in the absence of alternative measures. This is practiced throughout the region. In Seychelles, this practice has more or less been discontinued, but on the Island of La Digue people still burn their wastes. The impacts of burning municipal wastes are air pollution and smoke and toxic products of combustion such as dioxins (Yoshida et al. 2001).

Uncollected waste also degrades the aesthetic and natural beauty of the environment, discouraging efforts to keep streets and open spaces in a clean and attractive condition. Plastic bags are a particular aesthetic nuisance and they can cause the death of grazing animals (especially
in Comoros, which has a high livestock population), which eat them. It also known that turtles eat plastic bags mistaking them for jellyfish (Gramentz 1988).

**Impacts from improper disposal**

Impacts of improper disposal arise from poor collection systems, and disposal in open pits. As a temporary measure (although in many cases this extends beyond 10 years), governments try to collect the solid waste and deposit it somewhere “out of sight and out of mind”. For example, in Mauritius, five open landfills include the Poudre D’Or, Mt St Pierre, Riche Fond, Solferino, and La Martiniere while Beaux Songes and St. Martin have been rehabilitated for recreational use. In Seychelles, two such dumping sites exist at ‘La Retraite’, which is now closed, and Providence. In Madagascar, which is a much bigger island, an unaccounted number of open pits exist around the major cities. A number of environmental impacts need elaboration here.

Collection of the waste from the piles placed by the road side without proper receptacles impose a certain degree of risk to the waste collectors, as such wastes often contains sharp and broken objects. In some cases, the wastes, such as abandoned vehicles (seen in Mauritius and Seychelles), are not easily removed without proper equipment and heavy machinery (UNEP 2002).

Transport of the wastes in improper vehicles has two main impacts, spillage of wastes during the journey and leaking of liquid/decomposing wastes during the journey. Both these impacts have raised considerable concern in Seychelles and Mauritius. Open-top waste trucks have been observed to allow wastes to fall off their trucks resulting in a trail of wastes throughout streets and urban areas.

Disposal of the waste in open pits results in several short-term and long-term impacts and can affect the quality of the air, soil and water (Fent 2003). Mixing of solid wastes can cause them to auto-ignite, setting the landfill on fire. In Seychelles, one fire took several years to completely extinguish due the flammability and depth of the waste components in the landfill. Fires in landfills can generate toxic clouds/aerosols, including dioxins among other chemicals, which may have an impact on populations and ecosystems nearby.

Explosive containers, batteries and other explosive materials add to the danger. In the medium-term, landfill gas (which is produced by the decomposition of wastes) also presents an immediate danger to public safety, as it can be explosive if it is allowed to accumulate in confined spaces.

Soil contamination by leachates is perhaps not fully studied in the region, but depending on where the landfill is situated, the contamination of the soil can extend beyond the simple boundary of the open pit, as shown in the case of a sanitary landfill in the reclamation zone on Mahe Island, Seychelles (Payet 1999). Leaking of oils and other chemicals as well as decomposing organic matter can contaminate the soil rendering it infertile and also unsuitable for any further activity. Biochemical reactions also occur in open pits, which cause a number of toxic organic and inorganic chemicals to leach into the environment. Such chemicals can be transported for several kilometres and accumulate in both plants and animals, having an impact on the environment, the groundwater, agriculture and fisheries.

Contamination of watercourses, especially groundwater, is observed on several islands. For example, on La Digue (Seychelles), open dumping of wastes has a great risk of contaminating the groundwater. In Comoros, which depends on groundwater, the risk is even higher. Location of landfills close to the sea is also a potential problem, e.g. Providence Landfill in Seychelles. Leachates from the landfill may enter into the marine environment, accumulate in both shellfish and demersal fish, and could potentially affect human health. In Mauritius, the concentrations of six trace metals (chromium, nickel, copper, zinc, cadmium, lead) were analysed in the freshwater system at Flic en Flac. The results showed contamination from transport and industrial sources (Ramessur et al. 1998).

