Assessment

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 7.

Table 7 Scoring tables for the Benguela Current region.

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

IMPACT 0 No known impact · IMPACT 1 Slight impact · IMPACT 2 Moderate impact · IMPACT 3 Severe impact

The arrow indicates the likely direction of future changes. ↗ Increased impact · → No changes · ↘ Decreased impact

Benguela Current – Freshwater component

Benguela Current Freshwater component	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	3* ↗	3 ↗	2 ↘	2 ↗	2.5	1
Modification of stream flow	3					
Pollution of existing supplies	3					
Changes in the water table	3					
Pollution	3* ↗	3 ↗	2 →	1 ↗	2.5	2
Microbiological pollution	3					
Eutrophication	3					
Chemical	3					
Suspended solids	2					
Solid waste	3					
Thermal	1					
Radionuclides	3					
Spills	3					
Habitat and community modification	3* ↗	2 ↗	2 ↗	2 ↗	2.4	2
Loss of ecosystems	3					
Modification of ecosystems	3					
Global change	2* ↗	0 ↗	1 ↗	0 ↗	1.4	2
Changes in hydrological cycle	2					
Sea level change	-					
Increased UV-B radiation	2					
Changes in ocean CO_2 source/sink function	-					

Benguela Current – Marine component

Benguela Current Marine component	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Pollution	2* ↗	3 ↗	2 →	1 ↗	2.3	2
Microbiological pollution	2					
Eutrophication	1					
Chemical	1					
Suspended solids	2					
Solid waste	2					
Thermal	1					
Radionuclides	1					
Spills	3					
Habitat and community modification	2* ↗	2 ↗	2 ↗	2 ↗	2.3	2
Loss of ecosystems	1					
Modification of ecosystems	2					
Unsustainable exploitation of fish	2* ↗	2 ↗	2 →	2 ↗	2.1	1
Overexploitation	3					
Excessive by-catch and discards	1					
Destructive fishing practices	2					
Decreased viability of stock	0					
Impact on biological and genetic diversity	2					
Global change	1* ↗	0 ↗	1 ↗	0 ↗	1.3	2
Changes in hydrological cycle	2					
Sea level change	1					
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.

** This value represents the overall score including environmental, socio-economic and likely future impacts.

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

The enormous diversity of the Benguela Current region adds an additional level of complexity to an assessment which attempts to provide a general view for the region as a whole. No justification could be found for treating any of the transboundary aquatic systems identified as systems entirely discrete from the other transboundary aquatic systems of the region. The assessment for the Benguela Current region was thus conducted on the entire region. This did serve to create some confusion within the assessment process, and the impacts of an issue would often be entirely opposite within the two different aquatic components (freshwater and marine systems) of the region, or would vary enormously from place to place. The GIWA guidance of presenting the worst case scenario for an issue was used throughout the assessment. In many cases, of course, the worst case scenario does not necessarily hold true for the entire region. Under these circumstances, justification has been provided for the worst case scenario without necessarily indicating every example in which this does not hold true. In order to illustrate this, an assessment of severe pollution from spills into the marine environment, for example, does not indicate that the entire marine environment of the region is permanently covered in oil pollution. It does, however, indicate that the environmental, economic, health and social impacts of spills, which may vary temporally and spatially within the region, are severe.

The large differences in the environmental and socio-economic issues occurring in marine and freshwater environments in the Benguela Current region lead to the concerns of Pollution, Habitat modification and Global change being assessed separately for these environments. Since freshwater fisheries are not highly significant in the region, these were omitted, and the assessments are thus only concerned with unsustainable exploitation of marine living resources.

Freshwater shortage

Freshwater component

The climate over much of southern Africa ranges from semi-arid to hyper-arid with only a few relatively humid parts where rainfall greatly exceeds 500 mm annually (Davies & Day 1998). Over the Benguela Current region evaporation is high, exceeding the limited and highly variable rainfall (Table 8). The naturally low and variable rainfall, together with the water demand of an increasing population and the related demand for freshwater caused by industrialisation, agriculture and urbanisation has led to radical modifications of available surface and groundwater in the form of impoundments, abstraction and inter-basin transfers. This has caused dramatic changes to the flow and flood regimes of many rivers in the region and their related estuaries. The coast is also strongly influenced by the rivers that bring water, sediments, nutrients and pollutants to the coast. One of the most important threats to estuaries is the reduction of freshwater inflow as the result of the construction of dams and direct abstraction of water.

Table 8 Rainfall and evaporation in the Benguela Current region.

Country	Rainfall (mm/year)		Evaporation (mm/year)	Deficit/Gain (mm/year)
	Average	Range		
Angola	800	25-1 600	1 300-2 600	-1 275 to -1 000
Lesotho	700	500-2 000	1 800-2 100	-1 300 to -100
Namibia	250	10-700	2 600-3 700	-3 000 to -2 590
South Africa	500	50-3 000	1 100-3 000	-1 050 to 0

Note: Deficit/Gain indicates the discrepancy between rainfall and evaporation. Please note that these figures are for entire countries, not only for the portions of these countries falling within the Benguela Current region.

(Source: Snaddon et al. 1999)

Total water available in South Africa equates to about 50 km^3/year, approximately 10% of the water reserves of the southern African region. Currently, about 84% of total available water is in use (Table 9) (Snaddon et al. 1999, Conley 1995). The annual water deficit may reach an estimated 1 050 mm/year (Heyns et al. 1994, Snaddon et al. 1999). There is a high inter-annual variability in rainfall (Davies & Day 1998). In Namibia, total water available equates to about 9 km^3/year, approximately 2% of the southern African total (Snaddon et al. 1999,

Table 9 Water availability and consumption in the southern African countries.

