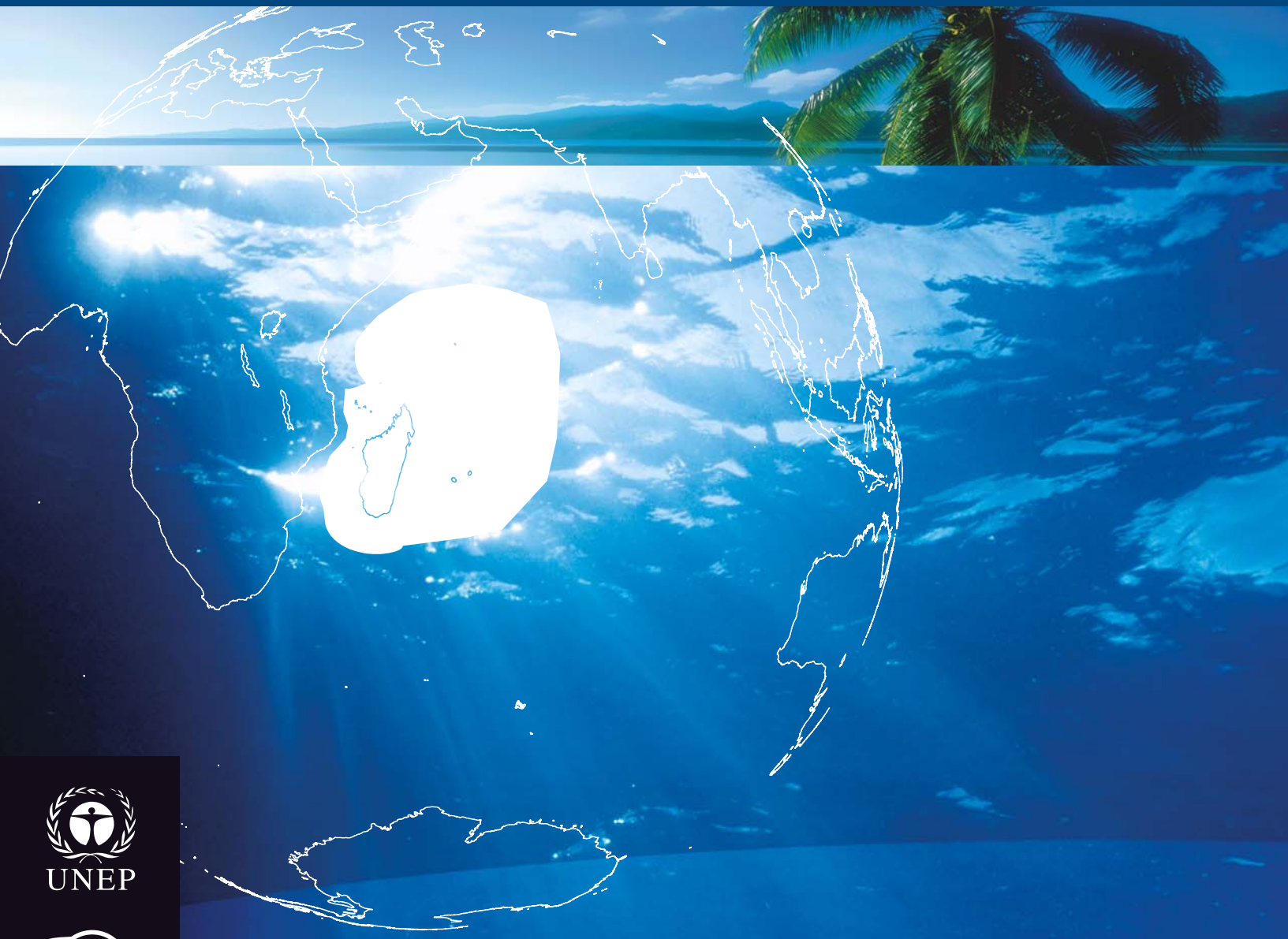
Global International Waters Assessment



Indian Ocean Islands

GIWA Regional assessment 45b

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Regional assessments

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Executive summary

The Indian Ocean Islands region comprises the island states of Comoros, Mauritius, Madagascar and Seychelles which are situated in the Western Indian Ocean (WIO). The combined total Exclusive Economic Zone (EEZ) of the Island States within the region is approximately 4.1 million km^2. This provides the approximate limits of the region (between latitudes 5° N and 30° S and extending as far as 70° E). In terms of economic development, Mauritius and Seychelles appear to have met the basic conditions for sustainable human development, but considerable work is required in Madagascar and Comoros.

The most salient features of the region in the context of the Global International Waters Assessment (GIWA) is the very low proportion of land to sea, and the smaller size of Comoros, Mauritius and Seychelles in relation to Madagascar. However, Madagascar shows the vulnerability of an island state and is also biogeographically, hydrologically, and economically linked to the rest of the region.

The large size of the EEZs in the region means that the GIWA issues are mostly oceanic which are influenced by activities that happen on land. The assessment of transboundary issues is therefore done in a special context, as the Island States are separated by large expanses of ocean and do not share any coastal marine environments nor freshwater resources. However, long-range transport of pollutants, movement of human pressure across boundaries and the impacts of global change are all significant issues that need to be considered in an international waters and transboundary context.

The impact assessment showed that the levels of human impacts on natural systems and resources have increased. This human pressure on existing ecosystems and limited resources threatens several endemic and migratory marine species. Growth in fisheries and tourism are likely to be the most significant economic forces in the region in the next 20 years. However, impacts of global change, such as coastal erosion and coral bleaching, seem to be the biggest threat to development in the region. The assessment concluded that Pollution was the most significant GIWA concern for the region, followed by Global change.

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

Pollution in terms of improper disposal of solid wastes and eutrophication as a result of poor treatment facilities, was singled out as being the most severe concern in the region. The risk of oil spills in the region is also considered significant, since there is high tanker traffic from the oil rich countries of the Middle East. Other issues such as overexploitation of fish and habitat modification also received attention, implying that those impacts are very much linked to the presence of humans.

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

The causal chain analysis identified four root causes:

Root cause 1: Lack of investment planning and priorities.

Root cause 2: Lack of effective mechanisms, inadequate institutional structure, laws and capacity.

Root cause 3: Lack of adequate facilities, services for collection and management of wastes.

Root cause 4: Lack of education and awareness.

Although some of these root causes may not be considered the absolute root cause of the problem, they are appropriate targets for policy interventions. Factors that are more widely recognised as root causes, such as population growth and increased consumption, can take years to redress and therefore, are less amenable to policy interventions.

The policy options analysis resulted in more than 30 possible policy options. However, when these were evaluated in their regional context for efficiency, equitability and practicality, only a few could be feasibly implemented, although in some cases local conditions will need to be taken into consideration. Further analysis of these selected policy options generated a series of recommendations as the key output of this report. These outputs are:

1. To perform a national survey of products/wastes that will form part of a refundable deposit system.
2. Reduce taxes on waste separation and treatment technologies.
3. Tax the disposal of solid wastes by industry.
4. Implement tax incentives to improve the quality and encourage use of recycled products.
5. Subsidies are provided (a) to the municipality to commence a waste collection service, and (b) to the private sector to facilitate investment in waste minimisation/treatment.
6. Establishment of a regulatory framework.
7. Development of emissions standards for landfills, etc.
8. Improve compliance through stakeholder involvement.
9. Training in legal enforcement.
10. Put in place an efficient solid waste collection service of the entire territory.
11. Governments should allocate a sizeable proportion of their national budget for solid waste management and use that for counterpart fund-raising.
12. Citizens should be given a constitutional right to a clean and safe environment, as well as a clear definition of existing property rights.
13. Explore opportunities for increasing revenue and employment from solid wastes.
14. Establish an education programme to increase awareness and action.

Major data gaps exist in several areas, including the key economic sectors. Several global assessments have not included this very small part of the world, for example, there are no census reports for the many threatened species in the region.

Abbreviations and acronyms

ACP	African-Caribbean-Pacific
AEO	African Environment Outlook
AUE	Associations des usagers de l'eau
BOD_5	5-day Biochemical Oxygen Demand
CCA	Causal Chain Analysis
CICE	Comite Interministeriel Consultatif pour L'Environnement
CNE	Conseil National pour L'Environment
COAP	Code of Protected Areas
DGE	Direction General de L'Environnement
DGR	Direction du génie rural
DGTP	Direction de Generale Travaux Publics
EEZ	Exclusive Economic Zone
EIA	Environment Impact Assessments
EPA	Environment Protection Act
EQ	Equatorial Current
FAO	Food and Agriculture Organization
FCPFD	Fish Catch per Fisherman Day
GEF	Global Environment Facility
GELOSE	Gestion Locale Securisee
GIWA	Global International Waters Assessment
GST	General Service Tax
ICZM	Integrated Coastal Zone Management
IOTC	The Indian Ocean Tuna Commission
IRA	Acute Respiratory Infections
ITZC	Inter-tropical Convergence Zone
IUCN	World Conservation Union
IWC	International Whaling Commission
MARPOL	The International Convention for the Prevention of Pollution from Ships
MPA	Marine Protected Area
MSY	Maximum Sustainable Yield
NEAC	Seycelles the National Environment Advisory Council
NEC	North Equatorial Current
NGO	Non-Government Organisation
PAE	Plan d'Action Environnementales
PNE	Politique Nationale de L'Environnement
POA	Policy Options Analysis
SARS	Severe Acute Respiratory Syndrome
SEC	South Equatorial Current
SECC	South Equatorial Counter-Current
SGRH	Service de Gestion des Réseaux Hydroagricoles
SWAC	Solid Waste and Cleaning Agency
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WIO	Western Indian Ocean

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Regional definition

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the Indian Ocean Islands region

The Indian Ocean is the third largest ocean on Earth with a surface area of 73 million km^2, bounded to the north by the Arabian Peninsula, to the west by Africa, east by the Malay Peninsula and to the south by Antarctica. The Indian Ocean Islands region is located in the western Indian Ocean between 5° North and 30° South, and between 42° East to as far as 70° (Figure 1). The region comprises of the island states of Comoros, Madagascar, Mauritius and Seychelles.

Table 1 Geographical characteristics of the Indian Ocean Islands.

Countries	Land area (km^2)	Coastline (km)	Territorial waters (km^2)	Continental Shelf (km^2)	EEZ (million km^2)
Comoros	2 230	469	12 684	1 416	0.161
Madagascar	581 540	9 935	124 938	96 653	1.079
Mauritius	2 030	496	16 840	27 373	1.274
Seychelles	450	747	45 411	31 479	1.288

Note: The figures may differ from various reports published for the region, but to ensure concistency all data was extracted from the same source. (Source: GEO Data Portal 2003)

The combined Exclusive Economic Zone (EEZ) of the island states in the region covers an ocean area of approximately 3.8 million km^2. The total land cover is only 586 250 km^2, of which Madagascar constitutes about 99 % (Table 1).

The island states of the region show some similar characteristics as well as important differences. The most important difference in the context of this report is the dwarfing of the smaller island issues by Madagascar, which in fact can be considered as a micro-continent. However, Madagascar shows the vulnerability of an island state and is also biogeographically, hydrologically, and economically linked to the rest of the region.

The percentage of land to sea area in the region is very low, meaning that the states in the region have large expanses of the ocean under their jurisdiction as specified in the Convention on the Law of the Sea, with respect to territorial waters, continental shelves and EEZs. This places the assessment of the transboundary issues in a special context as the island states are separated by large expanses of the ocean and do not share any coastal marine environments or freshwater resources. However, long-range transport of pollutants, movement of human pressure across boundaries and the impacts of global change are all issues which need to be assessed in a transboundary context.

The human pressure on existing limited resources is also an issue shared by all States of the region, and several endemic and migratory marine species are especially threatened. Growth in fisheries and tourism are likely to be the most significant economic forces in the region in the next 20 years.

Key data gaps exist in several areas, including the key economic sectors. Several global assessments have not included this small part of the world, for example there are no census reports for the main threatened species in the region.

Physical characteristics

Geophysical characteristics

The Indian Ocean harbours both seismic (ridges) and aseismic (banks and plateaus) formations. The seismically active Central Indian Ridge follows the north-south direction from the earthquake epicentres at the equator to 21° S where it intersects with the east-west running Rodriguez Ridge. Both these formations (aseismic and seismic) contribute to the diversity of islands in the region: Madagascar and part of the Seychelles are continental, and Comoros and Mauritius are volcanic in origin.

Characteristic of the Indian Ocean Islands region is the abundance of relatively shallow ridges and plateaus that are free from earthquake activity. These aseismic ridges or plateaus run predominantly north to south and divide the ocean into separate basins. They differ from the mid-ocean ridge in that they have a smoother topography, are commonly linear or angular in arrangement, are often bounded by faults, and are covered with sedimentary formations. The basement rocks are in most areas oceanic and in the case of the Seychelles Bank, continental.

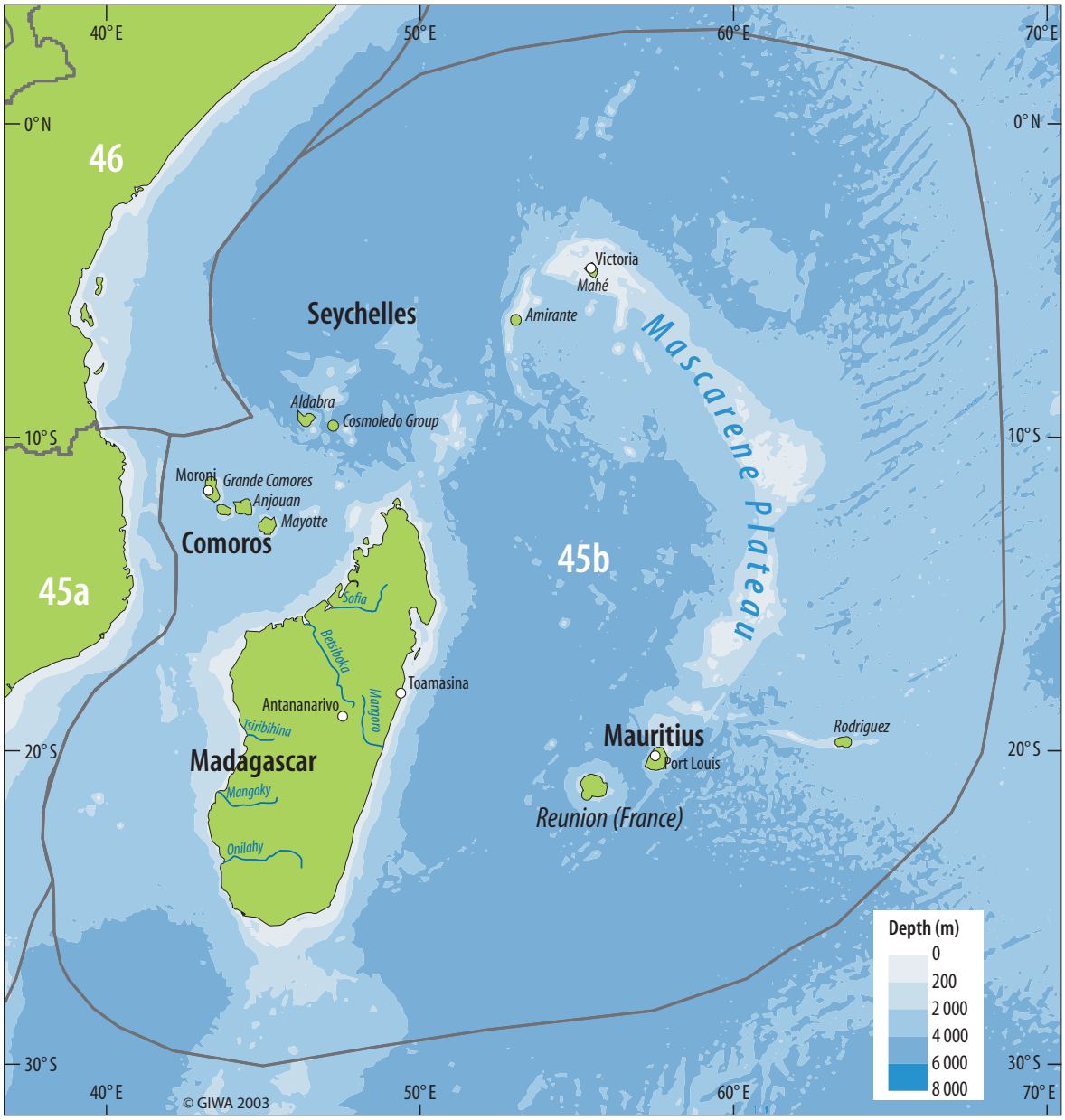

Figure 1 Boundaries of the Indian Ocean Islands region.

The Mascarene Plateau

The Mascarene Plateau extends as a fault composite arc for 2 300 km with a depth range from 0 to 100 m (Figure 1). The Precambrian granitic micro-continent of the Seychelles Bank extends southward through the coral reef capped volcanic structures of Saya de Malha, Nazareth Bank, and Cargados Carajos Banks to the Island of Mauritius. The granitic rocks of the Seychelles bank are unique on the mid-oceanic islands and have been described by Braithwaite (1984) and dated at 650 million years. Further south, the structure of Saya de Malha consists of a coral layer 1.5 km thick, which covers the oceanic type crust and similarly the Nazareth and Cargados banks. The Saya de Malha bank is part of the high seas and part of the Mascarene Plateau. The bank is subjected to numerous human activities ranging from fishing to aquaculture. Close to the granitic Seychelles bank is also the Amirantes bank. The Amirantes Plateau has depths ranging from 5 to 60 m abruptly dropping down to over 1 000 m in certain areas.

Mozambique and Madagascar Ridges

Little is known of the structure of the Mozambique and Madagascar Ridges. Both extend southward continuously from continental blocks, at depths between 1 000 and 2 000 m. At the southern ends they approach the Southwest Indian Ridge; the Madagascar Ridge joins it at the 3 000 m level. Both ridges have steep and linear scarps on their eastern side. The continental shelf ranges from 25 to 50 km in width offshore Somalia to 100 km offshore Madagascar and is terminated seaward by a shelf/slope break (Tomczak & Godfrey 2001).

Climate

The climate regime of monsoon and trade winds in the Indian Ocean is influenced by its geography. The monsoon regime occurs when the direction of average prevailing winds changes more than 90° from summer to winter (Ramage 1969). The monsoon regime dominates the northern part of the Indian Ocean and in the south such occurrences are mainly at the east and west extremes. Figure 2 indicates the regions affected by monsoons. There is no specific climatic description for the Indian Ocean Islands region, so a description of the climate of western Indian Ocean is provided.

Atmospheric pressure in January ranges from 1 010 to 1 012 millibars (mb), extending from the southern anticyclonic high pressure areas (30° - 40° S). In July, the southern anticyclone reaches its most northerly position at 25° S and is much stronger than in January. During that period, the atmospheric pressure ranges from 1 021 to 1 000 mb.

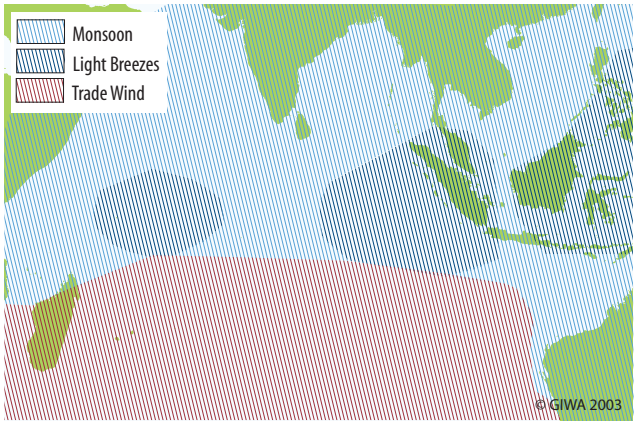

Figure 2 Areas within the Indian Ocean influenced by monsoons.
(Source: Redrawn from Ramage 1969)

In areas that are affected by the monsoon (for example Seychelles, Comoros and northern Madagascar) three climatic situations are observed. First, there is the Northeast monsoon, which blows from December to March following a north-south pressure gradient with the northeast winds prevailing at 2-3 m/s on average. Crossing the Equator, the northeasterly winds change to a northwesterly direction. Secondly, the Southwest monsoon, north of the equator, is an extension of the southeast trade winds. It lasts from June to September following a steep pressure gradient situated between the southern anticyclone and the low pressure areas of the northern Indian Ocean. Finally, the inter-monsoon period is dominant from April to May and from October to November. During these transitions a strong westerly flux dominates in the equatorial areas. A summary of these three climatic phenomena is shown in Figure 3.