**Impacts from natural movement of solid wastes**

Information available from other regions indicates that almost 60% of solid wastes in countries that have no national solid waste collection service end up in the ocean (Derraik 2002), the remainder trapped in ravines, drains, wetlands and mangroves. This is likewise observed along the east coast of Madagascar from Fort Dauphin to Tamatave, and in Grand Comores, from Moroni to Mitsamiouli.

In addition, derelict fishing gear (estimated to be about 5% of all marine debris) is in constant movement in the ocean environment causing damage to marine ecosystems and species. It is estimated that ingestion of debris, entanglement, or both, affects at least 267 species worldwide, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species (Laist 1997). Throughout the Pacific Rim, derelict fishing gear (lost or discarded at sea and made up mostly of synthetic lines from trawl, drift, seine and gill nets) has become an environmental concern for all nations. Information for the Indian Ocean Island region is not available but is likely to be of the same order of magnitude because of the enormous size of and volume of waste
generated in Madagascar, as compared to the relatively small islands in the Pacific Ocean. The east coast of Africa where similar problems exist on an even greater scale is also an important contributing factor.

Entanglement and asphyxiation by common items like fishing line, strapping bands and six-pack rings are not reported in the region, but it is believed that it occurs (Mortimer, pers. comm.). Once entangled, animals have trouble eating, breathing or swimming, all of which can have fatal consequences. Since some plastics take hundreds of years to degrade, they will continue to trap and kill animals year after year.

Solid waste also has an impact on ecosystems such as reef and seagrass beds, by forming mats and nets, entangling its parts and restricting growth. A net, or a buoy with long trails of strings can also affect coral reefs, as it drifts and gets entangled on the coral heads. As wave action moves it back and forth, the entangled net pulls on the coral destroying it, and that can happen in successive stages on a reef. The impact of a storm event can also be cumulative. Accumulation of litter in coastal areas can also lead to smothering of benthic communities in both soft and hard seabed substrates.

Some other research has indicated that floating debris can transport stowaway organisms (including invasive species) over long distances (Gregory 1999).

**Economic aspects**

The economic losses resulting from improper solid waste management can be observed in all productive sectors of the economy although they are not always obvious. Poor solid waste collection services increases environmental clean-up costs and health costs and reduces revenue from tourism, fisheries, aquaculture, and also affects safe navigation, flood defences and drains.

Environmental clean-up costs are very high and often exceed proper waste collection costs (Table 17). For example in Seychelles an average litter clean-up campaign costs around 6 000 USD per day for one island. Health costs could not be quantified. Reduction of revenue from tourism is expected when you consider that tourists will refuse to use beaches and recreational areas that are polluted. Divers can also be affected and in some extreme cases debris can lead to drowning. These situations also lead to high maintenance costs, for example, beach cleaning activities cost more than 40 USD per m² in the Seychelles (Table 18). In fact, to reduce this cost the local contractor recently purchased a mobile beach cleaning machine to reduce effort, time and cost associated with beach cleaning.

Entanglement of propellers, clogging of water intakes and blocking of pumping systems all contribute to additional costs of recreational boating and fishing. The major impacts of litter on fisheries include damage to nets, fouling of fishing grounds and damage to fish stocks. However, the exact costs of these impacts could not be determined, but can be very high as repair of gear is about USD 50 per m², which leads them to being discarded which only exacerbates the problem. Losses for fishermen can be in the time spent clearing litter from their nets, loss of catch due to contamination, loss of time due to fouled propellers including repair or replacement. Should these costs be summed up for each fisherman then the economic losses can be significant (Table 18).

The majority of costs of flooding can be attributed to blocked drains and flood protection works. In Seychelles, it is estimated that river and drain clean-up costs the country about 500 000 USD per year.