Country	Total water available (million m^3)	Share of southern African water (%)	Total water use (million m^3/year)	Share of total available water used (%)
Angola *	158 000	32	480	2
Zambia	96 000	19	360	2
Tanzania	76 000	15	480	2
Mozambique	58 000	11	760	3
South Africa *	50 000	10	19 040	84
Zimbabwe	23 000	5	1 220	5
Namibia *	9 000	2	ND	ND
Botswana	9 000	2	90	<1
Malawi	9 000	2	160	1
Swaziland	7 000	1	ND	ND
Lesotho *	4 000	1	50	<1
Total	499 000	100	22 640	100

Notes: ND = No Data.
** Countries within the Benguela Current region. Please note that these figures are for entire countries, not only for those portions falling within the Benguela Current region.*

(Source: Snaddon et al. 1999)

Conley 1995). Evaporation is high and Namibia's Eastern National Water Carrier, for example, which is an open canal (Omatako Canal Inter-basin Transfer) evaporates 70% of water in transit (Petitjean & Davies 1988). The resultant water deficit due to evaporative losses for this country is in the region of 2 590 to 3 000 mm/year (Heyns et al. 1994, Snaddon et al. 1999). The only permanent rivers of Namibia which fall within the Benguela Current region are the Cunene River (north) and the Orange River (south), both of which are transnational boundaries. The remaining rivers are all ephemeral. There is thus a strong reliance on groundwater and inter-basin transfers. Reservoirs suffer vast evaporative losses (Agula 2002). Namibia's water supply can thus be considered critical. Major damage has been done to ephemeral rivers of Namibia (Heyns et al. 1988, Jacobsen et al. 1995). The largest sectoral water user in Namibia is irrigation (Table 10).

Table 10 Water use by sector in Namibia.

Sector	Water use (%)
Irrigation	49
Urban (all inclusive)	24
Livestock	15
Mining	7
Rural domestic	5
Wildlife and tourism	<1

(Source: International Rivers Network 2004)

Total water available in Angola is about 158 km^3/year, approximately 32% of the total water available in southern Africa. The proportion of total available water in use is about 2% (Conley 1995, Snaddon et al. 1999). Water deficit due to evaporative losses is in the region of 1 000 to 1 275 mm/year (Heyns et al. 1994, Snaddon et al. 1999). Total water available in Lesotho is estimated at 4 km^3/year, roughly 1% of southern Africa's available water. Total annual water usage is approximately 0.2% of the total available (Conley 1995, Snaddon et al. 1999). Evaporation exceeds rainfall, leading to a water deficit of between 100 and 1 300 mm/year (Heyns et al. 1994, Snaddon et al. 1999).

Environmental impacts

Modification of stream flow

The environmental impacts of modification of stream flow are assessed as severe in the region. Many rivers in the region are modified by impoundments and many are overabstracted, resulting in a significant decrease in river flow. Up to a 75% reduction in stream flow has been recorded, this being in the Berg River, one of the few permanently open estuaries in the region (Berg 1993). The key river systems of transboundary significance in the region include the Orange-Vaal system, Berg River, Olifants River, Cunene River and Cuanza River. A brief description of the extent to which each has been modified (with the exception of the Cuanza River) is provided below.

Orange-Vaal system

The Orange-Vaal drainage basin is 1 million km^2 (Department of Water Affairs and Forestry 2005) and by far the largest catchment in the region. A clear trend of decreasing flow has been shown in the Orange River between 1935 and 1997 such that annual flow gaugings towards the end of this period are less than 50% of those at the beginning of this time series (Department of Environmental Affairs and Tourism 2000). In the Orange-Vaal drainage system flows are modified by turbines of Van Der Kloof Dam (originally PK Le Roux Dam) to the extent that seasonal differences of flow entering Gariep Reservoir (originally HF Verwoerd Dam) upstream are nullified (54% in summer, 46% in winter) (Cambray et al. 1986, Davies & Bergh 1999). The Vaal River has 16 major dams, while inter-basin transfer schemes from the Orange River (Senqu, Senquenyane and Malibamatso in Lesotho), Tugela, Usutu and Komati augment the supply to this river. Water is also exported from the Vaal River through inter-basin transfers to the Limpopo, Olifants and Komati rivers. Together with the Orange River the Vaal River is the most modified river in the Southern African Development Community (SADC) region (Braune & Rogers 1987).

In the Vaal system in the late 1980s, the return flows from the urban/industrial sector were already 55% of supply, thereby exceeding the natural mean annual run-off of 300 million m3/year (Braune & Rogers 1987). Drought in the early 1980s led to construction of pump/barrages reversing the flow of the Vaal River. These barrages washed away during later floods. This scheme was known as the Grootdraai Emergency Augmentation Scheme (1983). Completed in 20 weeks, it involved seven earth compacted weirs and pumps, and covered 208 km of reversed flow to Grootdraai Dam. In 1987 an additional pipeline was constructed for emergency supplies of coolant water to coal-fired power stations in Gauteng (Department of Water Affairs and Forestry 1991).

Inter-basin transfers from the headwaters of the Orange River in Lesotho to the Vaal River will reduce the yield of the Orange River Project (inter-basin transfer from Lake Gariep to the Fish and Sundays rivers in the Eastern Cape) by more than 1.5 km^3/year, whilst doubling the yield of the Vaal River (Davies et al. 1993). Completion of the Lesotho Highlands Water Project will result in 75% of the water in the Vaal River being derived from other catchments (Snaddon et al. 1999). The Orange-Vaal system contributes 22% of South Africa's water resources, but has no overarching basin authority (Cambray et al. 1986, Davies & Bergh 1999).

Berg River

Historical flow figures for the Berg River for 1928 to 1988 show periods of reductions in stream flow return of >75% due to human abstractions.

The Berg River had a mean annual run-off to the estuary of 903 million m^3/year compared to the present day figure of 693 million m^3/year, which represents a 23% mean annual reduction. Flows in all months are affected, but summer losses are particularly significant for the biota (Berg 1993, Ninham Shand Inc. 1992). The previously mobile Berg River Estuary Mouth was moved and hardened in 1966, changing tidal amplitude and resulting in higher seawater intrusion onto the floodplain. Impoundments prolong river low flows, increasing salinity intrusion and reducing sediment dynamics. The planned Skuifraam Dam will reduce flushing and scouring, and lead to possible closure of the mouth (Huizinga et al. 1993, Morant et al. 1997). Berg River floodplain vegetation includes 10 different communities, including five marsh types, two distinct pan communities, and three floodplain communities. It represents a unique system between southern Angola and St Lucia in KwaZulu-Natal on the east coast of South Africa. Impoundment and mouth entrainment are considered to be the most serious threats to the community structure (McDowell 1993).