Conditions for coastal upwelling are also influenced by the monsoonal shifts. Along the eastern coastline, winds favourable for upwelling are weak during the Northeast monsoon season and absent during the

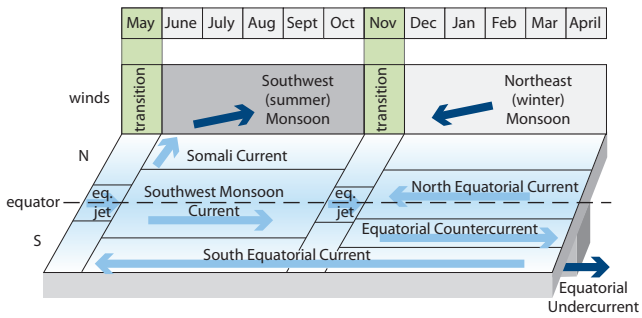

Figure 3 Characteristics of the monsoon in the Indian Ocean.
(Source: Tomzak & Godfrey 2001)

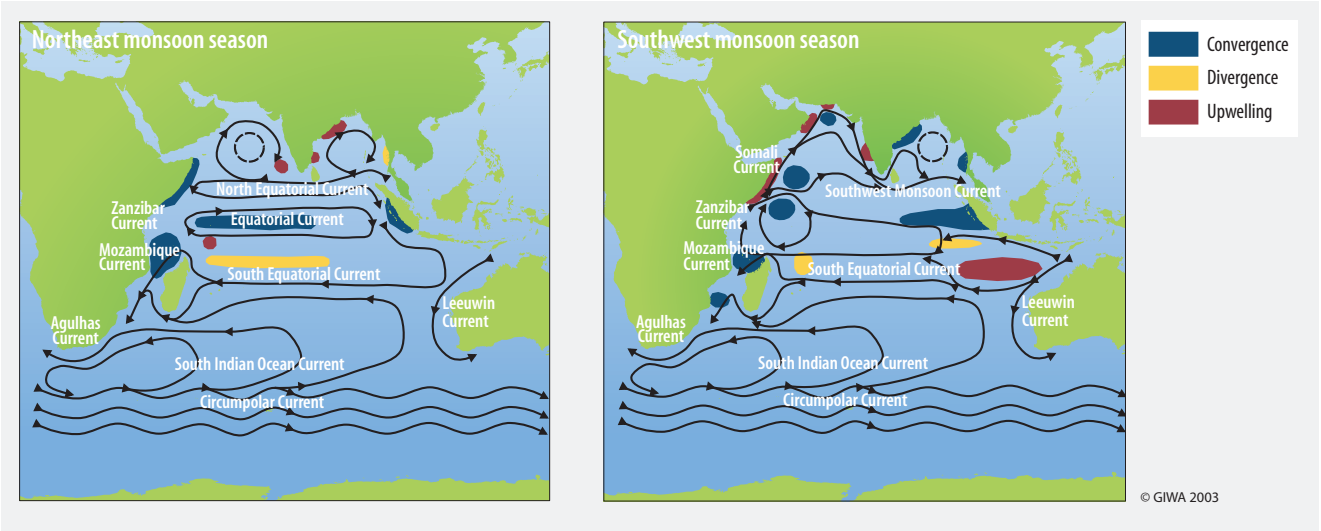

Figure 4 Currents, upwelling, convergence and divergence areas in the Indian Ocean during the Northeast and Southwest monsoon seasons.
(Source: Redrawn from Marsac & Stequert 1989, Tomczak & Godfrey 2001)

Southwest monsoon season. However, the strongest upwelling of the Indian Ocean occurs along its western coastline when the Southwest monsoon produces strong Ekman transport away from the coasts of Somalia and Arabia (Figure 4).

During the Northeast monsoon, wind bursts can occur when the atmospheric pressure gets very low in association with the Inter-tropical Convergence Zone (ITZC). Cyclones are thus formed in areas of atmospheric depression. Active cyclone formations last from December to April peaking around January and February. The cyclones usually travel westward of 8° S. The vulnerable areas are the Islands of Madagascar, Mauritius and to some extent the Comoros. Except for some outlying islands, such as Cosmoledo and Aldabra Atolls, Seychelles is situated to the north of cyclonic trajectories and generally escape the influence of cyclones.

Tropical rainfall levels are usually greatest in the central Indian Ocean with high levels on the east coast of Madagascar, averaging 2 000 mm/year (Table 2). There is a marked difference in rainfall between the east coast, which is exposed to the trade winds, and the west coast of Madagascar, bordering the Mozambique Channel. The west coast receives more than 1 700 mm annually in the northwest, 700 mm in the middle west and less than 500 mm in the southwest.

Table 2 Discharge and precipitation.

Country	Annual river discharge (m^3/s)	Average annual rainfall (mm)		
		min.	max.	mean
Comoros	ND	ND	6 000	900
Madagascar	2 267	400	3 000	1 700
Mauritius	19	700	4 000	2 180
Seychelles	23	1 290	2 370	1 740

Note: ND = No Data. (Source: World Bank 1992, FAO 1989, BDPA 1991, Voromarthy et al. 1998)

Mauritius has a moderate tropical climate, mainly because of its topographical relief and prevailing southeast winds. Two seasons prevail over the Island, with summer from November to April and winter from May to October. Mean monthly temperature is 22 to 28°C on the coast and 17 to 22°C on the inland central plateau. Rainfall varies over the year such that December to April is the wet season with February and March being the wettest months, especially when tropical cyclones may bring 200 mm to 1 000 mm of rain in a few days. September to November is the dry season with droughts occurring during that period. The graph of annual rainfall varies in an erratic saw-tooth pattern. Mean annual precipitation is of the order of 800 mm/year on the western coast and 3 800 mm/year on the central plateau. The potential evapotranspiration varies from 2 000 mm/year on the coast to 1 400 mm/year on the central plateau.

Comoros has a tropical climate characterised by two seasons; a warm season and a wet season similar to Mauritius (CIA World Fact Book 2002). The Northeast monsoon sometimes brings heavy precipitation and cyclones. The climate varies over a few kilometres by the wind fronts and altitude. The annual rainfall is well over 2 000 mm marked by a microclimate similar to mountainous islands.

The climate of Seychelles consists of the Northwest monsoon from mid-November to mid-March followed by an inter-monsoon period of light variable winds and frequent calms; the South East Trade Winds from the end of May to October, which average 6 m/s and frequently limit fishing activity; and a second inter-monsoon during October to November. Temperature and humidity usually remains high throughout the year with a mean temperature of 26.9°C and humidity of 80%. Seychelles receives, on average, 193 mm of rain per month with the maximum occurring around January and February.

Currents

Surface currents are often induced in areas of convergence or divergence (Figure 4). Divergence areas are the most productive and consequently, these are often considered the most favourable areas to find tuna, swordfish and small pelagic species. In the equatorial Indian Ocean, surface currents exhibit strong temporal and spatial variability. Inter-annual flow and direction variations of the main currents as well as seasonal changes (due to winds) on the surface strata and eddy type situations have been recorded (Stequert & Marsac 1989).

A number of current systems have been observed in the Indian Ocean (Nguta 1998), the most important in the region being the Equatorial Current (EC) and the South Equatorial Counter-Current (SECC).

The Equatorial Current

The change in surface currents through the seasons is shown in Figure 4. The North Equatorial Current (NEC) is dominant during January to March at the peak of the Northeast monsoon. This current runs from the Malacca Strait, westwards at a speed of about 0.3 m/s as far as Sri Lanka, where it bends southward to about 2° S and accelerates to reach 0.5-0.8 m/s. Also flowing westwards is the South Equatorial Current (SEC), which is dominant in the area south of 8° S with velocities rarely exceeding 0.3 m/s.

The South Equatorial Counter-Current

The SECC flows eastwards between the westward flowing NEC and SEC with a velocity ranging from 0.5-0.8 m/s, which decreases as it moves to the east. In January, the SECC does not reach beyond 70° E, being opposed in the east by weak westward flow (Tomczak & Godfrey 2001).

Mozambique and East Madagascar Currents

The dynamics of the subsurface induces very important enrichment processes vital for the fisheries of the region. Two of these processes are found within the Indian Ocean Islands region.

Two western boundary currents, one along eastern Madagascar and one along the coast of Mozambique, create a subtropical gyre in the southern part of the region. The bifurcation east of Madagascar and again near the African coast is also seen in the Sverdrup flow, as is the joining of the Mozambique and East Madagascar Currents into the Agulhas Current. However, further research is required to determine its relevance to the Agulhas Current (Bryden & Beal 2001).

An anticyclone gyre is situated in the northern basin associated with a water convergence in the centre with an average mixed layer depth of 100 m (July to September) coinciding with the cool season of the northern winter monsoon. The 20°C isotherm is found at a depth of 180 to 200 m. A converging eddy has also been observed in the channel's southern basin. At 16° to 18° S, an inverted circulation (cyclonic) is formed during the southern summer separating the two eddies. In the southern winter, the northern eddy would spread towards the southern part as a cyclonic circulation dissipating slowly. These currents induce seasonal upwelling west of Grande Comoros, west of Cap d'Ambre and Juan de Nova (Madagascar), and south of Madagascar (25° and 40° S) and Ford Dauphin.

High primary production is observed in the Mozambique Channel near Cap St Andre and Juan de Nova (Madagascar). Along this convergence the average chlorophyll a level is 0.4 mg/l. Lower concentrations have been observed in Tulèar compared with Nosy Be where the continental shelf is wider. Around the Seychelles, during the more suitable periods for the formation of upwelling along the plateau, chlorophyll a levels in the first 100 m depth layer have been found to be greater than 40 mg/m^2 compared to 20 mg/m^2 measured offshore (Cushing 1973).

Water catchments

The characteristics of the water catchments within the region vary from the large continental landmass of Madagascar to the small granitic islands of the Seychelles, the steep volcanic islands of Comoros and Mauritius, and the flat coral islands. Pollution and effects of land use change, such as sediments, are discharged into the coastal area as a result of terrestrial run-off. This has implications for the evaluation of transboundary issues discussed in later sections of the report. River discharge is highest in Madagascar and lowest in the small islands (Table 2) (Vorosmarty et al. 1998).

Comoros

Being a volcanic group of islands, the Comoros, especially on Grande Comores, have no perennial streams since the soils are too thin and permeable. As a consequence, water is collected in rain catchment

tanks, although there is an underground reservoir of freshwater floating over salty water, which has seeped in from the sea (World Bank 1979).

Comoros' major catchment is Lake Dziani Boundouni, which is situated in the Djando region, on the Island of Mohéli (Global Wetlands Database 2003). The closest main village is Itsamia off Chissioua M'chaco islet. It is a crater lake, one of the few freshwater lakes in Comoros. The remarkable limnological characteristics of the site, with upwelling that have led to local belief in a monster, suggest interesting subterranean volcanic phenomena. The ancient Crater Lake may have some connection with the ocean and the fauna that live in these extreme conditions could be of great scientific interest. There are no large animal species but the lake supports a rich and varied bird population. Observed species include *Ardeola idea*, *Butorides striatus*, *Bubulcus ibis*, *Egretta alba*, *Ardea cinerea*, *Gallinula chloropus*, *Tringa nebularia* and *Actitis hypoleucos*. Up to 450 *Tachybaptus ruficollis* occur there but their breeding site remains a mystery. Outside the site, the steep, rocky and unvegetated islet of Chissioua M'chaco, is inhabited by marine birds, which are protected by virtue of the inaccessibility of the place.

Madagascar

The island of Madagascar is of granitic origin, estimated to be around 1 500 million years, and encompasses a wide range of environments from semi-desert to tropical rainforests in the north. The Island also has isolated volcanic formations. Due to its topography and size, the eastern alluvial plain, granite faults, the central highlands and various areas of geological subsidence, Madagascar has the largest and most extensive terrestrial water system in the region. Madagascar can be divided into two major basin groups - one draining to the west into the Mozambique Channel and the other draining to the east into the Indian Ocean. Rainfall in Madagascar varies from that of tropical rainforest to near desert conditions (Bensaid 1992). Water areas, which include lakes, are estimated to have a combined volume of over 40 km^3. The rivers, which run over 3 000 km when combined, are more dominant on the west than on the east coast of Madagascar. The most important rivers and their associated water catchments are, from the west; Betsiboka River with a catchment area of 49 000 km^2, Tsiribihina with a catchment area of 49 800 km^2, Mangoky with a catchment area of 55 750 km^2, the Onilahy with a catchment area of 32 000 km^2, and the Sofia with a catchment area of 27 300 km^2. In the east, the largest catchment is the Mangoro River with an area of 17 175 km^2. There are also about 1 300 lakes on the Island, with a combined surface area of 2 000 km^2. The largest are; the Alaotra Lake (220 km^2) and Les Pangalanes (150 km^2) in the east, the Kinkony Lake (139 km^2) and the Loza Lake (45.6 km^2) in the northwest, the Ihotry Lake (97 km^2) and the Tsimanampetsoka Lake (30 km^2) in the southwest, and the Itasy Lake (35 km^2) in the central part of the Island. Several lakes formed within volcanic craters are also found. Figure 5 shows the monthly discharge from selected rivers in Madagascar.

Mauritius

The island of Mauritius is divided into 25 major river basins and 21 minor ones (ERM 1999). The largest basin is the Grand River South East (166 km^2), followed by Grand River North West (113 km^2), and then Riviere du poste (87 km^2). All these rivers empty into the Indian Ocean, discharge is estimated to be 0.5 km^3/year (Figure 5) (World Bank 1992). The surface water system is served by 92 rivers and 232 rivulets, which radiate from the centre of the Island through a dense and heterogeneous network. Most of the rivers are perennial with a few linking directly to the aquifers either by recharging the latter or draining

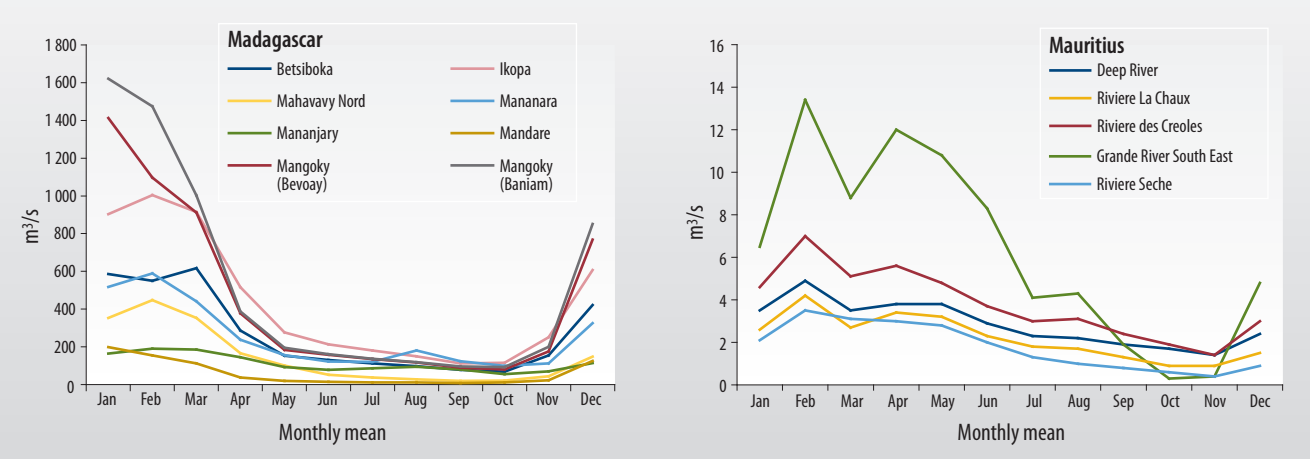

Figure 5 Monthly discharge for selected rivers in Madagascar and Mauritius.
(Source: Global River Discharge database 2002)

it. The surface water system has been subdivided into 48 river basins, which range from 3 to 164 km^2. It has been found that the average water resources potential in Mauritius is adequate to meet demands at least up to the year 2040. However, the random distribution of water in time and space results in periodical deficiencies.

Seychelles

The water catchment on Mahe, the main island in the Seychelles group, is very small due to the size of the Island and its topography. The granite of Mahe (Plummer 1995) weathers deeply to a reddish brown lateritic soil, which can often be seen as a distinct brown colouring of the coastal waters after heavy rains. The slopes are very steep, some as much as 1:4. Numerous streams, originating from the central mountain ridge, flow down boulder-choked "U" and "V" shaped catchments before discharging into the sea. Consequently, the granitic island is characterised by many small, steep watercourses, most of them having only ephemeral flows. Because of the steep topography, low retention capacity of the soil, and the relatively high density of urbanisation, high intensity rainfall has in the past caused large downhill water and mud movements and severe flooding along the coast for short periods (FAO 1989).

Main biotopes

The Western Indian Ocean is characterised by rich, diverse and distinct marine and coastal ecosystem. Common coastal and marine habitats include reefs, seagrass beds, lagoons, mangroves and the numerous shallow banks of the Mahe Plateau and Saya de Malha (Kelleher et al. 1995). Deep ocean habitats are as yet poorly documented. Of the 38 designated marine and coastal habitats, at least one third are found within each country of the region (UNEP 1984). These ecosystems sustain a great diversity of marine life and represent an important food source for most coastal communities (Gabriel et al. 2000).

Mangrove forests

The most significant stands of mangroves in the region occur in Madagascar (Table 3), and the main species are *Rhizophora mucronata, Ceriops tagal*, and *Bruguiera gvmnorhiza* (Lebigre 1990). Other species include *Avicennia marina*, *Avicennia officionalis*, *Heritiera littolaris, Lumnitzera racemosa, Sonneratia alba, Xylocarpus granatum,* and *Xylocarpus moluccensis*. Most mangrove stands in Madagascar exceed 500 ha in size with Mangoky, Tsiribihina, Ranobe (Besalampy), Betsiboka, Mahajamba and Mahavavy (Baie d'Ambaro) having stands of more than 20 000 ha (Taylor et al. 2003). In Seychelles, significant stands are found on both the granitic and coral islands. Twelve sites are found around Mahe Island, but the largest stands are found on the islands of Aldabra, Cosmoledo and Astove. In Comoros, the stands are very small, the largest being on the island of Moehli (91 ha). In Mauritius, mangrove stands (especially *Rhizophora mucronata* and *Bruguiera gymnorhiza*) occur along 50 km of the southeast coast.

Table 3 Mangrove distribution.

Country	Mangrove area (ha)	Number of species
Comoros	100	6
Madagascar	330 000	9
Mauritius	700	2
Seychelles	1 000	7

(Source: Ranaivoson 1998, Taylor et al. 2003, Scetauroute 1999)

Seagrass beds

The seagrass beds, which occur throughout the region, are a common feature of intertidal mud and sand flats, coastal lagoons, and sandy areas around the bases of shallow fringing and patch reefs (Gullström et al. 2002). Seagrass beds are commonly found adjacent to coral reefs and mangroves. Seagrass beds are among the most productive aquatic ecosystems and, of the 50 globally described species, only 13 are found in the region. Extensive seagrass beds are found in the Toliara Lagoon area (Madagascar), and in many areas along the coast, including Nosy Be (Cooke 1993). In Seychelles, they are dominant in Platte, Coetivy, Amirante Banks and in the Lagoon of Aldabra Atoll (Salm 1994). The most common species are *Thalassia hemprichii* and *Thalassodendron ciliatum*.

Coral reefs

Significant areas of coral reefs occur in the region (Table 4) (UNEP/IUCN 1988). Madagascar has the largest reef cover in the region and the reefs are most common along the east coast (McClanahan et al. 2000). Also, there are a number of emergent fossil reefs along some parts of the coast. A submerged and fragmented barrier reef has been described off Toamasina. Most of the granitic islands of the Seychelles are encircled by discontinuous, fringing reefs. Along the east coast of Mahe, reef flats exceeding 2 km in width and terminating in a high algal ridge are followed by a reef slope descending to a floor typically at 8 to 12 m.

Table 4 Estimated coral cover and species number.

Country	Estimated coral cover (km^2)	Number of species	Number of genera
Comoros	432 (Anjouan)	ND	ND
Madagascar	2 000	112	57
Mauritius	500	133	47
Seychelles	577	174	55

Note: ND = No Data. (Source: McClanahan et al. 2000)

Table 5 Number of marine fish species.

Country	Total	Reef-associated	Endemic	Native	Other
Comoros	446	294	ND	445	1
Madagascar	893	441	2	866	25
Mauritius	938	596	8	899	31
Seychelles	1 159	749	1	1 091	67

Note: ND = No Data. (Source: Fishbase 2003)

Table 6 Number of freshwater fish species.

Country	Total	Endemic	Native	Other (including introduced)
Comoros	11	1	10	ND
Madagascar	135	36	65	34
Mauritius	44	1	21	22
Seychelles	17	1	15	1

Note: ND = No Data. (Source: Fishbase 2003, Vanden Bossche & Bernacsek 1990)

The reefs on which the coral islands are situated exhibit a number of different morphologies including true atolls, raised atolls, submerged and partially submerged atolls. Mauritius is almost completely encircled by fringing reefs, with substantial lagoon and barrier reef development on the east and southwest coasts (Salm 1976). Rodrigues Island (Mauritus) is totally encircled by reefs, with wide shallow reef flats extending out from the shore, with its widest extent reaching 10 km in the west (Spalding et al. 2001). The main types of reefs in the Comoros are discontinuous fringing reefs, ranging from 15 m to several kilometres from the coastline. In Comoros, reef cover is most extensive on the Island of Anjouan (Scetauroute 1999).