**Health aspects**

Vulnerable groups (school children, scavengers and waste workers) and communities are the most at risk from improper management of wastes. People living close to open dumps are also at risk since the water supply may become contaminated either due to waste dumping or leakage from landfill sites, and also the propagation of vermin such as rats and mosquitoes. In particular, organic domestic waste poses a serious threat, since it ferments, creating conditions favourable to the survival and growth of microbial pathogens. Direct handling of solid waste can result in various types of infectious and chronic diseases. Fires

### Table 17  Costs associated with waste management.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comoros</th>
<th>Madagascar</th>
<th>Mauritius</th>
<th>Seychelles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of collection</td>
<td>USD/tonnes</td>
<td>42</td>
<td>60</td>
<td>67</td>
</tr>
<tr>
<td>million USD/year</td>
<td></td>
<td>2</td>
<td>ND</td>
<td>25</td>
</tr>
<tr>
<td>Cost of treatment/disposal</td>
<td>USD/tonnes</td>
<td>6</td>
<td>0.2</td>
<td>ND</td>
</tr>
<tr>
<td>million USD/year</td>
<td></td>
<td>0.3</td>
<td>ND</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: ND = No Data. (Source: GIWA Task team calculations 2003)

### Table 18  Economic costs of solid waste deposited along river banks, beaches and in the sea.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Madagascar</th>
<th>Seychelles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of road cleaning (USD/km)</td>
<td>30.8</td>
<td>ND</td>
</tr>
<tr>
<td>Cost of beach cleaning (USD/m²)</td>
<td>ND</td>
<td>40</td>
</tr>
<tr>
<td>Cost of river cleaning and unblocking (USD/year)</td>
<td>ND</td>
<td>500 000</td>
</tr>
<tr>
<td>Cost to fishermen (engine and net repair) (USD/year)</td>
<td>1 000</td>
<td>ND</td>
</tr>
</tbody>
</table>

Note: ND = No Data. (Source: GIWA Task team calculations 2003)
and aerial transport of wastes will also affect those communities. Within the suburbs of Antananarivo, Madagascar, these areas are very common. Co-disposal of industrial wastes with domestic wastes can also have serious impact on human health. However, since there have been no specific studies done in the region linking the issue of solid wastes to health problems, the remarks made here are merely speculative.

However, in all countries of the region uncollected solid waste can also obstruct stormwater run-off, resulting in stagnant water bodies that become breeding grounds for diseases, especially cholera and malaria, both of which are found in Comoros and Madagascar. Waste dumped near a water source also causes contamination of the water body or the groundwater source, and since there are no facilities to test the water for contaminants, the water is consumed anyway. Direct dumping of untreated waste in rivers, seas, and lakes results in the accumulation of toxic substances in the food chain through the plants and animals that feed on them.

Co-disposal of hospital waste requires special attention, throughout the region, especially with emerging diseases such as severe acute respiratory syndrome (SARS) and other epidemics. There are few specialised clinical waste disposal facilities in the countries of the region. In Seychelles, clinical wastes are incinerated in a small portable incinerator with no flue treatment. Dangerous items (such as broken glass, razor blades, hypodermic needles and other healthcare wastes, aerosol cans and potentially explosive containers and chemicals from industries) may pose risks of injury or poisoning, particularly to children and people who sort through the waste.

Beachgoers, in particular, cut themselves on glass and metal left on the beach. Marine debris also endangers the safety and livelihood of fishermen and recreational boaters.

**Conclusions**

The problem of solid waste is indeed far-reaching as previously expected. Although the majority of solid waste is generated on land, a huge proportion ends up in the coastal and ocean environment causing degradation of ecosystems and economic impacts.

In summary, the main impacts of solid waste in the region are: (i) pollution of groundwater, surface water, and wetlands; (ii) risks for human health; (iii) degradation of coastal marine environment (including coral reefs) and tourist attractions such as beaches; (iv) possible disease outbreaks and the destruction of fisheries; (vii) accumulation and toxic effects of leachates; and (viii) eventually impact on the economy.

It is concluded that these impacts are of sufficient cost to the economy that it justifies the implementation of proper waste management services and infrastructure. The next section explores the root causes of this problem in detail and proposes a policy framework to address the problem in the long-term.