Berg River Estuary benthic invertebrate communities have decreased over the past 40 years. Major contributing factors and threats include reduced flows, increased desiccation, increased salinities due to impoundment and mouth entrainment, and possibly pollution (Hockey 1993). The Berg River estuarine fish communities contain 77% of total coastal species (compared to 49-52% for other coastal areas). The Berg River has a higher percentage of residents (23% versus 4-18%), dependent species (27% versus 9-25%) and partially dependent species (30% versus 18-27%) than other estuaries in the region. Flow reduction in this system will have more impact on coastal fisheries than anywhere else in South Africa. The Berg River is one of only two permanently open estuarine nursery areas in the Namaqua Marine Biogeographical Province (Bennett 1993). An important sports fishery is developing on the estuary, but the commercial fishery is overexploited. This, together with increased salinity through reduced flows, makes the industry no longer viable (Schrauwen 1993). 127 species of birds have been recorded in the Berg River wetlands since 1975. In terms of regional importance, the Berg River floodplain rates second, only slightly lower than Walvis Bay, but above Langebaan Lagoon and St Lucia (KwaZulu-Natal, South Africa). In 1992, bird populations on the estuary were estimated to number 46 000 individuals, including individuals from five IUCN Red Data species.

Olifants River

The Olifants River drains a catchment of about 45 600 km^2 making it the second largest river on the South African west coast. It is one of the few perennial rivers in the arid western parts of South Africa. The Olifants River and estuary seldom dry up and therefore form one of the few perennial, calm waters areas in the region. The river itself has been highlighted as a hotspot of freshwater fish diversity in South Africa (Skelton 1993). It supports 10 indigenous fish species of which eight are endemic to the system. Intensification of agricultural activity in the catchment has precipitated alteration to the flow regime of the river though, and to some geomorphological degradation. These effects, as well as those caused by populations of alien fish being introduced into the catchment in the 1930s and 1940s, have been implicated in the serious decline evident amongst indigenous fish species in the Olifants River. The spread of alien fish is assisted by dams that have been constructed in the mainstream of the river (Impson 1997). The dams represent impassable barriers to the migration of fish, and have substantially increased the proportion of lentic and lotic conditions in the river, and altered the flow regime of the downstream reaches.

Cunene River

The Cunene River is about 1 000 km long and has a drainage basin of about 106 500 km^2. The surrounding environment of the river is characterised by a dry climate, low rainfall, low annual run-off and low sediment production. The river itself is already highly regulated through various dams and weirs including the Gove Dam (completed in 1973), the Matala weir (completed in 1954), the Calueque weir (completed in 1977) and the Ruacana hydropower station (completed in 1979). The Gove Dam was built with the purpose of downstream river regulation but has long since been in-operational because of war damages. The daily flow regime of the river has been substantially modified as a result of the Ruacana diversion weir and water abstraction, causing daily water level fluctuations of 30 to 40 cm at Epupa. Another scheme has been proposed for the lower portion of the river, the Lower Cunene Hydropower Scheme, and in spite of strong environmental opposition may still come into being (Members of the GIWA Task team pers. comm.). Very little development exists in the Cunene catchment, and the water is thus of exceptionally good quality.

The Cunene River has a diverse freshwater fish fauna consisting of 64 species, seven of which are endemic to this system. The Ruacana and Epupa Falls form large physical obstructions but do not restrict the distribution of species. Despite the alterations to the flow regime, sensitive fish species are still maintained, and the natural flow-related processes are still regarded as intact (NAMANG Consortium 1998). A total of 379 bird species are recorded in the Lower Cunene, of which 62 are listed as IUCN Red Data species. The majority of these are breeding residents (62%).

Pollution of existing supplies

Of the three countries which make up the bulk of the region, South Africa is by far the largest contributor to overall organic water pollution.

However, when this figure is converted to kilograms of emissions per worker per day, the highest figure is attributed to Namibia (World Bank 2001). Other pollution problems in the region's freshwater systems include chemical pollution, solid waste, radionuclide pollution and spills. In the region as a whole, pollution of existing freshwater resources is considered severe.

The Vaal River in South Africa has severe pollution and eutropication problems. The problems stem from agricultural (155 000 ha under irrigation in 1975 which equates to 42% of South African total agricultural production), urban (sewage effluent; 42% of population in 1975) and mining (79% of mining production in 1975) return flows (Braune & Rogers 1987). Of the return flows to the Vaal Barrage (37 000 m^3/day in the 1980s), about 75% is sewage effluent, 11% from industry, and 14% mining effluent (Oliveira 1986).

In the early 1980s mine discharges to the Vaal River amounted to an average of 60 000 m^3/day (Oliveira 1986). Intense mining in the Vaal catchment has lead to salinities of 75 to 500 mS/m (Van Vliet 1986, Viljoen & Van der Merwe 1986). Northern tributaries of the Vaal River have elevated total dissolved solids (>500 mg/l) predominantly from Sulphate (SO_4), Sodium (Na) and Chlorine (Cl) (Van Vliet 1986). Sulphuric acid pollution is also evident in the Vaal drainage basin from acid mine run-off (Harrison 1958, Davies et al. 1993).

Impoundment of the Vaal River, eutrophication and injection of reservoir plankton has led to significant increases in pest blackfly species (Simuliidae) to epidemic proportions (Chutter 1963, 1967, 1968, De Moor 1982, 1986). Blindness in sheep (*Chlamydia* sp., protoctistan parasite) and Rift Valley Fever (viral) are diseases commonly spread by blackflies (De Moor 1986). DDT used in the Vaal River to control epidemic outbreaks during the 1960s led to eradication of the indigenous insect fauna and rapid recolonisation by blackfly larvae after use (Howell & Holmes 1969).

Changes in the water table

Impacts related to changes in the water table are considered severe in the Benguela Current region. The problem revolves primarily around the use of fossil waters, which have long replenishment times. Overabstraction of aquifers, together with decreased base-flow of rivers to replenish supplies has resulted in exhaustion of aquifers and subsequent salinisation.