Marine life

The FAO Fishbase (2003) suggests 5 375 species of fish, in 330 families occur in the Indian Ocean. At least 1 607 species are commercially exploited. Table 5 shows the number of marine fish species within the Indian Ocean Island region. Coral reefs and mangroves are the most commonly associated biotopes. Seychelles has the highest diversity in both fish species and coral reef associated species (GEF 1992), whilst Mauritius demonstrates the highest endemism in fish species (Briggs 1974). Madagascar is also an area showing high diversity of fish species (McAllister et al. 1993). The Comoros, and now parts of Kenya, Tanzania, South Africa and Indonesia, is home to the coelacanth *(Latimeria chalumnae)*, described as a living fossil thought to have existed about 400 million years ago. A population of coelacanths not exceeding 200 individuals (currently protected under CITES Convention) lives at depths of 700 m off the Island of Grand Comores (Fricke & Hissmann 2000).

The region also supports several species of marine invertebrates including crustaceans, coelenterates, sponges, echinoderms, molluscs, and cephalopods (Matthes & Kapetsky 1988). Certain groups, such as molluscs, are reasonably well known. A number of endemic molluscs are known from Mauritius, such as the Double harp (*Harpa costata*) and the Violet spider conch (*Lambis violacea*),. Commercially valuable species include molluscs (green snail (*Turbo marmoratus)*, pearl oysters (*Isognomon* spp.)), cephalopods (octopus and squid), crustaceans (spiny lobsters, crabs, prawns), and echinoderms (sea cucumbers). The coconut crab (*Birgus latro*) which used to be abundant in the region is now globally threatened and found on Aldabra (Seychelles) and some other inhabited islands, but extinct throughout much of the region (IUCN/UNEP 1984).

Freshwater life

Freshwater life is especially important in Madagascar (Stiassny & Raminosoa 1994). The freshwater ichthyofauna of Madagascar is not unique in its large number of species, but they exhibit a very high level of endemism (Table 6). In Madagascar, the second largest family of freshwater fishes is Bedotiidae, which includes the genus *Bedotia*. An aquatic mammal, the Web-footed tenrec, lives along the banks of streams and the shores of marshes and lakes, at altitudes of 600 to 2 000 m. A freshwater turtle, *Eretmochelys madagascariensis*, is also present. Freshwater fish species are poorly documented in the region and many are yet to be identified.

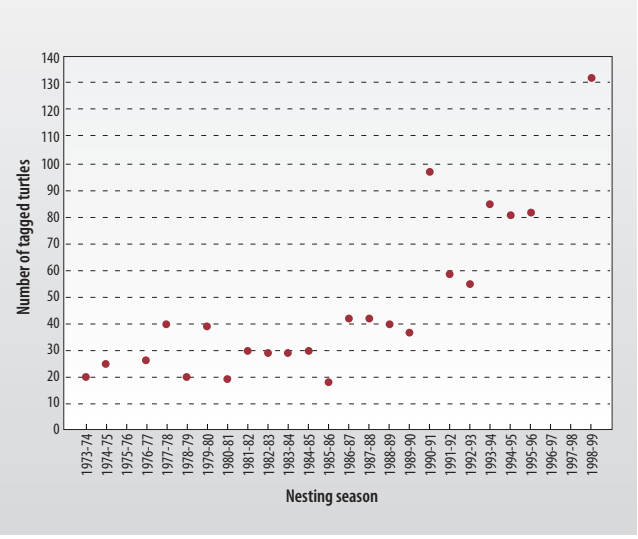

Figure 6 Trends in female Hawksbills nesting per season at Cousin Island, Seychelles.
(Source: Adapted from Salm et al, 2000)

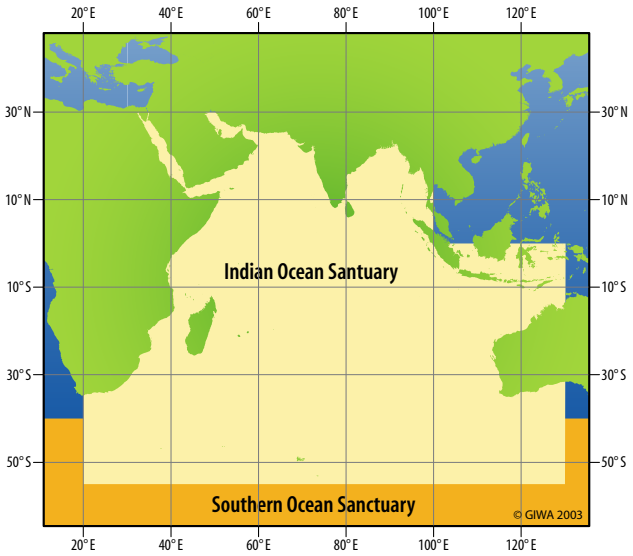

Figure 7 Indian Ocean whale sanctuary.
(Source: WWF 2002)

Threatened species

Many of the islands in the region are important areas for biodiversity and have high levels of endemism. For example Madagascar is regarded as the most endemic-rich country in Africa and the sixth in the world, with almost 700 endemic vertebrate species. Seychelles, on the other hand, exhibits one of the highest levels of endemism per square kilometre, especially in amphibians and reptiles (UNEP 1999).

The region is home to a number of important marine species such as whales, dolphins, the unique coelacanth, rare dugong species, and turtles. Many of these marine animals that live in the Indian Ocean are now endangered, including dugongs, turtles and whales (Kelleher et al. 1995).

Four species of marine turtle are found in the region, namely the Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*), and the Leatherback (*Dermochelys coriacea*). In most areas, marine turtles are at risk from exploitation and disturbance of and damage to their nesting beaches and feeding grounds (Kelleher, 1995). In Seychelles, during the period 1979-1986, Hawksbill turtles were legally exploited, particularly for their shells which were converted into artisanal products. However, with signs of seriously diminishing populations, stiff protection laws were established which, in conjunction with an artisan compensation/retraining programme, eliminated domestic trade by 1994 (Mortimer 1999). Consequently, there has been a subsequent increase in nesting activity on numerous islands (Figure 6) (Mortimer & Bresson 1999).

Dugongs (*Dugong dugon*) are listed as vulnerable to extinction on a global scale by The World Conservation Union (IUCN), and existing studies show that they are likely to become extinct in the region (Dutton 1998). Thought to have occurred in all four island states (Marsh et al. 2002), few individuals now remain in Seychelles (Aldabra), Comoros archipelago (Mayotte) and Madagascar (limited to the central, northwestern and northeastern coasts), with no reports of any sightings from Mauritius (Cockcroft & Young 1998).

At least 15 cetacean (whale) species have been recorded in the Indian Ocean. Commercial whaling (in particular Sperm whales) has been practiced since the 19th century but in 1979 The International Whaling Commission (IWC) declared the Indian Ocean (north of 55° S) a sanctuary (Figure 7), following an initiative by the Seychelles (WWF 2002).

Other marine populations which are threatened include sharks and sea cucumbers. However, data on the status of those species is very sparse.

Marine Protected Areas

In total, there are 15 Marine Protected Areas (MPAs) in the region, covering over 800 km^2 of the ocean within the Indian Ocean Islands region (Table 7). The MPAs in the region are mostly coastal with no high seas MPAs present. MPAs are managed by a variety of institutions, including governments, semi-autonomous government bodies, NGOs and the private sector.

Table 7 Characteristics of Marine Protected Areas.

Country	Name	Year established	Size (km^2)
Comoros	Moheli Marine Park	2001	404
Madagascar	Nosy Atafana Marine Park	1989	10
	Masoala Marine Park	1997	81
Mauritius	Fishing Reserves (Port Louis, Grand Port, Black River, Poudre d'Or, Poste Lafayette, & Trou d'Eau Douce	1983	63
	Blue Bay Marine Park	1997	3.5
	Balaclava Marine Park	1997	5
Seychelles	Aldabra Special Nature Reserve/World Heritage Site	1981	190
	Aride Island Special Reserve	1979	0.1
	Baie Ternay Marine National Park	1979	1
	Cousin Island Special Reserve	1979	1
	Curieuse Marine National Park	1979	16
	Port Launay Marine National Park	1979	1.5
	Silhouette Marine National Park	1987	20
	St Anne Marine National Park	1973	14

(Source: UNEP 2001)

The Continental Shelf

The average depth of the Indian Ocean Continental Shelf is about 3 960 m (excluding adjacent seas) compared with the Atlantic, which is 3 300 m, and the Pacific at 4 200 m. The average width of the Shelf is about 200 km. Historically, the Indian Ocean's has been strategically important for trade and the military, but fisheries is a growing sector. Opportunistic exploration for seabed minerals (such as polymetallic nodules and sand) and hydrocarbons has been conducted, but no commercial deposits have been found so far. The species of fish found on the Continental Shelf are less researched and only catch data indicates which fish can be found there (Cushing 1973).

Total marine fishery catches for the entire western Indian Ocean increased from a 1950s catch of about 0.5 million tonnes to nearly 3.8 million tonnes in 1992. Coastal fisheries in the region are substantial and are dominated by the local fishers whereas the more lucrative oceanic fisheries are mainly operated by foreign vessels. Shrimp catches are also one of the most important components of landings in Madagascar because of their importance to foreign exchange earnings (Ranaivoson 1997). Roughly 70% of total production of finfish and invertebrates in the region comes from the sea and about 95% from the EEZ (FAO 1997).

Socio-economic characteristics

The Indian Ocean carries half of the world's container ships, 30% of its bulk cargo traffic, and about 60% of the world's oil shipments. Before the construction of the Suez Canal, it was, and probably still is, the most important trade route between Europe and Asia. The economies of the countries in the region are small and vulnerable (with the exception of Madagascar), and constitue less than 0.04% of world trade (Davenport 2001). The problems encountered by islands states include small and narrow domestic markets, transport problems within islands, between islands and with the rest of the world, shortage of arable land, and over-dependence on north-south trade flows. Exports still centre on a few basic products, even though some diversification is now noticeable. Many consumer goods and virtually all intermediate products have to be imported (Peretz et al. 2001).

Economy

Mauritius, Seychelles and Comoros have very small economies (Table 8) and resources are limited to fisheries and tourism, which are both very volatile markets. There is also a high dependence upon custom duties, which can be as high as 60% in Comoros, 40% in Seychelles and about 32% in Mauritius (Salmon 2002).

When ranked according to the vulnerability index, and other indices, the small islands appear to be much more vulnerable than Madagascar. In fact, within the region Seychelles is ranked the highest on both the Briguglio's and UN (CDP) Vulnerability Indexes (Table 9) (Briguglio 1995, CDP 2000).

The structure of the Islands' economies is equally varied. In Comoros and Madagascar, agriculture employs 80% of the working population and produces 40% of GNP. Annual average economic growth for the period 1986-1996 was negative for Comoros (-1.5%) and Madagascar (-2.0%) and positive for Mauritius (4.5%) and Seychelles (3.5%) (World Bank 2000b). Tourism is expected to grow with significant implications for coastal quality, density and resource use conflicts (Table 10). In the Seychelles, the tertiary sector dominates, with 18% of GNP coming from tourism. The Mauritian economy is more evenly balanced between agriculture, industry, tourism and services, and is the only country that does not have a chronic lack of foreign exchange.

Table 8 Economic indicators.

Country	**Population 2000** (millions)	**GDP 2000** (Atlas method) (billion USD)	**GDP per capita 2000** (Atlas method) (USD)	**Share of the global trade in goods 1996-1998** (%)	**Share of the main exported good of the total export, 1998** (%)	**Services/goods export ratio, 2000**	**Tourism revenue** (million USD)
Comoros	0.56	0.21	380	0.0002	59, vanilla	1.5	16
Madagascar	15.5	3.9	250	0.0056	17, coffe	0.75	ND
Mauritius	1.2	4.5	3 800	0.0308	57, textile, clothing	0.55	503
Seychelles	0.08	0.59	7 310	0.0023	45, canned tuna	2.48	111

Note: ND = No Data. (Source: Adapted from Salmon 2002)

Table 9 Trade conditions and vulnerability index.

	1	2	3	4	5		6		7	
Country	**Export concentration ratio, 1998**	**Economic diversification index, 1995**	**Export instability index, 1990-1998**	**Custom duties/ fiscal resources, 1999** (%)	**Briguglio vulnerability**		**UN (CDP) vulnerability**		**Commonwealth Secretariat vulnerability**	
					index	**rank**	**index**	**rank**	**index**	**rank**
Comoros	0.60	0.913	18.2	60	0.602	17th	55.36	24th	5.425	43rd
Madagascar	0.269	0.825	ND	17	0.428	62nd	26.75	105th	4.772	90th
Mauritius	0.318	0.858	3.8	32	0.614	14th	35.21	86th	6.510	27th
Seychelles	0.824	0.896	19.5	41	0.756	3rd	57.02	14th	6.375	28th

(Sources: Adapted from Salmon 2002, Atkins et al 2001, Briguglio 1995, CDP 2000)

Notes: ND = No Data.

1: Export concentration ratio is the combined percentage of total industry output accounted for by the largest producers in the industry.

2: Economic diversification index is a composite index comprising the following indicators: (i) manufacturing and modern services as a share of GDP; (ii) concentration of goods and services exports; (iii) annual per capita electricity consumption; (iv) vulnerability to natural disasters (this indicator is under construction).

3: Export instability index is a derived measurment of the observed volume and value of exports against fitted values.

5-7: Vulnerability index provides a composite and comparative measure of the economic, environmental and social status of Small Island Developing States (SIDS), and provide means to integrate ecological fragility and economic vulnerability . The vulnerability ranking is given in decreasing order.

Table 10 Changes in GDP by economic sector.

Country	**Value added of GDP in agriculture** (%)			**Value added of GDP in industry** (%)			**Value added of GDP in services** (%)		
	1997	**2000**	**2001**	**1997**	**2000**	**2001**	**1997**	**2000**	**2001**
Comoros	40.9	40.9	40.9	11.9	11.9	11.1	47.2	47.2	48.0
Madagascar	31.5	29.1	29.8	13.4	14.5	14.5	55.0	56.4	55.7
Mauritius	9.7	5.9	6.3	31.7	31.6	31.2	58.6	62.5	62.5
Seychelles	3.2	2.9	2.9	23.1	26.3	24.8	73.7	70.8	72.3

(Source: World Bank country profiles database 2003)

Population growth has hovered around 1% in Mauritius and Seychelles, stabilised at around 3% in Madagascar and risen in Comoros, from 2.8% in the 1980s to 3.75% in 1996. The proportion of the population living on the coast varies throughout the region. The coastal population density is expected to increase in all countries; in Comoros from 223 persons/km^2 in 1995 to 648 persons/km^2 by 2020, in Madagascar from 20 persons/km^2 in 1995 to about 45 persons/km^2 by 2020, in Mauritius from 548 persons/km^2 in 1995 to 699 persons/km^2 by 2020, and in Seychelles from 161 persons/km^2 in 1995 to 203 persons/km^2 by 2015 (Payet 2002). Coastal population density increases are likely to be concentrated within 100 m from the coastline in the case of the small islands.

Fisheries

Fisheries contribute significantly to the economies of the countries in the region. They also have positive spin-off effects on employment opportunities, income generation, food security, foreign exchange earning, as well as on other economic sectors and government revenue.

Fisheries of the western Indian Ocean are known to be nearly fully exploited but localised overfishing may have already occurred in many coastal areas (Figure 8). Coastal fish production has continued to rise over the past decade reaching over 1 million tonnes.

Fish production in Madagascar rose from 86 000 tonnes in 1994 to 105 000 tonnes in 1999 (MPRH 1999) and Mauritius recorded a drop from 18 000 tonnes in 1994 to 14 000 tonnes in 1999 (Pierre de Boucherville 1997). The Seychelles recorded a rise from 4 500 tonnes in 1994 to 12 000 tonnes in 1999 (SFA 2000) and the Comoros levelled at 12 000 tonnes per year over the past five years. These coastal fisheries are important socio-economic activities of the region. The continuing growth of population along the coast implies intensive resource use and high values for coastal resources. It is believed that most of the

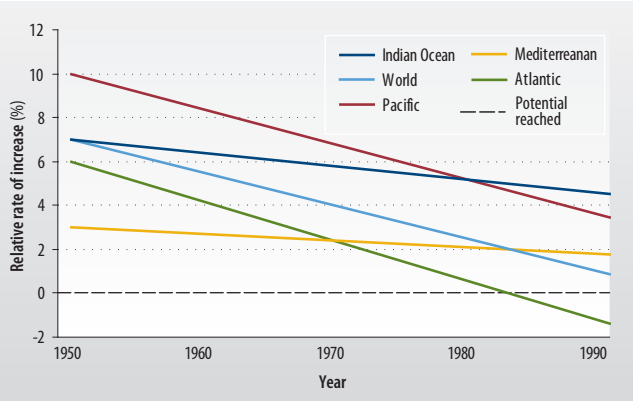

Figure 8 Trend in the relative rate of increase of landings in all marine waters.
(Source: Grainger & Garcia 1996)

coastal fisheries are being exploited beyond the Maximum Sustainable Yield (MSY). One important aspect is growing fishing capacity leading to overcapitalisation of the fishing industries. In the region, approximately 36 000 vessels are operating on the continental shelves with 165 000 fishers exploiting the different fish stocks (FAOSTATS 2002). Loss of jobs in the fishing sector is seen as a great concern to this region, especially in the collapse of fisheries since alternative employment opportunities seldom exist.

Freshwater fisheries are most significant in Madagascar (Figure 9), although some angling activities have been reported in the small reservoirs in Mauritius (Vanden Bossche & Bernacsek 1990). Inland fisheries in Madagascar occur primarily in the large lakes and lagoons. Seven of those lakes are heavily exploited with extractions of the order of 22 500 tonnes over an area of about 630 km^2 (1984 data), involving over 17 740 fishermen. Signs of overfishing are evident in two lakes (Alaotra and Itasy). Inland fish species include the common carp (*Cyprinus carpio*) and Tilapia (*Oreochromis* spp.) and at least 70% of the catch is for local consumption (Rabelahatra 1988).

Aquaculture is also a growing industry (Coche et al. 1994), most prominent in Madagascar where production rose from 128 tonnes in 1991 to 6 900 tonnes in 1998 (Rabelahatra 1988). The most commonly farmed species are *Cyprinus carpio*, *Tilapia* spp., *Cyprinus auratus*, *Penaeus indicus*, *Penaeus monodon*, *Bedotia marojejy*, *Oncorhynchus mykiss*, *Ptychochromoides vondrozo*, and *Rheocles derhami*. Seychelles' production from aquaculture was 678 tonnes (mostly tiger prawns, *Penaeus monodon*) in 1996 (SMB 2000), whilst Mauritius produces around 87 tonnes per year where mostly *Macrobrachium rosenbergii*, *Penaeus monodon*, and *Rhabdosargus sarba* are farmed (Bhikajee 1997). Comoros does not have any aquaculture activities. In most cases, the areas of high density of cultivation and reduced water exchange has provoked problems such as benthic enrichment and hypoxic water conditions. In Madagascar, the extensive conversion of coastal wetlands and mangrove areas to fish and shrimp pond culture has significantly reduced replenishment of the natural shrimp population, which uses these areas as nursery grounds. In addition, this has led to coastal erosion in numerous areas. However, the level of such destruction is undocumented.

Tuna fishing is a major activity occurring in the oceanic and international waters of the region (Payet 1997). It is a very important economic activity and most of the countries in the region manage it through access agreements with developing states (mainly within the European Union). These agreements are based on financial compensation and other aid to

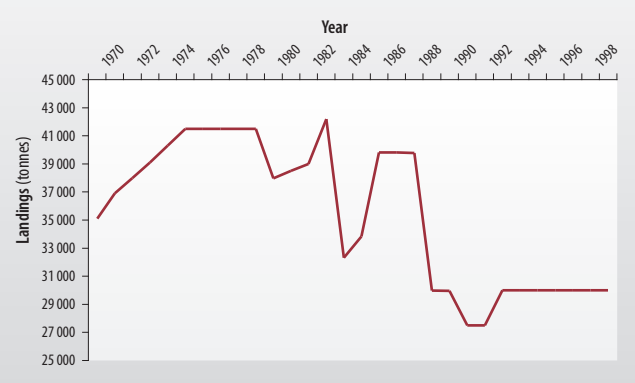

Figure 9 Freshwater fish landings in Madagascar (1970-1999).
(Source: Vanden Bossche & Bernacsek 1990)

the local fishing industry. The fisheries are exploited both on an industrial scale (purse seiners and longliners) and an artisanal scale (line fishing) (Stequert & Marsac 1989). The latter is however, considerably smaller.

The Indian Ocean Tuna Commission (IOTC) is the body under FAO for the management of tuna fisheries in the Indian Ocean, set up in Seychelles in 1997. Total catch (pelagic) from the western Indian Ocean in 1999 was estimated at 987 000 tonnes, a rise of approximately 240 000 tonnes from 1990 (Figure 10). There are concerns on the status of tuna and tuna like species stocks. Studies revealed that stock indicators for Yellow fin tuna (*Thunnus albacares*), which have more or less stabilised since 1993, could be interpreted as a sign of overexploitation with catch of this species above MSY since that year. Similarly, Bigeye tuna (*Thunnus obesus*) has been exploited well over its MSY for the last five years and potentially, should it continue to rise, the spawning stock biomass will fall. Overall fishing effort is on the increase and considered as very high although it is at present difficult to indicate the optimum fishing capacity for sustainable exploitation of the resources (IOTC 2002). Unregulated Illegal and Unreported catches (IUU) are still a concern in the Western Indian

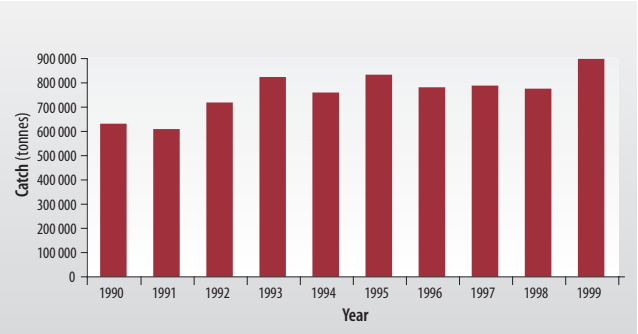

Figure 10 Catch of tuna and tuna like species, e.g. Spearfish (*Tetrapturus pfluegeri*) and Billfishes (*Scomberesox saurus scombroides*) in the Western Indian Ocean (1990-1999).
(Source: IOTC 2002)

Tuna Fisheries. Many vessels still neglect to report or underreport their catch and also, many vessels fish under the flag of convenience.

Agriculture

Agriculture is an important sector for Mauritius, Madagascar and Comoros. In Seychelles, the shift to tourism has reduced the agricultural sector to about 4% of the GDP, with a focus on poultry, vegetables and fruits for local consumption.

The area under cultivation in Mauritius is 90 100 ha or 48% of the total land available. About 90% of this land is occupied by sugarcane cultivation. Approximately 1 153 tonnes of pesticides (13 kg/ha) are imported annually into Mauritius, out of which 59% represents herbicides, 31% insecticides and 8% fungicides (MCA 1998). The annual import of fertilisers for the period 1979-1989 averaged 57 500 tonnes (640 kg/ha).

In contrast, cattle-rearing and rice production are the main agricultural activities in Madagascar, although there are also small areas of intensive production of sugarcane and cotton in the southwest of the country. The application of fertilisers in intensive agricultural areas was reported to be as high as 163 kg/ha in 1990, and has been linked to localised algal blooms and reduced fish catches in lagoons (Toliara). The clearing of forests in Madagascar, resulting in sediment mobilisation, siltation and the destruction of coral reef habitats has been identified as a major problem (Lundin & Linden 1995), particularly along the western coastline. The causes include bush-fires, harvesting of forests for production of charcoal and clear-felling for agriculture purposes.

Agricultural production occupies approximately 67% of land on the Comoros, employs between 70% and 80% of the total population, and accounts for 98% of export revenue. The main export crops include vanilla, ylang-ylang and cloves. Cereals, rice, potatoes, fruits and legumes are also grown for local consumption. The total quantity of pesticides used between 1991 and 1993 was approximately 70 tonnes. Steep slopes and continuous cultivation without the provision of fallow fields have led to the impoverishment of the soil and serious incidents of soil erosion and siltation of the coral reefs with deleterious effects on fisheries. Agricultural run-off is also considered to have led to pollution of groundwater although no data have been reported on which an assessment of the problem can be based.

Water use in agriculture varies according to the level of agriculture and extent of irrigation in each of the Island States (Table 11). In Seychelles, water is abstracted directly from rivers so there are only extremely small irrigation schemes for areas no greater than 2 to 5 ha (e.g. on La Digue Island). In contrast, the irrigation potential on the three main islands of Comoros is about 303 ha (Grand Comores, negligible; Anjouan, 203 ha; and Moehli, 100 ha), while in 1987 the area equipped for irrigation was only 130 ha (Banque Mondiale 1993). Information on the actual agricultural water use is not known. Irrigation potential in Madagascar is vast, an estimated 1.5 million ha or 19% of agricultural potential area. About 82% of the potential agricultural land has already been irrigated. Rice cultivation occupies at least 50% of cultivated lands. Access to irrigation water is higher in the highlands where almost 93% of farmers have access as compared to 50% of the coastal farmers. Irrigation works suffer from periodical flooding from heavy rainfall and cyclones (Bensaid 1992). In Mauritius, irrigation is extensive and used primarily for sugarcane cultivation (about 17 500 ha), extending over 83% of the agricultural areas (mainly sprinkler irrigation technique). Irrigation sources include primarily surface water, but groundwater is also used.

Tourism

Tourism is increasingly becoming important for the Islands in the region, in particular Seychelles and Mauritius (Figure 11). Madagascar and Comoros also have great potential for tourism.

In the Seychelles, tourism is a significant activity described as "the mainstay of the Seychelles economy today" (Lundin & Linden 1995). Direct revenue from tourism stands at 18% of the GDP, compared to 4%

Table 11 Water resource use in agriculture.

Country	Arable & permanent crops in 2000 FAOSTAT (ha)	Water resources					Water use	
		Average precipitation 1961-1990 IPCC (mm/year)	Average precipitation 1961-1990 IPCC (km^3/year)	Internal renewable water resources (km^3/year)	Groundwater produced internally (km^3/year)	Surface water produced internally (km^3/year)	Agricultural water use in 2000 (km^3/year)	Irrigation potential (ha)
Comoros	128 000	1 754	3.91	1.20	1.00	0.20	ND	303
Madagascar	3 500 000	1 513	888	337	55	332	14.31	1 500 000
Mauritius	106 000	2 041	4.16	2.21	0.68	2.03	0.37	ND
Seychelles	7 000	1 970	3.17	0.88	0.1	0.7	ND	ND

Note: ND = No Data. (Source: FAO Aquastat 2003)

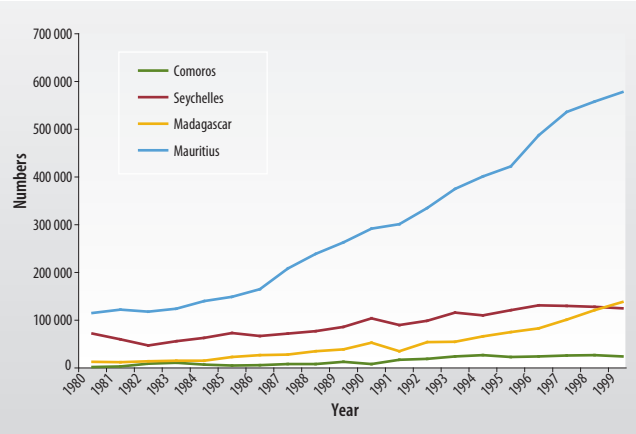

Figure 11 Tourism arrivals (1980-1999).
(Source: GEO Data Portal 2003)

from agriculture, fishing and forestry, amounting to 120 million USD per year. Tourism also accounts for 70% of total foreign exchange earnings and provide 20% employment on the labour market. The most intensely developed parts of the coast on Mahe are the northwest coast, and, more recently, the southwest. On the island of Praslin, the east coast is most developed in terms of tourism infrastructure. Currently, there are over 5 400 hotel beds, with a maximum of about 130 000 tourists expected every year. There are development plans to increase this to 200 000 per year by 2010. Tourism development on other smaller granitic islands and some outlying coral islands has also taken precedence over the last 10 years, with highly luxurious hotels being built on Fregate and Alphonse Islands. Already, four five-star hotels have been built and a number of existing hotels are upgrading to that level (Payet 2003).

Mauritius is less dependent on tourism because of the dominance of sugar production and processing activities. It has three main tourist zones (a) the northern zone from Balaclava to Grand Gaube, (b) the eastern zone from Roche Noire to Trout d'eau Douce, and (c) the southwestern zone from Flic-en-Flac to Le Morne. Tourist arrivals in 1997 had reached 536 125, representing and increase of 9.3% per year, while foreign exchange revenues had reached nearly 461 million USD in 1997, an increase of 17% per year since 1992 (ERM 1999). Tourist accommodation is 6 000 rooms plus 2 000 rooms in the informal sector. Hotels offer employment to about 14 000 people, total tourism-induced employment reaches over 51 000 accounting for 10% of total employment.

Tourism in Comoros is limited. Arrivals in 1993 were 24 000, representing a small share of only 4% of the arrivals in the countries of the West Indian Commission, totalling 600 000, while direct employment in tourism is about 500 people and 50 in related activities. Foreign currency earnings are reported at 88 million USD, roughly just over half of the earnings from exports.

In Madagascar, tourism is the primary earner of foreign exchange, with earnings growing from 44.6 million USD in 1996 to over 135.5 million USD in 2001. This also coincided with an increase in the number of visitors from 86 681 to about 200 000 during the same period. There are over 220 hotels, which directly employ over 18 000 persons (2001 data). However, Madgascar's tourism economy suffered during the domestic political crisis of 2002.

The water sector

In Mauritius and Seychelles, less than 1% of the population do not have direct access to potable water. However, in Comoros and Madagascar, at least 55% and 53% of the population, respectively, do not have access to potable freshwater (Table 12). Consequently, effects on the freshwater resources will affect the population as a whole, particularly those living within highly urbanised areas. For example, in Madagascar, potable water supply is available to 12% of the rural population, 73% of the urban population and 1.5% of the coastal population.

Key industries that are affected by water scarcity include tourism, agriculture, and industries. Tourism is particularly affected through restrictions in water supply and low quality of water. In rural areas, especially in Mauritius and Madagascar which have extensive agriculture areas, modification of streamflow has a serious impact on this sector (Banque Mondiale 1992). In Madagascar and Comoros, freshwater scarcity has led to population movements across the country. Food processing industries, in particular, are affected by water shortage due to restrictions and low quality.

Cost of treated water is somewhat similar in each country ranging from 0.4 USD/m^3 in Mauritius, 0.44 USD/m^3 in Comoros, 0.45 USD/m^3 in Seychelles, and 0.46 USD/m^3 in Madagascar. However, noting that the purchasing power is very different between countries, the cost of water

Table 12 Water consumption.

	Comoros		Madagascar		Mauritius		Seychelles	
	1990	2000	1990	2000	1990	2000	1990	2000
Population with access to treated water (%)	ND	45	44	47	100	100	82	99
Total water use (million m^3/year)	ND	ND	ND	15	ND	ND	8	ND
Water use per capita (m^3/year)	ND	ND	ND	937	ND	516	100	ND

Note: ND = No Data. (Source: UNICEF 2003)

is much more expensive in Comoros and Madagascar compared with Seychelles and Mauritius. In many instances such costs are subsidised by national governments.

Water consumption and works

The total volume of water used for irrigation in Mauritius is estimated at 340 million m^3 per year, including 50 million m^3 used by the sugar factories (WRU 1997). Although the area under sugarcane cultivation fell from 82 000 ha in 1991 to 76 800 ha in 1996, annual production has remained constant at approximately 5.5 million tonnes. This is a result of an increase in average yields from 65.9 to 73.3 tonnes/ha due to increased irrigation of the cultivated area. Therefore, a reduction in freshwater availability will have an impact on the productivity of this sector, likely a decrease from 5.5 million tonnes to 5 million tonnes, assuming a yield of 65.9 tonnes/ha as the baseline.

Yields from boreholes in Mauritius 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.

In Seychelles, the deficit between water supply and demand amounts to 3 700 m^3/day (1999) and will rise to 6 520 m^3/day by the year 2005 (Henri 1999). However, due to abnormally longer dry periods during the last four years, this deficit has increased prompting the government to invest in desalination plants (the existing desalination project costs 29.6 million USD) to meet demand. During these extended dry periods, water was delivered in tankers, increasing the operating cost by a factor of five. In fact, many of the hotels in Seychelles are now resorting to building large storage tanks to meet demand during periods of drought. Industries have also been affected. One company in 1999 had to stop production due to lack of water. Water scarcity has therefore led to increased operation costs.

In Comoros, the deficit in freshwater is much higher and is cause of concern (Banque Mondiale 1993). For example, on Grande Comores (the largest island in the group), which has a population of 304 706, only 5 342 m^3/day (18 litres/person/day) is available, while present demand is 15 235 m^3/day (50 litres/person/day). This situation is similar in other islands in the group, implying that due to growth in population and other sectors, water availability is constrained beyond supply, and any reduction in availability will further exacerbate the situation.

In Madagascar, of the 40 km^3 of freshwater available per day 224 m^3/day is used for generating hydroelectricity. This is done at the only hydroelectric station located on Vohitra River, which provides electricity to the capital Antananarivo and Toamasina. A reduction in the flow of this river will cause a reduction in the production of this clean form of energy, and increase other costs such as obtaining electricity from fossil fuel (World Bank 1998).

Institutional framework

In Comoros, the environment is administered by the 'Direction General de L'Environnement' (DGE), directed by and functioning within a national environmental policy (la Politique Nationale de L'Environnement (PNE)) and environment management plan (Plan d'Action Environnementales (PAE)). A multisectoral high-level committee, (le Comite Interministeriel Consultatif pour L'Environnement (CICE)) ensures co-ordination of activities across all sectors. Water-related environment legislation in Seychelles operates under the Ministry of Environment but is executed by the Public Utilities Corporation (Payet 2002).

In Comoros, responsibilities for water resources management are scattered among multiple public sector institutions, most of which are understaffed, have limited resources and lack technical capabilities. However, the Directorate of Public Works (Direction de Generale Travaux Publics (DGTP)) is the main agency responsible for water resources management and development (World Bank 2000a). In Seychelles, this function is undertaken by the Seychelles Public Utilities Corporation. Several institutions are involved in Mauritius, namely the Irrigation Authority under the aegis of the Ministry of Agriculture, Fisheries and Natural Resources, and the Ministry of Energy, Water Resources and Postal Service.

Several institutions in Madagascar are involved in water resources management. These include the Ministry of Rural Development (Ministère du développement rural et de la réforme foncière) with 'la Direction du génie rural' (DGR), both responsible for policy and implementation issues. The 'Service de gestion des réseaux hydroagricoles' (SGRH) and the 'Associations des usagers de l'eau' (AUE) are responsible for the maintenance of the network. Finally, the 'Direction des eaux et forêts' is responsible for technical aspects and research and the Ministry of Economic Planning for investments co-ordination (World Bank 1992).

The Governments are also advised through various inter-ministry committees; in the case of Madagascar, the 'Conseil National pour L'Environment' (CNE), in Comoros, the 'Comité Interministerial Consultafif pour L'Environnment' (CICE) and Seychelles, the National Environment Advisory Council (NEAC).

There are also several consultation forums, which involve the participation of Government, Non-Government Organisations (NGOs) and the private sector.

The role and importance of NGOs in sustainable development activities has increased. For example, in Seychelles, since 1996, at least seven NGOs have increased involvement in coastal activities and projects. Two NGOs are also involved in the management of marine protected areas.

The role of the private sector is also increasing, although more so in Mauritius and Seychelles than in Comoros and Madagascar. In Seychelles, the environment trust fund attracts about 1 million USD per year from the private sector. Notwithstanding, voluntary actions by the private sector are still isolated, especially since investments in infrastructure, such as wastewater treatment, can be quite high. Unfortunately, it is often only after significant legal pressure that the private sector complies with environmental regulations. The ISO standards are well established in Mauritius, but less so in the other countries in the region. In all the states of the Indian Ocean, the private sector is involved in a wide range of water and coastal-related development for both human settlement and industrial needs. The Environment Management Plan framework has been the primary driver for implementation of integrated water management: coastal zones and watershed management within the region (Payet 2002).

The most recent and legally binding regional framework is the Nairobi Convention and its related protocols (see also Annex IV). The Nairobi Convention, related protocols and the Action Plan were adopted in June 1985. Although Integrated Coastal Zone Management (ICZM) is not defined in the Convention, in Article 2 (a) specific reference is made to the coastal environment, and (b) identifies activities having an impact on coastal habitats and resources. Due to severe constraints, the Action Plan was reviewed in 1999, and a new programme reflecting the needs of the parties was drafted in the form of a Biennial Work Programme for the Implementation of the Nairobi Convention. The new programme focuses on coral reefs, shoreline changes, and land-based sources of pollution, all areas of priority determined by a regional study by UNEP (UNEP 1998). An exercise to update and review the Convention and its protocols is also ongoing and expected to be completed shortly for consideration by the Parties.

In the midst of all these regional developments, many of the island states have been implementing these resolutions at national level through development of relevant policies and legal frameworks. At the highest political and constitutional level, the concept of environment is well established in the region. For example, in the Seychelles, Article 38 of the constitution assigns the protection of the environment as a human right. In Madagascar, policy is guided by a general government policy document entitled the 'Document Cadre de Politique Economique'.

In general, the legal frameworks in the region are at different stages of development, but share many important similarities, both in origin and use of terms. There are however, considerations that are island specific; for example, in Comoros, Islamic law exists along-side modern law and customary law (Ahmed & Abdou 2002). In Seychelles and Mauritius, however, the law is based upon both the British and French systems often leading to complications in the application of law. Likewise, many of the sectoral laws in the region are as old as the 1960s with poor enforcement effectiveness. Amendments are also frequent, leading to further complications, especially in the application of law in the coastal environment. In Mauritius, laws pertaining to the coastal environment are fragmented leading to sectoral conflicts, which often results in ineffective enforcement. To facilitate legal proceedings and expedite convictions made under the Environment Protection Act, Mauritius has set up a special Environment Tribunal which was updated in 2002 to improve enforcement (Fagoonee & Daby 1993).

In Mauritius and Seychelles, the Central Water Authority Act No. 20 and the Public Utilities Corporation (Water Supply) Regulations S/I 26/1988 (regulate the supply of water to consumers, protection of water supply, and pollution prevention) are the main regulatory frameworks for water management, respectively.

A framework for environmental law also exists in all the countries of the region, but they are all relatively new and only in force since the early 1990s. For example, in Comoros, the EPA (Environment Protection Act) was enacted in 1994, Mauritius in 1991, and Seychelles in 1994. Important developments in the implementation of framework environmental law included concepts such as Environment Impact Assessments (EIA), environment quality standards, pollution control mechanisms, and designation of specific areas based upon environment criteria and dealing with environmental emergencies. In Madagascar, all activities listed in the annex to the regulations should be subject to an EIA, however this legislation is being simplified to enable some smaller applications to proceed faster and other larger investments to be subject to a much larger EIA. In Mauritius, part IV of the EPA relates to EIAs, and makes specific provisions for public inspection of the EIA, appeal through the Environment Tribunal, revoking of EIA license for non-compliance (Grange & Odendaal 1999).

On the other hand, the land use and land tenure legal framework is outdated, complicated and very controversial in almost all of the countries in the region. In Madagascar, conflicts over land tenure arise from the problem of access by local communities to coastal resources. These are governed by two pieces of legislation dating back to the 1960s, which are currently being revised. GELOSE (Gestion Locale Securisee) is a policy document, which attempts to provide communities security of tenure and a legitimate right to access and manage their resources (Joignerez et al. 2002). The Seychelles Town and Country Planning Act 1970 is currently being revised and updated to incorporate coastal and environmental issues. In Mauritius, the Town and Country Planning Ordinance of 1954 is being superseded by a modern Town and Country Planning Act.

Framework legislation addressing protected areas is relatively old in countries like the Seychelles (Nature Conservancy Act, 1969) and Madagascar (as far back as 1927). In Madagascar, a Code of Protected Areas (COAP) has been put in place providing for three types of protected areas: integral nature reserves, national parks and special reserves. Comoros, on the other hand, does not have a legal framework for protected areas, however two marine parks are planned and the legal framework will probably be set-up.

Since pollution from human activities cover such a wide range of issues from water pollution, marine pollution and wastes, the related legislation in the island states is dispersed and fragmented. For example, in Madagascar, more than 60 legislative texts covering control in use of chemicals, wastes and pesticides exist. The more recent environment management plans also led to a proliferation in legislation addressing water quality and to enactment of several pieces of legislation addressing land-based activities which have implications for the coastal integrity. Both the Mauritius and Seychelles EPA have very detailed pollution control provisions including provisions for declaration of effluent and emission standards, access to industry sites, as well as sample collection and analysis protocols.

Assessment

Table 13 Scoring table for the Indian Ocean Islands region.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter)

IMPACT 0 No known impacts
IMPACT 1 Slight impacts
IMPACT 2 Moderate impacts
IMPACT 3 Severe impacts

The arrow indicates the likely direction of future changes.