Overabstraction of aquifers is particularly concerning in Namibia. A good example can be found in the Karstveld Borehole Scheme (associated with the Eastern National Water Carrier inter-basin transfer scheme), where the water table has dropped from between 0 and 5 m to between 10 and 11 m below river bed level (Petitjean & Davies 1988, Snaddon et al. 1999). Of further concern is the fact that ephemeral rivers and groundwater support 50% of Namibia's population across 80% of the country, placing enormous stress on water tables (Heyns et al. 1988).

South Africa had an estimated 197 810 existing boreholes in 1999 (Department of Environmental Affairs and Tourism 2000). An additional 50 000 are estimated to be drilled annually, although the majority of these yield little or no water (Department of Environmental Affairs and Tourism 2000). Extraction of groundwater has increased from an estimated 1.8 to 2.0 km^3/year in the past 20 years, with irrigation agriculture accounting for approximately 78% of this usage (Department of Environmental Affairs and Tourism 2000). The cumulative impacts of the extraction of groundwater can only be guessed at, although groundwater failure has been known to occur in some areas (Basson et al. 1997)

Socio-economic impacts

Economic impacts

Most sectors are affected by freshwater shortages, including agriculture, mining, fishing, and tourism, in an area which is already water-stressed. The economic impacts of this concern are therefore considered severe by the GIWA experts. The costs of building dams, inter-basin transfer schemes, alternative water sources (especially desalination plants), and water treatment are high. There is a mismatch between the geography of supply and demand, which creates additional costs. In addition, in the more arid parts of the region there is a mismatch between peak demand and supply (e.g. the major tourist season coincides with the driest time of year).

The major economic impacts of modification of stream flow are the costs associated with the construction of dams and inter-basin transfer schemes to supply water. The costs of alternative sources of water (especially by desalination) are also high. Pollution results in economic impacts related to the costs of treatment of polluted or contaminated water, and the costs of alternative water supplies. The economic impacts of changes in the water table revolve primarily around salination of the water. These include the expense of alternative supplies, loss of agricultural income and potential, increased costs to industry of water treatment, costs of recycling, and in extreme cases (e.g. fish processing plants in Namibia) loss of industrial production due to water unavailability. These impacts are very difficult to quantify, and the Benguela Current Task team is unaware of these having been documented in the literature.

Health impacts

Modification of stream flow promotes the spread of water-borne diseases and their vectors, including malaria, hepatitis, cholera, typhoid, bilharzia and dysentery, in a number of ways, e.g lack of proper sanitation and limited access to safe potable water, and inter-basin transfer schemes. While data are certainly available which may document an increase in the spread of water-borne diseases and their vectors, the links between these and the modification of stream flow is a very difficult one to make. The Benguela Current Task team is unaware of any documented cases in which these links have been established. Where modification of flow leads to salination, health impacts include a range of physiological problems. Reduction of stream flow compromises the ability of running waters to dilute pollutants, resulting in many people being forced to drink poor-quality or contaminated water. The health impacts of pollution of freshwater supplies include a lack of proper sanitation and limited access to safe potable water, resulting in the spread of water-borne diseases.

The health impacts of changes in the water table are difficult to evaluate as there are no statistics available linking water table changes/salination to human health issues. In addition, salination may be important to human health over long time periods, and thus be ignored in the short-term. In areas where there is total dependence by communities on water bodies which are formed where the water table meets the surface, lowering of the water table may have disastrous implications for human health. The problems are of greatest threat to the rural poor in Namibia and Angola, and to the urban poor in South Africa and the impacts are considered moderate for the region as a whole.

Other social and community impacts

The problem relating to shortages of freshwater is so severe that there are already conflicts over water usage both between and within countries in the region (see Socio-economic characteristics), frequently causing community disruption.These impacts are assessed as moderate by the GIWA Experts. Many people have been displaced from their traditional lands by dam construction in the past. There has also been movement of people away from traditional lands due to shortages of freshwater, and in many cases these movements result in breakdown of family and community lifestyles. By way of example, the lifestyle of the Himba people is closely linked with the Cunene River. It is estimated that a new hydroeclectric dam on the River will flood 250 square miles (400 km^2) of land inhabited by the Himba people. In addition to flooding culturally important sites, the dam will also flood essential grazing lands and is likely to destroy the livelihoods and culture of these people (International Rivers Network 2004).

Conclusions and future outlook

The three issues relating to Freshwater shortage; modification of stream flow, pollution of existing supplies and changes in the water table, are all assessed as having severe environmental impact. Modification of stream flow was considered the most important of these three issues, as it has knock-on effects for other systems, including estuaries and the marine environment, and because virtually all the rivers in the region suffer from flow modification, some to the extent that they have dried up entirely. This not only affects the aquatic environment, but also has huge socio-economic implications.

The future outlook is also poor. There is an increasing demand for water in the region, combined with a decrease in supply due to alteration of rainfall patterns. Attempts to bring good-quality water to people will result in more river regulation through dams for storage and inter-basin transfers for redistribution of water. The situation as regards freshwater shortage will thus deteriorate further by 2020.

Contrasted with this is the fact that there is a growing awareness of water scarcity and the need to conserve water resources in the region, and several measures are in place to conserve water supplies. In South Africa, these include the new Water Law, which removes private ownership of water rights, and allows for an ecological reserve of water to flow in all rivers, and the Working for Water Programme of the Department of Water Affairs, the aim of which is to clear water-hungry alien vegetation from catchments, and to educate the public in water conservation issues. There is also a trend toward stricter water management by local authorities, and investigations into the feasibility of desalination and recycling are currently underway. Namibia is in the process of building its first desalination plant at Walvis Bay, and is ahead of the rest of the region in recycling of water. The legacy of the civil war in Angola results in these issues not having been addressed in this country.

The economic impacts of freshwater shortage are also likely to become worse in the future. As more people gain access to water, and as less water becomes available due to decreases in rainfall, so the problem will become worse. In the case of health impacts, there is a likelihood of improving water supplies in some parts of the region. This is a relatively high priority at present, particularly in South Africa. On the other hand, freshwater shortages in the future are likely to result in more resettlement of people from sites of dam construction, desertion of cultural lands due to increasing desertification, and the possible loss of complete cultures.