↗ Increased impact
→ No changes
↘ Decreased impact

Indian Ocean Islands	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.5* ↗	2.0 →	1.2 →	1.4 ↗	**1.6**	**5**
Modification of stream flow	1					
Pollution of existing supplies	2					
Changes in the water table	1					
Pollution	1.7* ↗	2.4 →	2.4 →	1.7 ↘	**1.9**	**1**
Microbiological pollution	1					
Eutrophication	2					
Chemical	1					
Suspended solids	1					
Solid waste	2					
Thermal	0					
Radionuclide	0					
Spills	2					
Habitat and community modification	1.5* ↗	2.4 →	1.7 ↘	2.4 →	**1.9**	**3**
Loss of ecosystems	1.3					
Modification of ecosystems	1.8					
Unsustainable exploitation of fish	1.6* ↗	2 →	1 ↗	1 →	**1.7**	**4**
Overexploitation	2.5					
Excessive by-catch and discards	0.8					
Destructive fishing practices	1.8					
Decreased viability of stock	0.8					
Impact on biological and genetic diversity	1.3					
Global change	1.2* ↗	2.3 ↗	0.7 →	1.8 ↗	**1.9**	**2**
Changes in hydrological cycle	1					
Sea level change	2					
Increased UV-B radiation	0					
Changes in ocean CO_2 source/sink function	1					

* *This value represents an average weighted score of the environmental issues associated to the concern. For further details see Detailed scoring tables (Annex II).*

** *This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).*

*** *Priority refers to the ranking of GIWA concerns.*

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.

IMPACT 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 reccurring 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).

Table 14 Main diseases by province in Madagascar.

	Country	Antananarivo	Antsiranana	Fianarantsoa	Mahajanga	Toamasina	Toliara
Malaria (%)	25.8	19.1	17.9	18.9	49.1	27.7	23.3
Diarrhoea (%)	8.5	10.1	19.3	8.2	0.2	8.1	9.5
ARI* (%)	23.3	31.1	14.1	36.3	16.6	16.7	19.3
Other (including wounds) (%)	42.4	39.8	48.6	36.6	34.0	47.0	47.9

** Acute Respiratory Infections. (Source: 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 (damming). 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

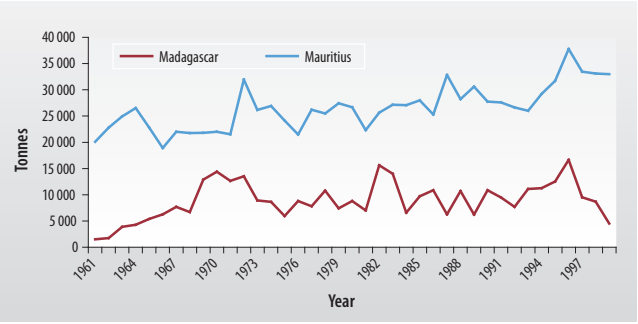

Figure 12 Fertiliser consumption in Mauritius and Madagascar (1961-1999).
(Source: GEO Data Portal 2003)

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.

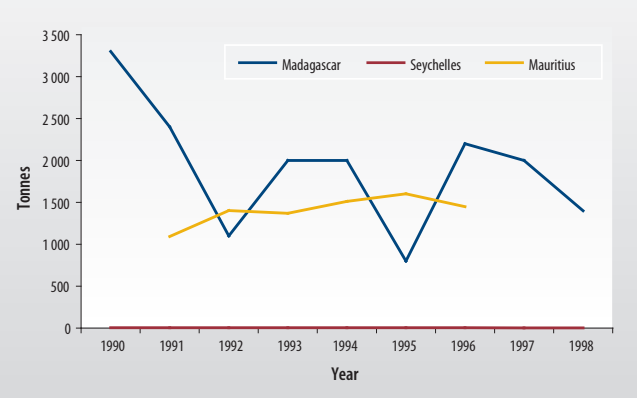

Figure 13 Imports of insecticides* in Madagascar, Mauritius and Seychelles (1990-1998).
*Note: * mainly chlorinated hydrocarbons, organo-phosphates, carbamates-insecticides and pyrethroids.*
(Source: GEO Data Portal, ERM 1999)

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 aqriculture 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.

Figure 14 Giant Tortoise on the beach of the World Heritage Site Aldabra.
(Photo: Souter 2001)

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 if 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 deminstrated 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 (see Priority concerns).

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).

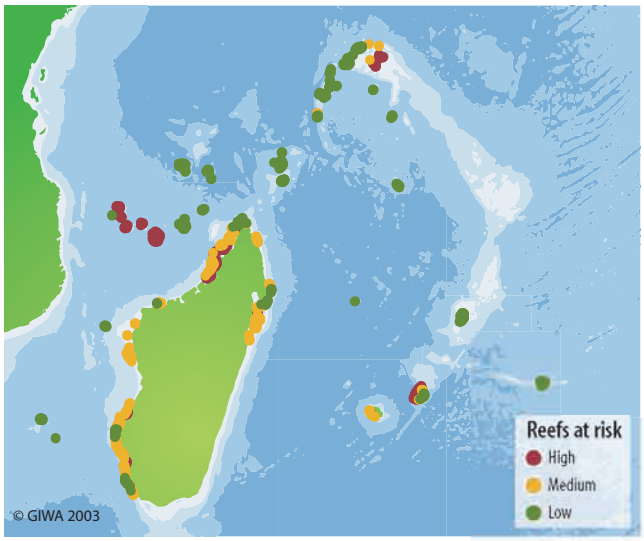

Figure 15 Indicator-based map of reefs at risk.
(Source: Bryant et al. 1998)

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 fining. 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 fining, all of which may become important fisheries in the region.

Figure 17 Bluestriped snapper.
(Photo: Getty Images)

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.

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.

	GHG*	GHG+A**
Period	**Annual mean temperature change** (°C)	
2050s	2.10 (±0.43)	1.64 (±0.23)
2080s	3.16 (±0.89)	2.61 (±0.65)

Period	**Annual mean precipitation change** (%)	
2050s	3.1 (±4.5)	1.6 (±3.9)
2080s	5.1 (±4.3)	4.3 (±4.9)

*Note: Numbers in brackets show standard deviations of modell projections. Atmosphere-Ocean General Circulation Model (AOGCM).*Green House Gases. **Green House Gases and Aerosols. (Source: IPCC 2001)*

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

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 Dulymamode 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

Figure 18 Solid waste on the beach in Grande Comores.
(Photo: Payet 2002)

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, run-off 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 thorughout 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

Figure 19 Marine debris landed on Cosmoledo Atoll.
(Photo: Payet 2002)

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 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 odours and dust are also a direct result. Aerosols and dusts can spread fungi and pathogens from uncollected and decomposing wastes. Children and human scavengers are known to contract asthma, lead poisoning and viral diseases as a result of foraging in such rubbish piles for food and other items (Nriagu et al. 1997). The total amount of solid wastes which could potentially cause these impacts and be transported across boundaries is about 1.3 million tonnes, with 83% of these wastes originating from Madagascar (Table 16).

Table 16 Estimated annual amount of solid waste.

	Comoros (tonnes/year)	Madagascar (tonnes/year)	Mauritius (tonnes/year)	Seychelles (tonnes/year)	Total (tonnes/year)
Domestic waste collected	27 090	219 000	370 369	44 400	
Ship generated waste collected	ND	ND	ND	1.3	
Domestic waste not collected	104 000	1 095 000	65 000	2 500	1 266 500
Waste collected from rivers and drains	ND	9 000	4	ND	9 000
Waste collected in clean-up campaigns	ND	ND	73	271	344
Waste collected on beaches	ND	40 000	520	120	40 640
Total waste likely to end up in the sea (estimated)					1 316 484
Area used for waste disposal (ha)	ND	ND	2.5	2	

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

Table 17 Costs associated with waste management.

Activity		Comoros	Madagascar	Mauritius	Seychelles
Cost of collection	USD/tonnes	42	60	67	136
	million USD/year	2	ND	25	6
Cost of treatment/ disposal	USD/tonnes	6	0.2	ND	45
	million USD/year	0.3	ND	8	2

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

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 m^2 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 associate 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 m^2, 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 18 Economic costs of solid waste deposited along river banks, beaches and in the sea.

Sector	Madagascar	Seychelles
Cost of road cleaning (USD/km)	30.8	ND
Cost of beach cleaning (USD/m^2)	ND	40
Cost of river clearing and unblocking (USD/year)	ND	500 000
Cost to fishermen (engine and net repair)(USD/year)	1 000	ND

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.

Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details, please refer to the chapter describing the GIWA methodology.

Introduction

The focus of the Causal Chain Analysis (CCA) is to determine the source, underlying constraints and the root causes of the solid waste issue in the Indian Ocean Islands region. Solid waste management and disposal is a major environmental concern in all the four island states. Besides a number of unmanaged dumping sites and uncontrolled landfilling in Comoros and Madagascar, the dumping of solid wastes in rivers, on beaches and in the sea is common practice. This also used to be the situation in Seychelles and Mauritius, but these activities have been discontinued through adoption of a national solid waste management plan and provision of the necessary infrastructure, where both countries have made considerable investments. For example, Seychelles has invested over 6 to 8 million USD in solid waste management over the last 10 years. Solid waste management is indeed very complex; for example, setting up refundable deposit systems, variable taxes on collection and siting of landfills in a way that does not harm the environment or people. Developing the appropriate mechanisms and capacity to control the entire process from waste generation and collection through to appropriate disposal requires an integrated approach.

Many of the states in the region have undergone a profound shift in consumption patterns in the past decades. One of the main drivers of consumerism has been the flood of products from developed countries and newly industrialised countries, particularly in South East Asia. For example, plastic packed food, polystyrene plates and aluminium cans came into fashion as fast food became popular with an increase in the purchasing power of the people. Improvements in travel, tourism and access to foreign markets, coupled with the influence of television have also had a profound impact on the consumption patterns of members of the public. The results of these changes are multifaceted, ranging from increase in solid wastes generation to obesity which can be seen as precursors of an affluent society. On the other hand, increase in fisheries development has also brought about additional problems such as nets and buoys that are constantly being washed ashore on many of the small islands in the archipelago.

The reasoning behind the choice of focusing the causal chain analysis on solid waste can be argued against, but because the extent of the problem is not the same on each island and each island suffers from significant amounts of solid wastes found lying in the street, some of which get washed up daily on beaches, the imperative to address the issue becomes even stronger.

The assumptions concerning the nature of the solid waste problem based upon the review in the previous section, Assessment, is summarised below:

- There has been a general increase in the consumption of packaged goods and other waste-related products in all four island states;
- The human generation of solid wastes has increased;
- Poor solid waste collection service is in place;
- There is generally a lack of appropriate land for the location of disposal facilities;
- Explosion in vermin and mosquitoes, which are disease-vectors, is common in many parts of Madagascar and Comoros;
- Overall, solid wastes have been found to clog up drains leading to flooding;
- There is an overall lack of in-country capacity to deal with the disposal of the waste;
- Some solid wastes would degrade or leach chemicals over time with long-term effects.

Furthermore, the impacts of wastes are also transboundary, both as a function of human movement and dispersal through natural forces such as wind and ocean currents. Transboundary issues that are relevant in this analysis include:

- Waste such as marine debris which floats and affects wildlife;
- Waste that get carried by ocean current to other islands and countries;
- Disposal of solid waste at sea;
- Waste that is dumped by boats, especially fishing vessels;
- Discarded fishing gear, which cannot be recovered, often remains in the ocean affecting wildlife for many years;
- The leaching of wastes into the marine environment, including accumulation in the food web;
- The commercial transport of waste to be disposed or recycled in another island state can be dumped on the high seas to minimise costs of treatment.

Methodology

Clearly, there has been much work done in other countries on the issue of integrated solid waste management, but it is necessary that this report emphasises, where possible, the local conditions required for the development of a suitable policy model to address the identified root causes.

Based on the discussion in the previous section, Assessment, combined with current available knowledge on the issue, the causal chain for the problem of solid waste was constructed. To facilitate the assessment a series of proxy indicators were developed (see Table 19). The selection of those indicators was based upon an assessment of availability of data and adequacy of the data.

Table 19 Proxy indicators developed to facilitate and ensure comparability of the assessment in the region.

	Indicators	Linkages					
		T	I	II	III	IV	V
E1	Habitat loss – the ratio of solid waste collected/not collected	✔			✔		
E2	Area used for solid waste disposal			✔	✔		
E3	Amount of solid waste removed from rivers and drains	✔	✔	✔	✔		✔
E4	Quantity collected during Clean-up-the-World Campaign	✔		✔			
E5	Number of wildlife affected by marine debris	✔	✔		✔	✔	
E6	Quantity of solid wastes collected on beaches	✔		✔	✔	✔	
C1	Cost of collection			✔			✔
C2	Cost of treatment and disposal			✔			
C3	Clean-up costs		✔	✔			
H1	Cost of pest eradication				✔		✔
H2	Number of cholera cases		✔				✔
S1	Cost of litigation (Not in my back yard)					✔	
S2	Proportion of population affected by location of discharge			✔			
S3	Bins/collection sites per capita			✔			

Note: E = environmental indicator; C = economic indicator; H = health indicator; S = social indicator; T = transboundary relevance; I to V = the five GIWA concerns.

Table 20 Characteristics of sites selected for the Causal chain analysis

Country	Sites	Area (km^2)	Population
Comoros	Grande Comore Island	1 025	250 000
Madagascar	Antananarivo City (mainly)	30	1.5 million
Mauritius	Mauritius Island	1 865	1.2 million
Seychelles	Mahe Island	154	60 000

(Source: GIWA Task team calculations 2003)

The choice of a definite geographical site for the CCA is problematic in view of the small size of some islands, e.g. Seychelles, where data is aggregated at national level, and large islands, e.g. Madagascar where data for some indicators are available in one area only. Secondly, the transboundary impacts can extend beyond several thousand miles. The final selection of sites for the CCA is given in Table 20.

The immediate causes of solid waste

The immediate causes of the problem of solid wastes are linked to the main sources generating these wastes, viz:

Municipal/industrial solid wastes – i.e. solid waste generated from urban and industrial centres. Such wastes are usually domestic, combined with industrial, which includes wastes from manufacturing industries as well as service industries, such as tourism establishments. Such wastes are mixed consisting of both organic, biodegradable and non-biodegradable components (ITW 1994).

Discards from beach users – includes solid wastes that are dumped on the beach by users, tourists, and so on. Such waste consists of plastics, cigarette butts, empty bottles (Payet 1996) and in some areas wastes similar to municipal wastes.

Sewage related debris – these are mainly originating from wastewater treatment outfalls in the major cities. This cannot be quantified but hypodermic needles, plastics, and other small items which have been observed.

Among those three listed immediate causes, the municipal and industrial wastes are the most significant in the region. As discussed in the previous section, at least 2.8 million tonnes of solid wastes are generated in the region, of which only 30% are collected routinely and beach deposited rubbish is estimated to be about 40 640 tonnes.

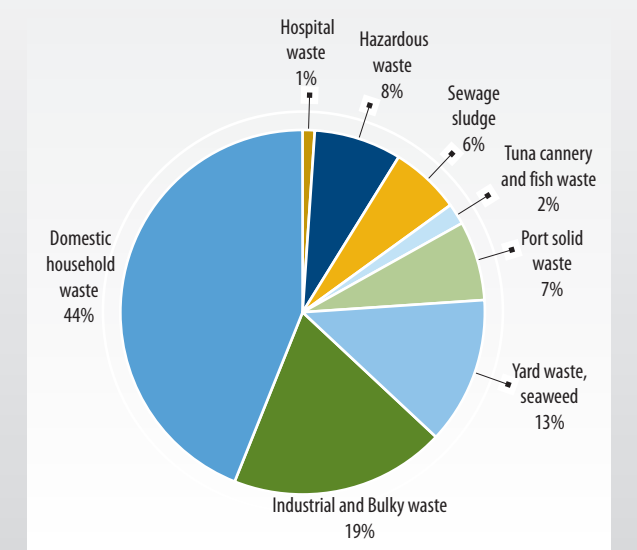

Figure 20 Solid waste sources in Seychelles.
(Source: ITW 1994)

Sector activities that generate solid waste

Sector-based data on solid wastes is not available in the region, except for Seychelles (Figure 20). However, from the analysis in the previous section, and observations of the authors, the following sectors in order of priority are the highest generators of solid wastes in the region.

Urbanisation and consumption – As presented in the socio-economic characteristics of the region above, coastal urbanisation is likely to double in Comoros and Madagascar by year 2015, with moderate growth in Seychelles and Mauritius. An increase in human settlement will lead to an increase in solid waste generation.

Industry – Will not likely increase beyond what it is now, due to emerging trade opportunities, but will continue to generate significant amounts of wastes. For example, growth in the industrial base in Madagascar due to its low cost of labour, or growth of tourism in Seychelles and Mauritius, will all likely contribute to an increase in solid wastes generated.

Transport – Will likely increase to meet tourism and trade demands. Additional tourism opportunities will be explored which may create growth in the sector. Both Madagascar and Comoros are functioning well below normal tourism trends, implying there is great potential for growth.

Between 30-50% of all solid waste generated comes from domestic sources (Figure 20). The domestic sector is therefore the primary waste generator followed by industry. Due to relatively low levels of transport in the Indian Ocean Islands region compared with many other regions, such as the Caribbean, wastes generated by this sector are expected not to exceed 10% of total generated wastes.

Root cause analysis

The determination of root causes can be a complex task especially where the problem is linked to other social and economic issues. The main root causes identified are, in order of priority:

Root cause 1: Lack of investment planning and priorities.

Root cause 2: Lack of effective mechanisms, inadequate institutional structure, laws and capacity.

Root cause 3: Lack of adequate facilities, services for collection and management of wastes.

Root cause 4: Lack of education and awareness.

However, to undertake an in-depth analysis of these root causes, it is important that the following issues are also considered. The scope of each of these root causes is discussed in detail.

Root cause 1: Lack of investment planning and priorities

National development planning is a critical process whereby national priorities are defined, and in many countries the World Bank and various UN agencies provide support for the development and implementation of national development plans. In Seychelles, national development planning has existed since the early 1980s, but it was only at the beginning of the 1990s that sustainable development issues were specifically integrated as part of national planning.

The Environment Management Plan framework has been the primary driver for implementation of solid waste management polices within the national development process in all the countries in the region. In the case of Mauritius and Seychelles, the issue of solid waste management was clearly identified in the Environment Management Plan, and significant funding was dedicated to address the problem. Being ACP (African-Caribbean-Pacific) countries within the European Union Cooperation Programme, both countries benefited from European expertise to establish integrated solid waste management programmes. This included the identification and development of fully engineered landfills (disposal options), improvements in the waste collection service with participation from the private sector and exploring other aspects of solid waste management such as composting, recycling and recovery. However, both Madagascar and Comoros are still in the very early stages of developing integrated waste management approaches.

In spite of this progress, as indicated in the previous section, Assessment, a number of problems still exist such as lack of adequate land for solid waste disposal, reduction of littering, and most importantly putting in place a sustainable financing mechanism for finalising solid waste management in the long-term. In Seychelles, for example, people are not directly charged for solid waste collection, but instead the annual budget for solid waste management is sourced from the government budget. One of the factors that cannot be addressed in the short-term is the problem of population growth and increasing purchasing power. Although it is a root cause in itself, the problem lies at the centre of national planning and therefore deserves some treatment to illustrate the linkages and how the population problem affects this root cause.

Population changes

The population growth and projections to year 2015 for the region are given in Table 21. Madagascar, the largest country will have the largest population, with probably the largest impact in the region. Madagascar's population will effectively double by 2015, but growth rates are expected to decline from 3% to about 2.5 %. Population growth in both Seychelles and Mauritius will be low.

Table 21 Population growth.

Country/ Region	1975 (million)	1998 (million)	2015 (million)	Population growth rate % (1998-2015)
Comoros	0.3	0.7	1.0	2.5
Madagascar	7.8	15.1	23.4	2.6
Mauritius	0.9	1.1	1.3	0.8
Seychelles	0.06	0.08	0.10	0.87
Indian Ocean Islands	9.06	16.98	25.8	~2.5

(Source: UNDP 2000)

Solid waste generation is closely linked to the economic growth of the country and the purchasing power of its people. Considering the figures given on the GDP, it is likely that the amount of wastes currently generated will increase (Table 23). For example, in Mauritius, about 0.7 kg of solid waste per person per day is generated, which will likely increase to 0.9 kg by the year 2010. In Seychelles, solid waste generation is about 0.39 kg (1994 estimate) per person per day and it is estimated that this will likely increase to 0.53 by 2015 (UNDP 2000). For Comoros and Madagascar per capita data is estimated to be about 0.1-0.2 and 0.2-0.4 kg per person per day, respectively. Tourism development in the region will also increase solid waste generation.

Movement of the population within Comoros and Madagascar will be mainly influenced by better job opportunities and livelihood in the cities (Table 22). In Mauritius, the urbanisation rate has decreased due to government policies for providing good communication and services within the communities. In the case of Seychelles, urbanisation is strongly influenced by the lack of land for communities to expand in view of high conservation value of many areas, and therefore population centres will be planned development on the reclaimed areas around the city of Victoria.

Table 22 Changes in urban population.

Country/ Region	1975 (%)	1998 (%)	2015 (%)
Comoros	21.2	32.1	42.6
Madagascar	16.1	28.3	39.3
Mauritius	43.4	40.9	48.6
Seychelles	33.3	56.9	67.3
Indian Ocean Islands	28.5	40.0	50.0

(Source: UNDP 2000)

Solid waste is an issue that should remain a national priority, as it is closely related to the performance of the economy, especially if it depends upon tourism. Compared with other investments such as water and sewage, solid waste collection services entail huge costs every year, and policies aimed at reducing those costs whilst maximising the amount of waste collected would be the optimum approach. To achieve this optimum, a number of policy instruments will need to work together, as discussed in the next section. However, to implement any of these policy instruments consistent political will, national planning and a dedicated government budget is required every year.

Whilst the role of government in solid waste management is undoubtedly important, mechanisms should be put in place for private sector involvement and re-investment in the sector. These could then create the right investment environment for recycling, deposit-on-return, zero-packaging, green eco-labels and other schemes.

Root cause 2: Lack of effective mechanisms, inadequate institutional structure, laws and capacity

Mechanisms

The quantity of solid waste generated is closely linked with economic development. The states within the region can be conveniently divided into groups depending on the economic data presented in Table 23 and also in Table 8 and 9.

In Mauritius and Seychelles, it is envisaged that solid waste generation will continue to increase with increases in population, consumption and development activity being pushed towards the private sector (Table 24). However, Madagascar is expected to experience much more rapid growth, depending upon political stability and reform policies being implemented. In order to promote national unity and investments at community level, the government is likely to become increasingly invovled to ensure better management at grass roots level and also serve to tackle some of the ingrained problems related to ecosystem degradation in Madagascar. This kind of analysis is based upon expert views rather than an analysis of available data. Table 25 is a further extension of this analysis which considers the magnitude of changes in output between now and the year 2020.

The size of change in output was difficult to determine due to lack of data and macro-economic scenarios for the region. Based upon past and historical data in economic growth, the proposals have been summarised in Table 25. Whilst it is expected that there will be increased industrialisation in Madagascar and Mauritius, Seychelles and Comoros will likely become more service oriented. Imports of goods are likely to generate more solid waste, and increased production will also increase

Table 23 Economic indicators.

	GDP 1995 (USD billion)	GDP annual growth rate 1980-1996 (%)
Comoros	0.2	2.0
Madagascar	3.2	-0.1
Mauritius	3.8	5.7
Seychelles	0.5	3.3

(Source: UNDP 2000)

Table 24 Likely changes in private and government consumption.

Country	Consumption 1998 (as % of GDP)		Consumption 2020	
	Private	Government	Private	Government
Comoros	93.8	11.6	+	++
Madagascar	88.6	6.1	+	+
Mauritius	65.0	11.0	+	-
Seychelles	65.7	17.0	+	-

Note: + =increase, - = decrease. (Source: UNDP 2000)

Table 25 Expected output change to the year 2020.

	Exports of goods & Services	Imports of Goods & Services	GDP
Comoros	+	+	+/-
Madagascar	++	+	+/-
Mauritius	++	+	+
Seychelles	+	+	+

Note: += increase, -=decrease. (Source: GIWA task team calculations 2003)

solid waste as a by-product and as a product of consumption. The GDP of Madagascar and Comoros may or may not increase depending upon political stability and economic reform. The GDP of Mauritius and Seychelles will likely continue to increase.

Growth in the shipping industry is closely linked to the economic prosperity and consequently the trade input/output from the country. The countries in the region have considerable outputs in terms of both fisheries (Mauritius, Madagascar and Seychelles) and agriculture (Mauritius, Madagascar and Comoros). Marine transport being the cheapest and most favoured is thus the most important link between these islands and the world trade centres. However, with this increase in trade, an increase in marine wastes is highly probable. This is further exacerbated by ports in the region competing for the least cost. Competing on the basis of least cost foregoes the option of provision of waste reception facilities, as these can have a high cost associated with them.

Taxes and subsidies for solid waste management in the region are not well developed. There are taxes on consumer products, highest in the Seychelles, and this lowers customer purchasing power and has an effect on solid waste generation. Restrictions in availability of consumer products due to lack of convertible currencies in Seychelles, Madagascar and Comoros also results in less waste being generated.

In Mauritius, the government spends nearly 25 million USD per year (that is about 21 USD per person) for the collection, transportation and disposal of refuse waste. In Seychelles, spending is about 6 million USD per year or about 57 USD per person.

Legal

The institutional and legal framework for countries in the region is discussed in detail the first section of this report but the most salient points are worth emphaising here..

Mauritius addressed the issue of solid waste management by the creation of the Department of Environment in 1989 and the enactment of the Environment Protection Act (EPA) in 1991 (revised in 2002). Under Section 6 of the EPA 1991, it is the duty of the Minister of Environment to propose and develop policies on all aspects of environment protection and management pursuant to national objectives and goals set by the National Environment Commission. The Department of Environment of the Ministry of Environment functions as the Waste Regulation Authority and it formulates policies on waste management. The Environment Protection (Polyethylene Terephthalate (PET) Bottle Permit) Regulations has been promulgated in 2001 under the EPA. The aim of these regulations is to develop "product responsibility" among bottlers for the proper management of the bottles after distribution. Bottlers, grouped in an association, have put up a system of collection of used PET bottles which are exported for recycling.

However, close monitoring is required and, to date, these regulations have not been enforced due to lack of staff. The polluter pays principle has been adopted where the 'Police de L'Environement' issue fines if somebody is caught littering. This unit was created in December 2000 and is based at the Ministry of Environment. Its main functions are to enforce the laws (EPA, Local Government Act, Noise Prevention Act etc.). It comprises 26 policemen who work in a shift system to ensure that they are available round the clock. From 1st December 2000 to 2003, 5 897 contraventions have been established for illegal littering and 70 contraventions for illegal dumping under the 'Dumping and Waste Carrier's Regulations, 2003'. However, the number of Policemen of Environment is not enough for the 1.2 million people living in Mauritius. Still, some littering does occur, especially in rivers and other watercourses.

In Seychelles, an authority was created to manage solid wastes. The authority, called the Solid Waste and Cleaning Agency (SWAC), is responsible for solid wastes and hazardous wastes management in the country. It operates through the management of contracts for collection and management of the landfills. The Environment Protection Act 1994, which makes specific provision for the management of solid wastes was utilised to develop subsidiary legislation to deal with solid wastes. To date, SWAC has over 30 staff members who are engaged in various enforcement and supervisory work that covers public collection points, maintaining certain public places, beaches and some drains. SWAC also undertakes several educational and sensitisation activities to promote waste reduction and recycling. Recycling fairs have also been organised to show how waste materials can be recycled into productive uses.

In Madagascar and Comoros, there are no dedicated solid waste management agencies. In Madagascar, management responsibility for solid waste is a function of the municipality, whereas in Comoros, the Ministry of Environment is responsible to issue contracts and ensure collection is done promptly. In both countries there are very few people who are involved in the management of solid wastes.

All the island states in the region are signatories to MARPOL (The International Convention for the Prevention of Pollution from Ships), and should comply to its requirements. However, due to problems linked to the root causes presented here, MARPOL is not at a high

level of implementation in the region. For example, the establishment of reception facilities can be a sound private sector investment but, due to a lack of regional harmonisation, no one is willing to put in the investment and risk those facilities not being used. A regional approach and timetable may be required to resolve the issue.

Root cause 3: Lack of adequate facilities, services for collection and management of wastes

The knowledge of treatment and management of wastes is most advanced in Mauritius and Seychelles. In Comoros and Madagascar, solid waste dumpsites dominate with no significant technology in the treatment of solid waste. Both Mauritius and Seychelles have one fully engineered landfill each, but another sanitary landfill is currently being used in Seychelles waiting for this fully engineered landfill to open.

In Seychelles, use of the fully engineered landfill will depend upon the performance of a solid waste sorting and composting facility, which is already operating, generating compost for local use and export. At this landfill at Anse Royale, only inert wastes, such as glass and certain types of plastics, will be deposited with the remainder being recycled (plastics, metal and waste oil) or converted into compost.

There are no large municipal solid waste incinerators in the region. A few small incinerators (e.g. in Seychelles and Mauritius) are used for special wastes such as hospital wastes.

In all the island states there are various levels of waste recycling, but nothing is done on a large commercial scale, except for a few factories in Mauritius that recycle plastics into other products and convert bagass (fibrous by-product of sugar refining) into energy. In Seychelles, recycling almost occurs at an artisanal scale, probably related to the small quantities produced. In Comoros and Madagascar, recycling is also artisanal but as an alternative livelihood to avoid poverty. Recycling is limited at national level due to the scale of economies, but at regional level there is large potential.

There are no proper reception facilities for ship-generated wastes in the region. It can be concluded that a huge proportion of the solid wastes generated by the shipping industry is dumped at sea, and the remainder in sanitary landfills on land.

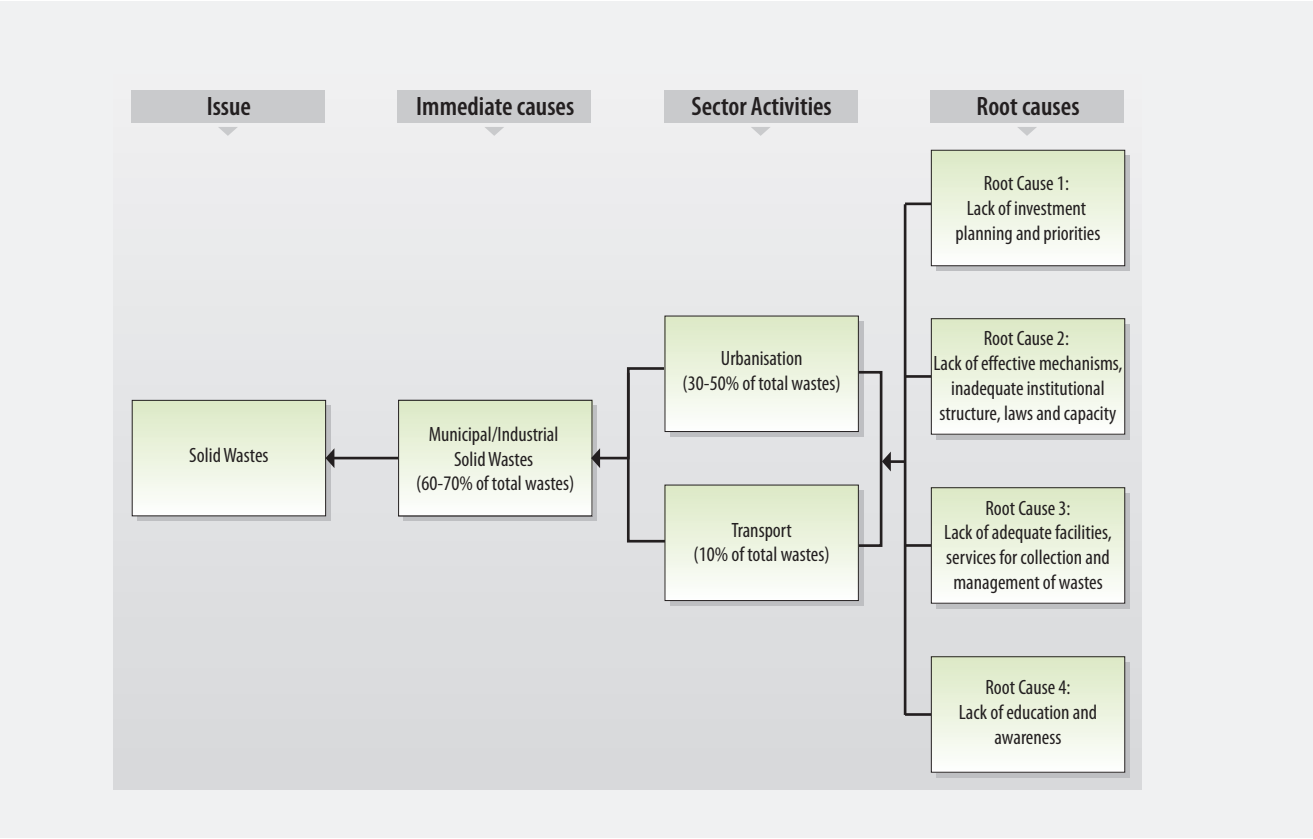

Figure 21 Causal chain diagram for solid waste.

Root cause 4: Lack of education and awareness

Lack of education and awareness is a root cause that transcends all levels of a society. Solid waste education is a specialised field but several activities or initiatives can be launched at national and local level to encourage reduction in waste generation, littering, illegal waste dumping, proper use of the receptacles, recycling, etc.

In the region, some education programmes have been conducted, and the "Clean-up the World Campaign" is held in each country every year. Other initiatives include short programmes on national TV, exhibitions and tips through the eco-home programme in Seychelles.

Despite all these efforts, public education is not easy and it takes years (in some cases as long as a generation) to change habits and tendencies. However, education programmes are done in a haphazard manner and not linked to public responses and a measurement of the improvements achieved is lacking. Solid waste management programmes in the region are therefore fragmented and opportunistic.

An effective combination of mechanisms ranging from enforcement to education and awareness can provide the tools to address this root cause in the short- and long-term.

Conclusions

The root causes elaborated in this section include a consideration of forces that are beyond the immediate control of governments (population growth and urbanisation) and those that can be addressed using a series of policy measures, such as altering consumer patterns and generation of wastes. The conceptual model showing the root causes in the context of the solid waste issue is depicted in Figure 21.

The root causes are closely linked to one another, and to the issues of population growth and economic development, both of which are rather long-term issues.

Policy options

This section aims to identify feasible policy options that target key components identified in the Causal chain analysis in order to minimise future impacts on the transboundary aquatic environment. Recommended policy options were identified through a pragmatic process that evaluated a wide range of potential policy options proposed by regional experts and key political actors according to a number of criteria that were appropriate for the institutional context, such as political and social acceptability, costs and benefits and capacity for implementation. The policy options presented in the report require additional detailed analysis that is beyond the scope of the GIWA and, as a consequence, they are not formal recommendations to governments but rather contributions to broader policy processes in the region.

The Policy options analysis (POA) present a series of policy options that address the main root causes discussed in the previous section. Also, experience from the region, e.g. Mauritius and Seychelles, shows that many of these root causes can be turned into advantages to address the problem of solid wastes, which is becoming an increasingly important transboundary issue since wastes are transported to and across the open sea. It is important to note, however, that there are significant differences between all four countries in the region, and whilst some policies may work in the majority of cases, they may not necessarily work in all instances. The analysis only attempts to provide insight into which policy options may work and under particular conditions.

Problem definition

The problem can be defined as:
Lack of management of solid wastes in the Indian Ocean Islands region leading to serious environmental and health problems on land and sea resulting in economic collapse of resources. The issue is transboundary since solid wastes are transported to sea by run-off and river discharges, and to other countries by ocean currents.

Establishment of preliminary hypotheses

The development of preliminary hypotheses was facilitated by the identification of, possible areas for implementation (Table 26) and the subsequent consolidation into the following hypotheses:

1) The increased generation and improper disposal of solid wastes has caused an increase in marine debris with ecological and economic consequences in the region.
2) The situation can be reversed through the implementation of legal, economic (market) mechanisms, and proper investments/ technology transfer in the causal sectors.

Table 26 Summary of possible areas to explore in the Policy option analysis.

Subject: Reducing the transboundary impacts of solid waste	
Issues that can be addressed:	
Sources of solid waste	Economic approaches to solid waste management
Clean-up effort and costs	Legal frameworks for solid waste management
Efficiency of collection system	Investment policies for solid waste management
Lack of funds for implementation	Community behaviour/change in attitudes
Waste reduction, recycling, reuse policies	Investments in properly engineered disposal systems
Monitoring of marine activities	Reducing health threats
Per capita consumption of wastes	Treatment technologies
Provision of solid waste management infrastructure and support	Dealing with potential hazardous wastes and its degraded components

These two preliminary hypotheses will be vital components in the development of the policy options analysis. In this case, the hypothesis will be tested using a qualitative assessment of quantitative data in

the form of proxy indicators. Whilst explanations can be given on the assumptions (also with reference to peer reviewed and published documents in other regions) in such a case, it is not possible to quantitatively determine the relevance of these hypotheses. However, the exercise will identify existing gaps and suggest how this additional information may be acquired in the future.

Finally, although a number of cases policy development is done in the absence of hard scientific information, it is equally important that the several principles enshrined in Agenda 21 are maintained in the review process; for example, the precautionary approach and the polluter pay principle.

Construction of policy options

In the following section, a series of policy options aimed at addressing each root cause is presented and analysed.

Root cause 1: Lack of investment planning and priorities

Agency budgets

- Add/Increase budget allocation for solid waste management;
- Shift allocation from another item in the budget to the use for solid waste management;
- Use budget allocation to raise additional financing for solid waste management.

The Government budget is usually the first point of consideration for any investment programme and service. Usually, this comes out of management plans or through political will. Unfortunately, solid wastes do not attract attention until they become an acute problem. Countries with solid waste infrastructure in place need the budgets for maintenance of the facilities and also the collection services. This could result in an increase in the budget (mostly unlikely, given current economic situations). In many instances, governments in the region are now using their budget, both capital and operating costs, as counterpart funding to raise funding (in loan and grant form), particularly from the World Bank and the GEF, for development projects. The risks involved include tying up limited funds in project work, but the benefits include achievable targets beyond what might be funded using annual budgets.

Modify framework of economic activity

- Provide the service contract to several operators;
- Provide specialised services to only one operator;
- Set the price for purchase of recyclable materials and compost;
- Increase employment opportunities.

As with any environmental problem, there is a need to link the issue with economic policies. These options attempt to introduce competition in the market in a structured manner: competition encouraged for certain components. Employment opportunities will be the likely outcome of any creation of new services.

Taxes

- Introduce taxes on consumer products;
- Reduce taxes on waste separation and treatment technologies;
- Tax the disposal of solid wastes by industry;
- Reduce tax on recycled materials;
- Introduce refundable deposits on containers.

Taxes may provide the required funds to put in place proper waste management services. Introducing taxes on certain consumer products, i.e. those that are not biodegradable and designed to be disposable, would cause a reduction in the import of such products and also provide funds for the establishment of proper disposal facilities, assuming that a sufficient amount continues to be imported. Reducing taxes on waste control technologies would provide the incentive for industries and consumers alike to invest in these technologies, with reduction in solid waste generation required for disposal. Polluters would be made to pay for the amount of waste they generate. There are several advantages and disadvantages in practice of this policy option. Reducing tax on recycled consumer products would allow those types of products a bigger share of the market, thus encouraging producers to buy such products, as well as raising the awareness for more recycled products. The recycled product should also be evaluated according to its biodegradability or "recyclability" after use. Refundable deposits on containers such as bottles have worked for over 20 years in the Seychelles. The Seychelles Brewery uses glass bottles at least 8 to 10 times through a bottle refundable deposit system. This has brought about cuts in imports and reduction in wastes.

Subsidies and grants

- Introduce subsidies for all commercial operators that have a waste collection service contract;
- Introduce subsidies to the municipality for solid waste collection;
- Provide grants for further research in the solid waste generation and collection.

This option is more complicated in the context of solid wastes in the region. The introduction of subsidies to encourage all commercial operators to have waste collection contracts will provide some funding for a solid waste company to start operations and, through additional subsidies to the local municipality, provide funding for the collection of public wastes.

Grants and financial support for proper research is required to assist in the development of best collection and disposal practices and strategies.

Root cause 2: Lack of effective mechanisms, inadequate institutional structure, laws and capacity

Regulations

- Establish waste management regulation to address: legally designated areas for solid waste disposal, specific environmental conditions/criteria for siting of landfills, and provide enforcement powers to officers;
- Adopt new standards for the construction of landfills, leachate discharge, air quality at landfill sites and disposal of solid waste by marine vessels;
- Identify and close loopholes in the law to improve on enforcement against littering and dumping of wastes at sea;
- Explore more creative means of using the law to ensure compliance to existing laws/standards for solid waste disposal;
- Improve enforcement capacity through training, more legal powers and redevelop patrol strategy;
- Improve levels and convictions and reduce court time;
- Effective follow-up of complaints by the public.