The region is generally arid, and has a limited and declining water supply. The flow of almost all river systems in the region is already modified. The demands for water are continually increasing, exacerbating the problem. Poverty, poor education and knowledge, scarcity of resources, inadequate sanitation, urbanisation, institutional weakness, and the loss of assimilative capacity due to the reduced flow of riverine systems all combine to result in a worsening of the situation by 2020. At present, the use of water is already greater than the supply, and many supplies of fossil water are already exhausted. Exacerbating the problem are increasing populations and aspirations to a higher standard of living (which usually implies greater usage of water).

Pollution

Freshwater component **Marine component**

Virtually the entire coastline of the Benguela Current region is exposed to the open ocean and can thus be considered to experience a high degree of wave exposure on global standards. Strong wave action and currents tend to dissipate any pollution reaching the marine environment very rapidly. Pollution of the marine environment is therefore not of great concern and is mostly evident in localised areas or hotspots such as ports and enclosed lagoons. Pollution in freshwater systems is more of a concern as freshwater is a very limited resource in the region. Much of the pollution generated in the interior of the country ultimately finds its way into one of the river courses draining the subcontinent. Because of these differences, pollution of freshwater and marine environments was assessed separately. A brief summary of the severity of each of the pollution issues is provided below.

Environmental impacts

Microbiological

The problem of microbiological pollution is generalised in freshwater systems, although the worst impacts are centred around urban areas. The environmental impacts of this issue are assessed as severe in the freshwater component. The massive growth of coastal urban centres in Angola has left existing infrastructure unable to cope, with resultant increases in human waste pollution around towns (UNEP 2005). In South Africa, the Vaal River as well as its tributaries are organically polluted, impacts of which have been noted on invertebrate communities (Chutter 1971). Sewage effluents discharged to the Vaal River daily in the early 1980s amounted to 37 000 m^3 (Oliveira 1986). Gross organic contamination (sewage effluent and sewage spills) has also been reported in the Little Lotus and Black rivers of Cape Town (Davies et al. 1993). The Black River is in fact considered the most organically polluted river in the Western Cape Province. Reported faecal coliforms during the 1980s ran at 25 million to 2 billion cells/ml (Davies & Day 1998).

In marine systems the impacts of microbiological pollution are related primarily to coastal organisms, and are generally localised in space and time and therefore considered of moderate nature. More than 60 pipelines discharge effluent into the coastal zone of South Africa. Of these, 33% discharge domestic sewage, amounting to a total input of approximately 66 million litres per day (Pick 'n Pay 2003). In Angola, untreated industrial waste pumped into the Bay of Luanda results in bacterial contamination (UNEP 2000). Stormwater run-off is also responsible for microbiological pollution of coastal urban areas. Microbiological pollution from stormwater can contribute significantly to microbiological pollution of coastal zones, especially when carrying run-off from informal settlements which lack adequate sanitation (South African Coastal Information Centre 2003).

Eutrophication

Eutrophication of freshwater systems is considered severe because of major eutrophication in all groups of standing water, as well as in some running waters. In marine waters, however, eutrophication is considered slight since it is generally highly localised around point discharges. Total inputs of organic pollutants to freshwaters in the three countries which make up the bulk of the Benguela Current region are presented in Table 11. Of these three countries, South Africa is the greatest contributor to organic water pollutants, with emissions of 241 922 kg/day in 1998 as opposed to 7 350 kg/day for Namibia and 1 472 kg/day for Angola. These emissions arise from a variety of sectoral sources, with the food and beverage industry being the greatest contributor in all three countries (World Bank 2001).

Table 11 Organic water pollution in the Benguela Current region.

Country	Emissions of organic water pollutants									
	(kg/day)	(kg/day/worker)	By industrial sector (%)							
			Primary metals	Paper and pulp	Chemicals	Food and beverages	Stone, ceramics and glass	Textiles	Wood	Other
Angola	1 472	0.20	8	3	9	66	<1	6	4	4
Namibia	7 350	0.35	0	5	2	90	<1	1	1	1
South Africa	241 922	0.17	12	16	9	42	<1	11	3	7

(Source: World Bank 2001)

Eutrophication in the Vaal River is occasionally so severe as to cause permanent algal blooms that interfere with water supply and treatment, and become health hazards. Spring algal blooms are normally associated with increases in run-off, total dissolved solids and nitrate (NO_3-N) and nitrite (NO_2-N) loads. Scum formation at water intakes and filter-blocking are common water supply problems (Pieterse 1986). Spread of alien invasive species such as Water Hyacinth (*Eichhornia crassipes*), Parrot Feather (*Myriophyllum aquaticum*) and Kariba Weed and Water Ferns (*Salvinia* sp. and *Azolla* sp.) have been recorded in the Vaal system in response to pollution and increased nutrient input (Bruwer 1978, 1979). Bloemhof Dam is infested with Water hyacinth due to eutrophication, as is most of the lower Vaal River (Grobler et al. 1986, Bruwer 1986).

Eutrophication has also been reported for the mid-reaches of the Berg River with effects on benthic invertebrates (Figure 5). Agriculture, distilleries, storm waters, faecal contamination and canning factories have been implicated as the main contributors (Harrison 1958). Fish kills have been associated with eutrophication in Zandvlei, a coastal lake (ex-estuary) on the Cape Peninsula (Bruwer 1979).

Figure 5 Alien aquatic vegetation spreads rapidly and choke waterways, Western Cape, South Africa.
(Photo: B. Davies)

Chemical

In freshwater systems mining leachates, slimes dams and pesticides (including banned pesticides) result in many hotspots where the impacts are regarded as severe, and some large areas of the region are also considered to be experiencing moderate impacts of chemical pollution. Overall the impacts of chemical pollution in the region's freshwater systems are considered to be severe.

The Vaal Dam and Barrage system supplies drinking water to 40% of the human population of South Africa and its condition is thus of great importance in the region. Organic pollution analyses have revealed dibutyl phthalate and phenols (including 2.4 dichlorophenol) at all sampling points in the reservoir. Average phenol concentrations in raw water for the town of Parys was 10 mg/l, rendering water unsuitable. Average concentration in Parys water of (predominantly) chloroform was 165 mg/l, well exceeding the 100 mg/l limit set by US Environmental Protection Agency for drinking water (Van Steenderen et al. 1986).