Command and control approaches are still very common options adopted by governments in addressing a problem. In Comoros and Madagascar a legislative framework for solid waste management is lacking. Standards can be adopted, noting that many countries have several years of experience in the commissioning and management of landfills. Technology transfer experience would be required especially with the introduction of new standards. In existing laws and regulations, the need to identify and address loopholes is an ongoing exercise designed to improve effectiveness of the laws as well as motivate those who implement them. In view of the nature and complexity of the waste management problem, more creative approaches need to be explored to ensure compliance; for example, reduction of enforcement demand through involvement of the public in enforcement by giving them special powers or titles. One of the biggest hurdles in policing regulations is building up a good enforcement team and keeping it. Enforcement is one of the most serious problems facing countries the world over. Working with the judiciary is also required to improve effectiveness of the prosecution process and also to ensure that cases are dealt with efficiently. The public presents a good opportunity to learn what is happening, as enforcement officers cannot always be present at every location all the time. However, it is important that public complaints are taken seriously and proper follow-up is ensured.

Modify structure of private rights

- Re-assign/modify property rights to assign responsibility for collection of wastes;
- Introduce liability duties to protect against ground water pollution;
- Amend constitution to provide for a "right to enjoy a safe and clean environment";
- Improve labour laws to ensure there are sound occupational health standards for the handling, collection and disposal of solid wastes;
- Upgrade corporate and company law to allow companies to use recycled waste materials in their products.

Improper allocation of property rights is often a root cause of several problems, including dumping of rubbish all over the place. Since solid waste management involves a degree of risk to the environment and the welfare of people, introduction of liability funds (or compulsory insurance) may provide for those affected in the future by improper disposal of solid wastes. This may also include compensation to fishermen for loss of catch as a result of marine debris.

Root cause 3: Lack of adequate facilities, services for collection and management of wastes

Financing and contracting

- Provide loans (soft or low-interest) for investment in new equipment and facilities;
- Setup a public enterprise to address the problem of wastes;
- Privatise viable components of waste management;
- Reduce out-of-contract claims.

These options are the most common and are implemented in a number of instances, for example the creation of the Solid Waste Cleaning Agency (SWAC) in Seychelles. Provision of loans to all operators in the solid waste sector would allow them to prioritise areas of need and also respond

to the improvement and performance reviews done to consistently improve the level of service. Reducing claims outside a contract is often one of the largest sources of over-expenditure in a project.

Bureaucratic and political reforms

- Decentralise service to the municipalities;
- Improve collection frequency and coverage;
- Reduce time for issuance of solid waste disposal permits;
- Increase opening hours of landfills.

The centralisation process is more pertinent in larger countries, but in small countries, the public can play the role in monitoring the service provided by the state or a contracted company. Providing a better service with less bureaucratic loopholes would interest the private sector and encourage foreign investment in the country.

Provide a service

- Introduce a waste collection service to cover the entire country, or add to an existing service to cover other towns;
- Improve public use of the service by conducting outreach events;
- Improve relationship among all service providers within the sector to keep costs down and increase efficiency.

Providing a new service or extending on an existing service is a requirement in the region, since in some areas there is no service at all. In some states, such as Madagascar, the best service is confined to the capital, where less than 1% of the population lives. Activities can be organised to improve public perception and effective use of the service. For example, in Seychelles, there is a recurrent problem of how the public should use the public bins provided. Improving the relationship among all operators within the sector is critical in keeping costs down and reducing cases where wastes are not collected over extended periods of time.

Root cause 4: Lack of education and awareness

Information

- Monitoring and information sharing;
- Collection of data on waste consumption, disposal (by type and source).

The use of information in the implementation of solid waste management is vital as it can improve understanding and management of the solid waste issue. In fact, many studies have shown that costs can be cut and the service improved if appropriate information for management is obtained.

Education and consultation

- Education campaign to inform consumers about littering, accumulation of solid waste stockpiles along the road;
- Consultation activities to obtain citizen views on how the collection service should be done and how the service can be improved;
- Develop a series of guidelines for the management of solid wastes;
- Training and capacity building programme.

Public education is a vital component of any solid waste management strategy, as the population needs to be educated in the proper use of the waste receptacles, undertake home recycling schemes and so on. Consultation is also vital to understand public preferences and behaviour. A solid waste management system is heavily dependent upon the co-operation of the public. Improvements in the service should be a continuing activity to reduce the amount of waste not collected. If a new service is being provided a dedicated training programme needs to be established, and existing service staff needs retraining and upgrading from time to time.

Identification of the recommended policy option

The identification of the recommended policy options was based upon the analysis of the policy option against three main criteria: efficiency, equity and practicality. The analysis is summarised in Table 27. It is once again important to stress that the analysis is based upon the views of the experts involved in the GIWA Task team and not necessarily the views of the Governments, nor should it be implemented without proper in-depth analysis of the local conditions. This exercise has however, attempted to narrow down the potential policy areas which may be further explored in future work.

Twenty-six policies were selected using this initial screening process. The discussion and analysis in following sections will further refine that list to develop a feasible policy framework to address the issue of solid wastes in the region.

Table 27 Rapid screening of policy options based upon the main criteria for Policy option analysis.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
T1	Introduce taxes on consumer products	✓			
T2	Reduce taxes on waste separation & treatment technologies	✓	✓	✓	✓
T3	Tax the disposal of solid wastes by industry	✓	✓		✓
T4	Reduce tax on recycled materials			✓	
T5	Introduce refundable deposits on containers	✓		✓	✓
R1	Establish waste management regulation to address: legally designated areas for solid waste disposal, specific environmental conditions/criteria for siting of landfills, and provide enforcement powers to officers	✓		✓	✓
R2	Adopt new standards for the construction of landfills, leachate discharge, air quality at landfill sites and disposal of solid waste by marine vessels		✓	✓	✓
R3	Identify loopholes in the law to improve on enforcement against littering and dumping of wastes at sea		✓		
R4	Explore more creative means of using the law to ensure compliance to existing laws/standards for solid waste disposal	✓	✓	✓	✓
R5	Improve enforcement capacity through training, more legal powers and redevelop patrol strategy		✓	✓	✓
R6	Improve levels and convictions and reduce court time		✓		
R7	Effective follow-up of complaints by the public		✓		
S1	Introduce subsidies for all commercial operators for waste collection service contract				
S2	Introduce subsidies to the municipality for solid waste collection		✓	✓	✓
S3	Provide grants for further research in the solid waste generation and collection				
P1	Introduce a waste collection service to cover the entire country, or add to an existing service to cover other towns	✓	✓		✓
P2	Improve public use of the service by conducting several outreach events		✓	✓	✓
P3	Improve relationship among all service providers within the sector to keep costs down and increase efficiency	✓	✓		✓
B1	Add/Increase budget allocation for solid waste management				
B2	Shift allocation from another item in the budget to use for solid waste management	✓			
B3	Use budget allocation to raise additional financing for solid waste management	✓		✓	✓
I1	Monitoring and information sharing	✓	✓		✓
I2	Collection of data on waste consumption, disposal (by type and source)	✓	✓		✓
PR1	Re-assign/modify property rights to assign responsibility for collection of wastes	✓			
PR2	Introduce liability duties to protect against ground water pollution				
PR3	Amend constitution to provide for a 'right to enjoy a safe and clean environment'	✓	✓		✓
PR4	Improve labour law to ensure there are sound occupational health standards for the handling, collection and disposal of solid wastes		✓	✓	✓
PR5	Upgrade corporate and company law to allow companies to use recycled waste materials for their use	✓		✓	✓
EC1	Provide the service contract to several operators	✓	✓	✓	✓
EC2	Provide specialised services to only one operator			✓	
EC3	Set the price for purchase of recyclable materials and compost		✓	✓	✓
EC4	Increase employment opportunities	✓	✓		✓
ED1	Education campaign to inform consumers about littering, accumulation of solid waste stockpiles along the road			✓	
ED2	Consultation activities to obtain citizen views to improve service		✓	✓	✓
ED3	Develop a series of guidelines for the management of solid wastes	✓	✓	✓	✓
ED4	Training and capacity building programme	✓		✓	✓
FC1	Provide loans (soft or low-interest) for investment in new equipment and facilities	✓	✓		✓
FC2	Setup a public enterprise to address the problem of wastes			✓	
FC3	Dismantle a public enterprise	✓			
FC4	Reduce out-of-contract claims	✓			
BP1	Decentralise service to the municipalities	✓	✓		✓
BP2	Improve collection frequency and coverage		✓		
BP3	Reduce time for issuance of solid waste disposal permits	✓		✓	✓
BP4	Increase opening hours of landfills		✓		

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

Performance of the chosen alternatives

In attempting to develop a policy framework to address the issue of solid wastes in the region, it is important to emphasise two issues. Firstly, it is important that this framework is seen in the context of both market failure and government failure. Market failures occur due to the lack of value given to water bodies, the coastal and open seas. These areas are often perceived by the public to be infinite and thus are used as human dumping grounds. Adoption of a valuation and property assignment mechanism to those resources may provide some early pro-active measures. Although the Government has intervened with laws and policies in an attempt to address the issue, they have not resolved the issues which is why an analysis of government failure is also an important part of this analysis.

Secondly, whilst the choice of policy instrument is based on the criteria given in the GIWA methodology for policy option analysis (and many environmental economics text books), there are nevertheless only three decision issues that need to be addressed in a policy design process. These are (i) the choice of the appropriate target to which the policy should be applied - emissions, production, exposure, etc.; (ii) the addressee - an individual, group of companies, the public, etc.; and (iii) the target area - a catchment, village, the EEZ, a regional sea, etc. These issues are discussed where relevant in the analysis but no specific details are provided.

A detailed analysis of each of the types of policy instruments as they apply to the issue is presented on the basis of their effectiveness, efficiency, equity, political feasibility, and implementation capacity. A definition of those criteria is given in the GIWA methodology document.

Root cause 1: Lack of investment planning and priorities

Agency budgets

Allocation of budget resources is always the preferred approach to financing solid waste management. Whilst this may be important in the initial start-up phase, it is important that the costs of solid waste collection are passed in a transparent manner to the polluters. If the government is to pay for solid waste collection, then the public remain ignorant of the real costs, and thus are not inclined to take pro-active measures to reduce the generation of wastes. Although there are situations where the poverty levels are so high that they warrant government intervention, it is important that the financial implications and the benefits are emphasised in awareness programmes.

B3 - This policy option provides the best framework for capitalising on the use of the budget to secure additional funds that may be required at the beginning to obtain solid waste collection and handling equipment. Several banks, including the Asian Development Bank and the World Bank offer soft loans for the establishment of proper sanitary facilities. In Seychelles, the solid waste management plan has been financed jointly from a grant from the Government of Seychelles and the European Union country programme.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
B1	Add/Increase budget allocation for solid waste management				
B2	Shift allocation from another item in the budget to use for solid waste management	✓			
B3	Use budget allocation to raise additional financing for solid waste management	✓		✓	✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

Recommendation: Governments should allocate sufficient budgetary resources for solid waste management and use it for counterpart fund-raising.

Modify framework of economic activity

Solid waste has the potential to provide revenue to government and employment if the national framework is designed accordingly. Often, governments are occupied with such grand schemes that the potential benefits of recycling and reusing solid wastes are sidelined. The two policies that will be considered here show that even in small economies some policy instruments can provide revenue in terms of waste management.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
EC1	Provide the service contract to several operators	✓	✓	✓	✓
EC2	Provide specialised services to only one operator			✓	
EC3	Set the price for purchase of recyclable materials and compost		✓	✓	✓
EC4	Increase employment opportunities	✓	✓		✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

EC1 - This policy option appears conducive, but it promotes a contractual relationship, which does not include conditions for sorting

and recycling of solid wastes. Under this arrangement, there are no incentives to the contractor to minimise on wastes, as more wastes mean more business.

EC 4 - The solid waste service can provide jobs in various areas of integrated solid waste management, from landfill operators, waste collectors and operators of composting plants, sorters and so on. It is important however, that certain occupational health and safety procedures are put in place to safeguard the health of those workers.

Recommendation: Explore opportunities for increasing revenue and employment from solid wastes.

Taxes

Taxes are designed to target the person/organisation responsible for the environmental problem; in this case, the problem of solid wastes. Taxes can be applied on each unit of consumption/emission (for example a tax could be put on plastic bags, to reduce consumption and hence disposal of plastic bags) or tax incentives could be provided to encourage reduction of waste generation (for example no collection taxes should be applicable to companies who keep their solid waste output at 10% of their production output). The rapid screening process identified the following polices as being feasible for implementation in the region:

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
T1	Introduce taxes on consumer products	✓			
T2	Reduce taxes on waste separation & treatment technologies	✓	✓	✓	✓
T3	Tax the disposal of solid wastes by industry	✓	✓		✓
T4	Reduce tax on recycled materials			✓	
T5	Introduce refundable deposits on containers	✓		✓	✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

T1 - Whilst the introduction of taxes on consumer products would have a significant impact on reducing pollution, since most of the population are within poor communities, and consumerism is not peaking, it was felt that this tax would hit the poorest the hardest. In terms of equity, a universal tax would impact in a similar manner both the urban and the rural lifestyles. Political feasibility is also questionable as it implies a general rise in the cost of living, without the public understanding exactly why. The UNDP human development report uses an index called public purchasing power to reflect ability, rather than the traditional GDP figures as a measure of wealth. The vulnerability of small economies also needs to be taken into consideration, as often products are not imported in bulk and therefore do not attract the same prices. Secondly, government already imposes various levels of tax on consumer products to raise finances for government and projects. For example, taxes on consumer products in Seychelles range from 5% (e.g. computers) to 150% (cars), with general consumption products such as food taxed between 10 and 40%, although this has recently been superseded by a General Service Tax (GST) regime. In Mauritius, a VAT system applies in view of progress towards market liberalisation. The implementation capacity to administer a new tax is not considered to be a big issue as the institutional framework is in place for the management of taxes in the region.

T2 - Reduction of taxes on imports of waste treatment technologies was seen as a possible policy option for the region, on the basis of the following arguments: (i) to increase private sector investment in the area of solid waste management, incentives need to be created as such investments are costly; (ii) the tax foregone implies that there will be less waste generated and more wastes being treated cost effectively (cost of treatment of waste may be reduced); and (iii) government can put pressure on industries to comply with existing standards much more easily. The only draw-back with this policy is that it can mainly be applied to the private sector, leaving a large proportion of those who are polluting unregulated. This policy needs to be combined with other polices in order to bring about net benefits to the country. In fact, in the region (and within the international customs harmonised system), there is no separate category for waste minimisation technologies to allow this policy to be implemented easily without high administrative overheads.

T3 - Taxes imposed on industries exceeding permissible limits (calculated based upon their production and a benchmark for waste generation specific to that of industry) can be implemented based on similar reasons given for T2, although the same disadvantages exist in that they are restricted to large companies where administrative costs would be low. Application of the tax to small and medium enterprises and individuals is not feasible in terms of cost-effectiveness and implementation capacity. However, trials in the US, where individuals were given pre-sized containers and they pay according to the number of pre-sized containers used, have been successful in some areas and not in others. Experience shows that the system may cause an increase in illegal dumps or cheating by consumers. Such a policy will also depend upon the environmental awareness of the community to which the policy is being applied (reason why the addressee is an important consideration in policy development).

T4 - A reduction of tax on recycled materials would seem to be a good policy, but the initial screening indicated otherwise because: (i) the levels of recycling are not yet sufficiently high to address the problem adequately, although the benefits are clearly discernible; (ii) recycled products are usually produced inside the country and therefore do not attract a tax per se, but are protected against imports in some countries; (iii) consumer confidence in the quality of recycled products is lacking; and (iv) imported recycled products (such as paper) tend to be more expensive, implying either the production costs are still higher or the demand is still very low on the global market. It is clearly an area where more work needs to be done, so it is recommended that this policy option is modified to reflect more clearly the situation, vis:
T4 (revised) - Implement tax incentives to improve the quality and encourage use of recycled products.

T5 - A refundable system on containers has been tried and has worked in some countries of the region. Refundable deposits require an additional capital (for the deposit fund) and adequate technology to clean and allow the re-use of the container. However, in the case of PET bottles, these can be returned for shredding and recycling into other plastic products. Such a system has two basic advantages: (i) it ensures the waste is returned to the owner who is then responsible for its disposal and, as a consequence, part of the disposal cost is passed on to the consumer, so the polluter pays; and (ii) it saves the cost of sorting waste, as the containers have to be submitted free of other types of rubbish. It is important that the system is not only limited to certain companies or products. A nation-wide audit can yield interesting results. Having a huge proportion of wastes that are based upon the refundable deposit system can reduce the subsequent release of wastes into the marine environment. The refundable deposit should also be sufficiently high to make returning the container after use worthwhile for the consumer.

Recommendations: On the basis of the above critical analysis, the following tax instruments are proposed:

- A national survey of products/wastes that will form part of a refundable deposit system;
- Reduce taxes on waste separation and treatment technologies;
- Tax the disposal of solid wastes by industry;
- Implement tax incentives to improve the quality and encourage use of recycled products.

Subsidies and grants

The adoption of subsidies or grants as a policy option for the management of solid wastes is important for two main reasons: (i) to facilitate transfer of technology; and (ii) to reduce the cost of initiating a solid waste collection/management service. Of the three subsides suggested (Table 27), only one was considered feasible for implementation.

S2 - Introducing subsidies for the municipality is critical to obtaining support from the municipality, but clear deliverables will need to be specified and could be used as indicators such as, collection service once a week, placement of receptacles within 100 m of each household, etc. Provision of subsidies could also be provided to the private sector but only in the case for the introduction of a new solid waste minimisation or treatment technology. This will also offset costs of complying to the standards and ensure rapid implementation.

Recommendation: Subsidies are provided (a) to the municipality to commence a waste collection service, and (b) to the private sector to facilitate investment in waste minimisation/treatment.

Root cause 2: Lack of effective mechanisms, inadequate institutional structure, laws and capacity

Regulations

Regulations have been the traditional approach adopted by governments to address the growing problem of solid wastes, opting to fine those that fail to respect designated areas for solid waste disposal and refuse to make use of the facilities offered. On the other hand, without those facilities, government cannot enforce the law, even though these are in place.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
R1	Establish waste management regulation to address: legally designated areas for solid waste disposal, specific environmental conditions/criteria for siting of landfills, and provide enforcement powers to officers	✓		✓	✓
R2	Adopt new standards for the construction of landfills, leachate discharge, air quality at landfill sites and disposal of solid waste by marine vessels		✓	✓	✓
R3	Identify loopholes in the law to improve on enforcement against littering and dumping of wastes at sea		✓		
R4	Explore more creative means of using the law to ensure compliance with existing laws/standards for solid waste disposal	✓	✓	✓	✓
R5	Improve enforcement capacity through training, more legal powers and redevelop patrol strategy		✓	✓	✓
R6	Improve levels and convictions and reduce court time		✓		

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

R1 - In Madagascar and Comoros, a framework for waste management is definitely required. Such regulations should also make the provision for an environmental impact assessment to be undertaken prior to establishment of the landfill.

R2 - Standards to control emissions from landfills are important to protect landfill workers and to reduce pollution of the surrounding environment. Standards, however, need to be supported by an adequate monitoring programme, something that is lacking in the region, except for Mauritius, which has advanced facilities for pollution monitoring.

R4 - Ironically, exploration of creative legal means is not possible without the involvement of stakeholders. Stakeholder input in the legal development process is often ignored but it can be useful in brainstorming around potential legal problems and in many cases come up with practical, but unorthodox, solutions to impending problems.

R5 - This option is a definite necessity because, without adequate training, cases are usually not prepared very well, and successful prosecutions are rare.

Recommendations:

- Establishment of regulatory framework;
- Development of emissions standards for landfills, etc.;
- Improve compliance through stakeholder involvement;
- Training in legal enforcement.

Modify structure of private rights

The structure of property rights in the island states of the region can be complex, since the islands were colonised by the French and British and, in the case of Comoros, have a strong influence of Islamic customs and laws. In Madagascar and Comoros, traditional precedence occurs, whereas in Mauritius and Seychelles, land tenure is based upon the British system. However, a number of areas are declared as government state land or as "public domain" that is belonging to the state for the enjoyment of the public. These include river banks, wetlands, beaches and the sea. Consequently, solid wastes are most associated with those areas that have been labelled "public domain". So the dilemma is how to use existing land tenure frameworks, which differ across the region to address this problem. A number of options are presented and briefly explored below.

PR3 - Providing a constitutional right to a clean and safe environment is one of the most important activities, especially for small island states. Although this policy may not be entirely feasible in the short-term in some countries, it is important to have it on the agenda as and when the constitution is revised to provide a clear mandate and constitutional stand on issues of environmental rights.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
PR1	Re-assign/modify property rights to assign responsibility for collection of wastes	✓			
PR2	Introduce liability duties to protect against ground water pollution				
PR3	Amend constitution to provide for a right to enjoy a safe and clean environment	✓	✓		✓
PR4	Improve labour law to ensure there are sound occupational health standards for the handling, collection and disposal of solid wastes		✓	✓	✓
PR5	Upgrade corporate and company law to allow companies to use recycled waste materials for their use	✓		✓	✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

PR 4 - Improvements in the quality of life for those who handle solid waste is an important consideration, but that can be considered part of the operational procedures for the waste collection service.