Vaal River salinity (Total Dissolved Solids) between 1934 and 1985 rose at an alarming rate of 2.5 mg/l per year and is still rising due to agricultural return flows from land irrigated under conditions of high evaporative losses and acid rain on the South African highveld, with a mean pH of 4.15. Salinity in the Vaal Barrage increased from <200 mg/l in the 1930s to >550 mg/l in the early 1980s (Davies et al. 1993). The problem of salinisation of the Vaal River and associated systems is considered intractable, the only solutions to the problem being dilution and reverse osmosis (O'Keefe et al. 1992)

Chemical pollution of marine environments is most frequent around major coastal cities. Many industries discharge untreated wastes into rivers, with this ultimately finding its way into the oceans (UNEP 2000). In the marine environment of the Benguela Current region, contaminants are derived from a number of sources, and include sewage and fish factory effluents, stormwater run-off and hydrocarbons. While some localised hotspots are considered to display moderate impacts (such as harbours, urban centres, etc.), the impacts are considered slight over most of the region. The environmental impacts of chemical pollution on the marine environment of the Benguela Current region are thus assessed as slight.

Suspended solids

The impacts of suspended solids are considered to be moderate in the region, both for freshwater and marine environments. For freshwater systems, this is caused mainly by poor agricultural practices resulting in excessive sediment loads to rivers. In some areas (for example the upper catchment of the Orange River) the situation is very serious, but the problem is generally contained within a few basins. In marine systems, the primary cause on the western coasts is marine diamond mining, while poor agricultural practices throughout the region result in addition of suspended solids via rivers to estuaries, lagoons and sheltered bays.

Solid waste

In freshwater systems, the impacts of solid waste pollution are considered severe, with widespread dumping of rubbish into rivers. Despite this being a recognised problem, no data are available with which to quantify the impacts of solid waste on these freshwater systems (Department of Environmental Affairs and Tourism 2000).

Solid waste pollution in marine systems in the region is regarded as moderate. Solid waste pollution in marine systems is primarily in the form of plastic pollution and discarded fishing gear. More than 80% of marine litter is made up by plastics. A survey conducted in the coastal waters of South Africa collected approximately 3 500 particles of plastic per km^2 (Ryan 1996). Scientific surveys of some of South Africa's beaches in 1984, 1989 and 1994 revealed a significant increase of macroplastics and fishery-related products, indicating a trend of increasing solid waste pollution in the coastal waters of the region. Two of the major biological impacts of solid waste in marine systems are entanglement in, and ingestion of, plastics. Off the South African coast, entanglement has been recorded to have affected five species of mammals, 13 species of seabirds, two species of marine turtle and six species of fish (Ryan 1996). These lead to death of the individuals concerned, although it is deemed unlikely that this is a major threat to healthy populations of these species. Ingestion of plastic has been reported in seven species of mammals, 36 species of seabirds, two species of turtles and seven species of fish off South Africa. Ingestion by some pelagic seabirds is particularly high even by global standards, with almost all Great Shearwaters (*Puffinus gravis*) and Blue Petrels (*Halobaena caerulea*) containing plastic in their stomachs (Ryan 1996).

Thermal

Thermal pollution is considered slight in both freshwater and marine systems in the region, as it comprises only very few point source discharges from desalination plants and nuclear and coal power stations. By way of example, the coastal area surrounding the nuclear power generation plant at Koeberg on the South African west coast is characterised by an average sea temperature of 13°C, with a minimum of approximately 10°C and a maximum approaching 20°C. Annual surveys by researchers at the University of Cape Town have found no detrimental effects on marine life resulting from the warm water plume surrounding the power station, nor any settlement of opportunistic warm water species or reduction in species diversity of benthic marine communities in the area (PBMR EIA Consortium 2001, Eskom 2003).

Radionuclides

In freshwater systems the impacts are thought to be of a sufficient magnitude to be considered severe by the GIWA Experts. The major problems are associated with uranium mining on the East Rand, in South Africa, and various mining activities in Namibia and Namaqualand. No publically accessible literature could be found which quantifies the extent of such pollution in freshwater systems of the region, possibly because of the sensitive nature of such information.

In marine systems the impacts are considered slight. What impact may exist would be most likely to emanate from one nuclear power station (Koeberg, on the southwestern coast of South Africa), and would thus be very localised. No data could, however, be obtained either to support or to deny the existence of such possible pollution in the surrounding marine environment.

Spills

Spills cause severe impacts in both marine and freshwaters in the region. In the case of freshwaters these includes spills of petrol, chromium, and other contaminants into water supplies (both from factory and road accident sources), while in the case of the marine environment this is mostly associated with oil in the form of fuel and cargo oil. Of the world's 20 largest oil spills listed by Intertanko, three of these (15%) have occurred in or near the Benguela Current region (Table 12). According to UNEP (2005), oil pollution has caused negative impacts on the living marine resources off Angola, although there are no known studies which quantify the extent of the problem. Spills on this coast are attributed predominantly to shipping, but oil and gas exploration, production and transport are also regarded as posing a risk (UNEP 2005).

Two oil spills into the coastal zone near Cape Town within the last decade can be used as examples of the impacts of such spills on the marine environment. The Apollo Sea, a Chinese ore carrier, sank close to the coast on 20 June 1994, and leaked some 2 500 tonnes of heavy fuel oil. Impacts included the oiling of endemic coastal and seabirds, and of coastal amenities. In the four-month long clean-up operation, a total of 6 500 tonnes of oil and oil debris were removed from beaches in the vicinity of Cape Town, and an additional 15 tonnes were removed from the shallow seabed with a vacuum (Moldan 1994). The effect on the nearshore environment was relatively small, as the heavy fuel oil was of a relatively low toxicity (Moldan 1994). There was, however, a large impact on the African Penguins (*Spheniscus demersus*), endemic to the

Table 12 The 20 largest tanker oil spills in the world.

Ship name	Year	Location	Oil lost (tonnes)
Atlantic Empress	1979	Off Tobago, West Indies	287 000
ABT Summer *	1991	700 nautical miles off Angola	260 000
Castillo de Bellver *	1983	Off Saldanha Bay, South Africa	252 000
Amoco Cadiz	1978	Off Brittany, France	223 000
Haven	1991	Genoa, Italy	144 000
Odyssey	1988	700 nautical miles off Nova Scotia, Canada	132 000
Tory Canyon	1967	Scilly Isles, UK	119 000
Urquiola	1976	La Coruna, Spain	100 000
Hawaiian Patriot	1977	300 nautical miles off Honolulu	95 000
Independenta	1979	Bosphorus, Turkey	95 000
Jakob Maersk	1975	Oporto, Portugal	88 000
Braer	1993	Shetland Islands, UK	85 000
Khark 5	1989	120 nautical miles off the Atlantic coast of Morocco	80 000
Prestige	2002	La Coruna, Spain	77 000
Aegean Sea	1992	La Coruna, Spain	74 000
Katina P.	1992	Off Maputo, Mozambique	72 000
Sea Empress	1996	Milford Haven, UK	72 000
Assimi	1983	55 nautical miles off Muscat, Oman	53 000
Metula	1974	Magellan Straits, Chile	50 000
Wafra *	1971	Off Cape Agulhas, South Africa	40 000

*Note: * Spills in or near the Benguela Current region.*
(Source: Intertanko 2005)

upwelling waters of the Benguela Current in South Africa and Namibia (Figure 6). The total world population of African penguins stands at approximately 180 000 birds. Of these, approximately 10 000 were oiled during this event (Underhill et al. 2000). Approximately 7 500 penguins were collected, cleaned and released, with a 63% survival rate (Moldan 1994). At the time this was the biggest seabird oiling event on the southern African coast (Crawford et al. 2000).

On 23 June 2000 the Treasure, a bulk ore carrier, sank with 140 000 tonnes of iron ore and 1 300 tonnes of fuel oil on board (Trevenen-Jones 2000). In excess of 19 000 African penguins were oiled, double the number oiled during the Apollo Sea spill in 1994. In this case, total mortality was about 2 000 adults and immatures, and 4 350 chicks, and survival rates were better than those achieved during the Apollo Sea spill (Crawford et al. 2000). In addition to the African Penguins, a number of other coastal birds were also affected by the spill. These included Bank Cormorant (*Phalacrocorax neglectus*), Cape Cormorant (*P. capensis*), Crowned cormorant (*P. coronatus*), Great Cormorant (*P. carbo*), Kelp Gull (*Larus dominicanus*), Hartlaub's Gull (*L. hartlaubii*) and Swift Tern (*Sterna bergii*). Of these, Bank Cormorant, Cape cormorant, Crowned Cormorant and Hartlaub's Gull are species endemic to southern Africa, while the races

Figure 6 African penguins at Boulder's Beach, Simontown, South Africa.
(Photo: M. Karlsson)

of Kelp Gull and Swift Tern, which occur here are globally unique. These birds were collected and rehabilitated in far smaller numbers than the penguins (Members of the GIWA Task team pers. comm.).

Socio-economic impacts

Economic impacts

The economic impacts of pollution in the Benguela Current region are considered to be severe, particularly as they are widespread and the costs of treatment are high. The costs include those of water treatment for both household and industrial use, ensuring alternative supplies, management of water, clean-ups, emergency services, control of eutrophication, sewage treatment, dam maintenance and aesthetic or tourism costs. Although some pollution issues are sporadic or temporary, most (and especially those which result in the largest impacts) are continuous in nature.

Costs incurred as a result of microbiological pollution and eutrophication are enormous in freshwaters due to the costs of water treatment, both for household and industrial use, and alternative supplies. The spread of invasive alien plant species as a result of eutrophication leads to greater evaporation from standing water bodies, thus further exacerbating the problem of a natural shortage of freshwater. In the marine environment, however, the costs related to eutrophication are not important in the region.

The major economic impacts of chemical pollution are the increased costs of mining processing techniques to address the problem, the treatment of contaminated water, and the costs of supplying water from alternative sources. The economic impacts of chemical and oil spills are enormous, considering both clean-up operations and rehabilitation of fauna, flora and functional ecosystems. These costs can be extremely large, running into millions of UDS. The costs associated with the Apollo Sea spill near Cape Town in 1994 were originally estimated at approximately 2 million USD. The final cost, however, was approximately 3.5 million USD (Kleinschmidt 2000). The cost of the cleaning and rehabilitation of the endemic African Penguins alone was approximately 64 000 USD (Department of Transport 1994), and that with an army of unpaid volunteer workers. The costs of the clean-up from the Treasure oil spill in 2000 were estimated at 17 million USD (Trevenen-Jones 2000).

Economic impacts related to suspended solids are primarily felt in freshwater systems. These include the costs of dam maintenance (i.e. dredging, etc.), the costs of dam losses through extreme sedimentation during flood events, and the costs of treatment of freshwater for human use. In the marine environment, costs include dredging of accumulated silt in estuaries and harbours. Solid waste pollution results primarily in costs associated with clean-ups and in costs to fisheries due to gear damage and fouling. The costs of beach cleaning in South Africa during one year (1995) amounted to some 1.2 million USD (Ryan 1996). The more than 55 000 km of beach cleaned annually in South Africa amounts to more than 30 times the length of sandy beaches in the country (Ryan 1996). There is also an aesthetic cost which may affect tourism potential and lead to further economic losses in the region. These costs are difficult to quantify, although a survey of beach-goers near Cape Town indicated that beach cleanliness was an important criterion in the selection of holiday destinations among tourists (Ryan 1996).

The costs of preventing thermal pollution are related to the cooling of effluent for the protection of the surrounding environment. Although costs exist, they are relatively low at present. There is currently very little information available regarding the impacts of radionuclide pollution in the region, and little is being done to address the associated problems (there is a substantial attitude of denial of the problem). There are thus very few known related costs at present.

Health impacts

The issues surrounding human health and water pollution are considered moderate by the GIWA Experts, and are primarily related to a shortage of potable water. Although pollution of freshwater supplies may result in death, this usually only occurs under exceptional circumstances. The major problems are chronic problems related to microbiological (especially water-borne diseases) and chemical pollution.