PR 5 - Allowing use of recycled products by the private sector will be an important step forward but will not address the root cause associated with property rights.

Recommendation: Citizens should be given the constitutional right to a clean and safe environment, as well as a clear definition of existing property rights.

Root cause 3: Lack of adequate facilities, services for collection and management of wastes

Provide a service

The provision of consistent and adequate services is the backbone of any successful solid waste management policy. Whatever policies are put in place, solid wastes will still be generated and these will need to be disposed of in the most sustainable manner. Recycling, reuse etc., can occur at local level, but residual wastes will always remain, and those often end up in the environment. For example, on the refundable bottle there is a cap, and since there is no refund for the bottle caps in Seychelles, they end up at the beaches. A bottle-top competition was organised in 1994/1995 which resulted in the collection of more than 500 000 bottle tops.

P1 - Following establishment of the municipal waste service, opportunities to extend the service to rural areas must be explored. This

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
P1	Introduce a waste collection service to cover the entire country, or add to an existing service to cover other towns	✓	✓		✓
P2	Improve public use of the service by conducting outreach events		✓	✓	✓
P3	Improve relationship among all service providers within the sector to keep costs down and increase efficiency	✓	✓		✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

could be done through public-private sector initiatives with financial support from the central government. In providing funds for the waste collection service, one should weigh the costs of return on tourism and the cost of solid waste management.

Recommendation: Put in place an efficient solid waste collection system for the municipalities in the first instance with plans to extend the service to rural areas of the country.

Root cause 4: Lack of education and awareness

Information

Information forms the basis of any policy development, and without adequate information policy alternatives cannot be adequately considered. This report identified a number of areas where data is lacking.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
I1	Monitoring and information sharing	✓	✓		✓
I2	Collection of data on waste consumption, disposal (by type and source)	✓	✓		✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

I1 and I2 - Having in place a solid waste collection, disposal and performance of the landfill is important for policy and technical reasons. Sharing of information is a requirement, especially when all stakeholders including the private sector are becoming involved in this new type of business. The cost of implementing this policy can be rather long-term as the impacts of awareness campaigns are not immediately noticeable.

Education and consultation

This is neither a cost-effective nor efficient policy, but is needed to ensure long-term involvement of stakeholders in maintaining the solid waste management system. Whilst the initial stage of a management system may include collection of wastes in a mixed state, later developments in the service would require the public to start sorting their waste into plastic, paper and glass. Without proper education this is unlikely to be successful. For example, in Seychelles, individual waste sorting schemes are being pilot tested in one small village before the initiative is launched nationwide. Piloting will allow lessons to be learned and also gauges public response to the new approach.

	Policy options	Evaluation			
		Eff	Eq	Pr	FPO
ED1	Education campaign to inform consumers about littering, accumulation of solid waste stockpiles along the road			✓	
ED2	Consultation activities to obtain citizen views to improve service		✓	✓	✓
ED3	Develop a series of guidelines for the management of solid wastes	✓	✓	✓	✓
ED4	Training and capacity building programme	✓		✓	✓

Note: Eff = economic efficiency; Eq = equitability; Pr = practicality; FPO = Favourable Policy Option; ✓ = fits policy criteria; blank = does not fit policy criteria.

Recommendation: Put in place an education programme to increase awareness and action.

Conclusions and recommendations

In order to develop a policy framework to address one of the most serious international waters issue in the Indian Ocean Islands region, the four step GIWA assessment process was adopted. Each of these steps provided a series of insights into the main issues within the region. Most importantly, the report concluded that in contrast to many other regions, the Indian Ocean Islands region is characterised by one large island and three small islands, each having very large Exclusive Economic Zones. Although the catchments and flood plains are very small, the impact of activities on those islands are considered to be alarming, especially within the coastal and shallow marine environment.

The impact assessment showed that the levels of human impacts on natural systems and resources have increased. Impacts of global change, such as coastal erosion and coral bleaching, seem to be the biggest threat to development in the region. The assessment, however, concluded that Pollution is the most significant GIWA concern for the Indian Ocean Islands region, followed by Global Change. The improper disposal of solid wastes and eutrophication as a result of poor treatment facilities were identified as the most severe issues. The risk of oil spills is also considered to be an important issue for the region, since it is located within an area of high tanker traffic. Other issues, such as overexploitation of fish and habitat modification, also received attention, implying that those impacts are very much linked to the presence of humans.

The causal chain analysis resulted in the identification of four root causes:

- Lack of investment planning and priorities;
- Lack of effective mechanisms, inadequate institutional structure, laws and capacity;
- Lack of adequate facilities, services for collection and management of wastes;
- Lack of education and awareness.

Data presented in the causal chain analysis describes the volumes of uncollected solid waste in each of the four countries within the Indian Ocean Islands region and illustrates the transboundary implications of solid waste dispersal once it ends up in the sea.

The policy analysis resulted in more than 30 possible policy options but when these were evaluated in their regional context for efficiency, equitability, and practicality, some were rejected. Further analysis of the selected policy options generated a series of recommendations as key output of this report. These recommendations are:

1. **To perform a national survey of products/wastes that will form part of a refundable deposit system.**
2. **Reduce taxes on waste separation and treatment technologies.**
3. **Tax the disposal of solid wastes by industry.**
4. **Implement tax incentives to improve the quality and encourage use of recycled products.**
5. **Subsidies are provided (a) to the municipality to commence a waste collection service, and (b) to the private sector to facilitate investment in waste minimisation/treatment.**
6. **Establishment of a regulatory framework.**
7. **Development of emissions standards for landfills, etc.**
8. **Improve compliance through stakeholder involvement.**
9. **Training in legal enforcement.**
10. **Put in place an efficient solid waste collection service of the entire territory.**
11. **Governments should allocate a sizeable proportion of their national budget for solid waste management and use that for counterpart fund-raising.**
12. **Citizens should be given a constitutional right to a clean and safe environment, as well as a clear definition of existing property rights.**
13. **Explore opportunities for increasing revenue and employment from solid wastes.**

14. Establish an education programme to increase awareness and action.

In conclusion, it is important to highlight the various knowledge and research gaps which may need to be tackled in another programme. These include:

- Lack of long-term assessment data;
- No information on the status of certain marine mammals and reptiles;
- Socio-economic information is not within easy access.

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Annexes

Annex I
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Annex II
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	50
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Economic impacts		**2.00**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Health impacts		**1.20**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	2	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Other social and community impacts		**1.40**	

II: Pollution

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
4. Microbiological	1	10	Pollution	1.65
5. Eutrophication	2	20		
6. Chemical	1	5		
7. Suspended solids	1	20		
8. Solid wastes	2	25		
9. Thermal	0	0		
10. Radionuclide	0	0		
11. Spills	2	20		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	30
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight average score for Economic impacts		**2.40**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	30
Degree of severity	Minimum – Severe 0 1 2 3	3	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight average score for Health impacts		**2.40**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	30
Degree of severity	Minimum – Severe 0 1 2 3	1	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	40
Weight average score for Other social and community impacts		**1.70**	

III: Habitat and community modification

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
12. Loss of ecosystems	1.25	60	Habitat and Community Modification	1.45
13.Modification of ecosystems or ecotones, including community structure and/or species composition	1.75	40		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	3	40
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight average score for Economic impacts		**2.40**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	40
Degree of severity	Minimum – Severe 0 1 2 3	1	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight average score for Health impacts		**1.70**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	3	40
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight average score for Other social and community impacts		**2.40**	

IV: Unsustainable exploitation of fish

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
14. Overexploitation	2.5	25	Unsustainable exploitation of fish	1.59
15. Excessive by-catch and discards	0.75	5		
16. Destructive fishing practices	1.75	30		
17. Decreased viability of stock through pollution and disease	0.75	20		
18. Impact on biological and genetic diversity	1.25	20		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	40
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Economic impacts		**2.00**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	30
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	30
Weight average score for Health impacts		**1.00**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	30
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	30
Weight average score for Other social and community impacts		**1.00**	

V: Global change

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
19. Changes in the hydrological cycle	1	20	Global Change	1.20
20. Sea level change	2	40		
21. Increase UV-B radiation as a result of ozone depletion	0	20		
22. Changes in ocean CO_2 source/sink function	1	20		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	3	50
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Economic impacts		**2.30**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	50
Degree of severity	Minimum – Severe 0 1 2 3	0	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Health impacts		**0.70**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	30
Degree of severity	Minimum – Severe 0 1 2 3	2	50
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Other social and community impacts		**1.80**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.5	2	2	2	1.2	1	1.4	2	**1.6**
Pollution	1.7	2	2.4	2	2.4	2	1.7	1	**1.9**
Habitat and community modification	1.5	2	2.4	2	1.7	1	2.4	2	**1.9**
Unsustainable exploitation of fish and other living resources	1.6	3	2	2	1	2	1	1	**1.7**
Global change	1.2	3	2.3	3	0.7	1	1.8	3	**2**

If the results in this table were not giving a clear prioritisation, the scores were weighted by assigning different relative importance to present/future and environmental/socio-economic impacts in the following way:

Weight averaged environmental and socio-economic impacts of each GIWA concern

Present (%) (i)	Future (%) (j)	Total (%)
60	40	100

Environmental (k)	Economic (l)	Health (m)	Other social and community impacts (n)	Total (%)
40	20	20	20	100

Concern	Types of impacts					Rank
	Time weight averaged Environmental score (o)	Time weight averaged Economic score (p)	Time weight averaged Human health score (q)	Time weight averaged Social and community score (r)	Time weight averaged overall score	
	(a)x(i)+(b)x(j)	(c)x(i)+(d)x(j)	(e)x(i)+(f)x(j)	(g)x(i)+(h)x(j)	(o)x(k)+(p)x(l)+(q)x(m)+(r)x(n)	
Freshwater shortage	1.7	2	1.12	1.64	1.63	**5**
Pollution	1.82	2.24	2.24	1.42	1.91	**1**
Habitat and community modification	1.7	2.24	1.42	2.24	1.86	**3**
Unsustainable exploitation of fish and other living resources	2.16	2	1.4	1	1.74	**4**
Global change	1.92	2.58	0.82	2.28	1.90	**2**

Annex III
List of important water-related programmes and assessments in the region

Country	Project Name	Region	Focal Area	Agency	Project Type	Cost (million USD)	Donor
Regional	Addressing Land-based Activities in the Western Indian Ocean (WIO-LaB)	AFR	International Waters	UNEP	Full Size Project	4.511	GEF
Regional	Coral Reef Monitoring Network in Member States of the Indian Ocean Commission (COI), within the Global Reef Monitoring Network (GCRMN)	AFR	Biodiversity	IBRD/COI	Medium Size Project	0.737	GEF
Regional	Western Indian Ocean Islands Oil Spill Contingency Planning	AFR	International Waters	IBRD/COI	Full Size Project	3.164	GEF
Regional (Excluding Madagascar)	Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa	AFR	International Waters	UNEP/ACOPS	Medium Size Project	0.750	GEF
Regional (Excl. Madagascar, Comoros)	Reduction of Environmental Impact from Coastal Tourism through Introduction of Policy Changes and Strengthening Public-Private Partnerships	AFR	International Waters	UNEP	Full Size Project	5.000	GEF (in pipeline)
Regional (excluding Mauritius & Seychelles)	Southwest Indian Ocean Fisheries Project (SIOFP)	AFR	International Waters	IBRD	Full Size Project	6.350	GEF (drafting)
Regional (Excl. Seychelles, Comoros, Mauritius)	Institutional Strengthening and Resource Mobilization for Mainstreaming Integrated Land and Water Management Approaches into Development Programs in Africa	AFR	Multiple Focal Areas	IBRD	Medium Size Project	1.000	GEF
Global (Excl. Seychelles, Comoros, Mauritius)	Biodiversity Country Studies - Phase II	CEX	Biodiversity	UNEP	Enabling Activity	2.000	GEF

(Source: http://www.gefonline.org/projectList.cfm)

Annex IV
List of conventions that affect water use in the region

No.	Convention	Comoros	Madagascar	Mauritius	Seychelles
1.	The Nairobi Convention 1985 and Protocols	✓	✓	✓	✓
2.	The Arusha Resolution 1993		✓	✓	✓
3.	Convention on Biological Diversity	✓	✓	✓	✓
4.	UN Framework Convention on Climate change.	✓	✓	✓	✓
5.	UN Law of the Sea Convention	✓	✓	✓	✓
6.	The Ramsar Convention on Wetlands	✓	✓	✓	
7.	International Convention for the Prevention of Pollution from Ship (MARPOL)			✓	✓
9.	The Bamako Convention on the Ban of the import into Africa and the control of Transboundary movement and Management of Hazardous Waste within Africa.			✓	
10.	Basel Convention on the control of Transboundary movement of hazardous wastes and their disposal.	✓			✓

(Note: Data as at 1st March 1999)

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Indian Ocean Islands. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and

policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF".*

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: "*GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference*".

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

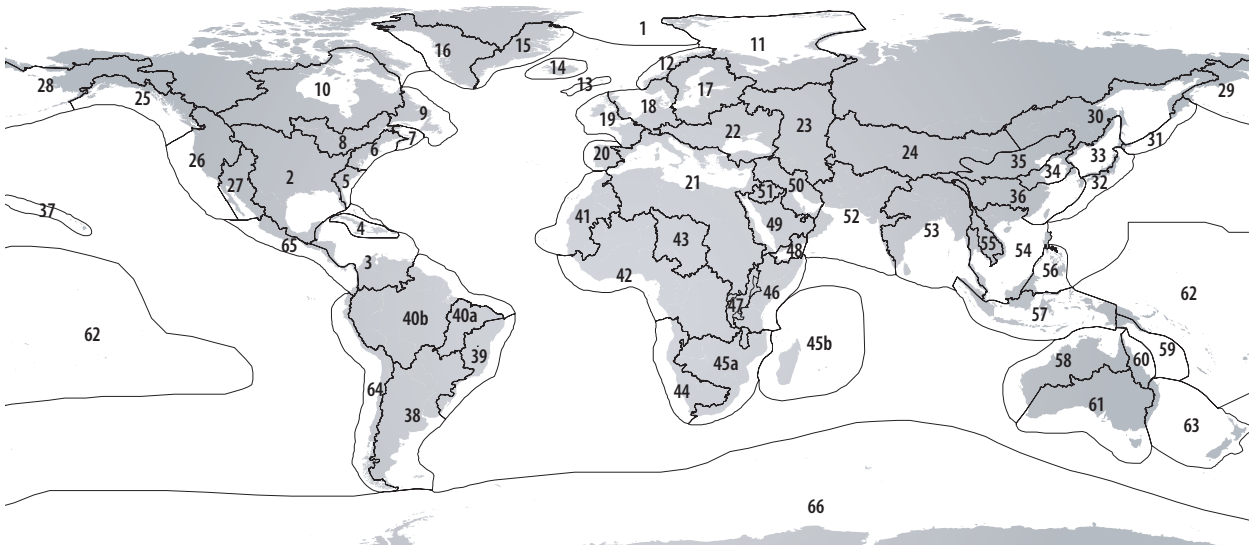
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1	*Arctic*	12	*Norwegian Sea (LME)*	24	*Aral Sea*	36	*East-China Sea (LME)*	46	*Somali Coastal Current (LME)*	58	*North Australian Shelf (LME)*
2	*Gulf of Mexico (LME)*	13	*Faroe plateau*	25	*Gulf of Alaska (LME)*	37	*Hawaiian Archipelago (LME)*	47	*East African Rift Valley Lakes*	59	*Coral Sea Basin*
3	*Caribbean Sea (LME)*	14	*Iceland Shelf (LME)*	26	*California Current (LME)*	38	*Patagonian Shelf (LME)*	48	*Gulf of Aden*	60	*Great Barrier Reef (LME)*
4	*Caribbean Islands*	15	*East Greenland Shelf (LME)*	27	*Gulf of California (LME)*	39	*Brazil Current (LME)*	49	*Red Sea (LME)*	61	*Great Australian Bight*
5	*Southeast Shelf (LME)*	16	*West Greenland Shelf (LME)*	28	*East Bering Sea (LME)*	40a	*Brazilian Northeast (LME)*	50	*The Gulf*	62	*Small Island States*
6	*Northeast Shelf (LME)*	17	*Baltic Sea (LME)*	29	*West Bering Sea (LME)*	40b	*Amazon*	51	*Jordan*	63	*Tasman Sea*
7	*Scotian Shelf (LME)*	18	*North Sea (LME)*	30	*Sea of Okhotsk (LME)*	41	*Canary Current (LME)*	52	*Arabian Sea (LME)*	64	*Humboldt Current (LME)*
8	*Gulf of St Lawrence*	19	*Celtic-Biscay Shelf (LME)*	31	*Oyashio Current (LME)*	42	*Guinea Current (LME)*	53	*Bay of Bengal S.E.*	65	*Eastern Equatorial Pacific*
9	*Newfoundland Shelf (LME)*	20	*Iberian Coastal (LME)*	32	*Kuroshio Current (LME)*	43	*Lake Chad*	54	*South China Sea (LME)*	66	*Antarctic (LME)*
10	*Baffin Bay, Labrador Sea, Canadian Archipelago*	21	*Mediterranean Sea (LME)*	33	*Sea of Japan/East Sea (LME)*	44	*Benguela Current (LME)*	55	*Mekong River*		
		22	*Black Sea (LME)*	34	*Yellow Sea (LME)*	45a	*Agulhas Current (LME)*	56	*Sulu-Celebes Sea (LME)*		
11	*Barents Sea (LME)*	23	*Caspian Sea*	35	*Bohai Sea*	45b	*Indian Ocean Islands*	57	*Indonesian Seas (LME)*		

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

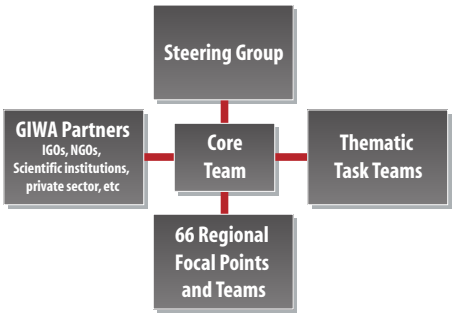


Figure 2 The organisation of the GIWA project.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO_2 source/sink function	**V Global change**

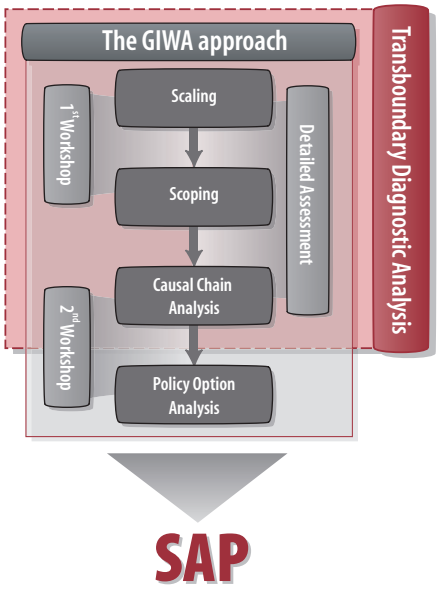

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the

results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.*" The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern.
In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small — Very large 0 1 2 3	2	50
Degree of severity	Minimum — Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short — Continuous 0 1 2 3	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

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Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/ suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of all the world's transboundary waters that recognises the inextricable links between freshwater and coastal marine environment and integrates environmental and socio-economic information to determine the impacts of a broad suite of influences on the world's aquatic environment.

Broad Transboundary Approach

The GIWA not only assesses the problems caused by human activities manifested by the physical movement of transboundary waters, but also the impacts of other non-hydrological influences that determine how humans use transboundary waters.

Regional Assessment - Global Perspective

The GIWA provides a global perspective of the world's transboundary waters by assessing 66 regions that encompass all major drainage basins and adjacent large marine ecosystems. The GIWA Assessment of each region incorporates information and expertise from all countries sharing the transboundary water resources.

Global Comparability

In each region, the assessment focuses on 5 broad concerns that are comprised of 22 specific water related issues.

Integration of Information and Ecosystems

The GIWA recognises the inextricable links between freshwater and coastal marine environment and assesses them together as one integrated unit.

The GIWA recognises that the integration of socio-economic and environmental information and expertise is essential to obtain a holistic picture of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

The GIWA indicates priority concerns in each region, determines their societal root causes and develops options to mitigate the impacts of those concerns in the future.

This Report

This report presents the assessment of the Indian Ocean Islands, one of two oceanic assessments conducted by the GIWA. The region covers the Island States of Comoros, Mauritius, Madagascar and Seychelles and the vast oceanic expanses between them. The most important transboundary concern is pollution, particularly solid wastes, which end up in the coastal and oceanic environments causing degradation of ecosystems and considerable economic impacts. Policy options to address the root causes of solid waste pollution are presented and their efficiency, equitability and practicality are discussed.