Microbiological pollution of waters in the region causes high levels of dysentery, particularly in areas where the population does not have ready access to treated water. Although it has not happened as yet, the potential for outbreaks of toxic algal blooms as a result of eutrophication are massive, and their potential impact on human health could be profound. The major health impacts related to chemical pollution include illness caused by acid drainage (although this is difficult to quantify and to link to the cause) and illness related to the use of alternative water supplies which may also be contaminated in some way. Pollution by suspended solids raises a major concern regarding the resuspension of accumulations of heavy metals by dredging operations both in highly silted dams, and in harbour areas. There is, however, no direct evidence of a link between such heavy metal resuspension through dredging and human health in the region.

The health impacts of solid wastes are generally fairly small, and include cuts from sharp objects, and suffocation by plastic bags. There are no known human health impacts associated with thermal pollution of aquatic environments in the region at present. According to the GIWA Experts there is evidence of increasing numbers of cases of leukemia and other illnesses in areas affected by radionuclide pollution. However, there is a problem of denial, and no data are available to support this at present. There are no known cases of death from spills in the region. However, there are certainly other health impacts of spills. These include breathing of toxic fumes that may be harmful to human health, and the eating of contaminated fish.

Other social and community impacts

The GIWA Experts considered that there were no major social and community impacts arising from pollution which had not been dealt with under issues of Freshwater shortage, but that those that exist are slight.

Conclusions and future outlook

Marine pollution is not a priority concern in the Benguela Current region at present. Polluted areas that do exist are mostly highly localised. In Namibia, the highest concentrations of pollution in the marine environment occur in the ports of Walvis Bay and Lüderitz, and off the town of Swakopmund. Most of the pollution in the ports originates from fish factory effluent, accidental oil spills, dredging and hazardous substances used in the repair and maintenance of fishing vessels and other ships. Most of the rest of the Namibian coastline is free of pollution from land-based sources as it lies within the Skeleton Coast Park or the Namib/Naukluft Park. Although it has not happened yet, the risk of a major pollution event arising from oil tankers that travel along the coast is, however, always present.

On a global scale, South Africa's coastal waters are considered to have low levels of marine pollution, which do not pose a serious threat to the environment or human health (Brown 1987). However, with an increasing population, industrialisation and pressure on the coastal environment, regular assessment and monitoring of coastal water pollution levels are essential. By the mid-1980s there were as many as 61 waste disposal pipelines located around the coastline of South Africa pumping sewage and effluent into the sea (Lusher 1984). This number has increased with the rapid increase in population and industrialisation of South Africa. With the associated increased discharge from both industrial and domestic effluents into the marine environment, it is important to monitor pollution levels against defined water quality criteria. In the early 1980s, a select group of specialist scientists and conservationists established a unique and simple guide to water quality criteria, providing monitoring strategies for measuring water quality in South African waters. This document provides a guideline for tolerance levels (safety levels) of organic and inorganic pollutants in marine waters and continues to be used as a reference guide. Legislation preventing marine pollution in South Africa is considered to be comprehensive, although responsibility for implementation thereof is currently fragmented, being distributed among several organisations (Marine and Coastal Management, Department of Water Affairs and Forestry, South African Maritime Safety Authority and Department of Transport). Intentions have been expressed to amalgamate the responsibility of monitoring and preventing marine pollution to become the responsibility of one organisation, but this has yet to be implemented. Marine pollution in South Africa is specifically governed by the Prevention and Combating of Pollution of the Sea by Oil Act, 6 of 1981, the National Water Act, 3 of 1998, the Water Services Act, 108 of 1997, and the South African Public Health Act, 36 of 1919.

The outlook for the future is that the environmental impact of all types of pollution will become worse by the year 2020. As more people in the region are given better access to water, one would expect improvements in health. However, increased access usually equates with increased usage, which in turn applies greater pressure to the freshwater systems, and reduces their capacity for resisting pollution. The status quo concerning the health situation is expected to remain until 2020. It is also foreseen that, as environmental pollution issues deteriorate in the region, so will other social and community impacts. However, there is low confidence in this prediction, as there are many unpredictable factors that could play a role in the future (e.g. the stabilisation of the Angolan political situation).

Habitat and community modification

IMPACT **Freshwater component** IMPACT **Marine component**

Data relating to modification and/or loss of specific ecosystem types are not always readily available. In order to compensate for the lack of hard evidence, the Benguela Current Task team has attempted to provide information on the perceived extent of modification and/or loss of ecosystems in the region. Estimated percentages are thus given in the descriptions below. They are provided merely as a guide to how severe loss and modification of each habitat is in the region, and are not necessarily substantiated by hard data, nor should they be cited as being quantitative substantiation of ecosystem modification and/or loss. Please also note that, due to a paucity of habitat-specific data in the region, the assessments of the future of these habitats are based to a large extent on the professional opinions of the Benguela Current Task team, and are not necessarily substantiated by hard data. For detailed scores for the individual habitats, please see Annex II.

Environmental impacts

Freshwater habitats

The overall environmental impact in freshwater habitats was assessed as severe. In the absence of ecosystem-specific information, data regarding the percentage of threatened species can be used as an approximation of the modification and/or loss of ecosystems in general. Data for amphibians and freshwater fishes in South Africa indicate that 17 and 36% of these species respectively are listed as threatened (Department of Environmental Affairs and Tourism 2000). If these figures are extrapolated as indicators for loss and/or modification of freshwater ecosystems, this would suggest that this country has suffered loss and/or modification of up to 36% of its freshwater ecosystems.

Wetlands

Wetlands, are in South Africa, as well as in other parts of the Benguela Current region, regarded as among the most threatened of all aquatic habitats (Walmsley 1991). Pressures are placed on wetlands through a number of human activities, including modification of flows, water abstraction, pollution, agricultural practices, development, etc. Although little data are available regarding the loss of natural wetlands, it is estimated that there have been substantial reductions in the natural extent of these in South Africa (Kotze et al. 1995). This is most marked within the westerly arid areas of the country where reductions in natural wetland extent of over 50% have been postulated (Kotze et al. 1995, Department of Environmental Affairs and Tourism 2000).

Soligenous bogs

Soligenous bogs only occur in the upper headwaters of the major tributaries of the Orange River system. They control the rate of seepage release to the headwaters, thus driving the entire Orange River Basin. The soligenous bogs are also highly important in filtering and maintaining water quality. The GIWA Experts estimate that more than 30% of this habitat type has been lost in the region primarily due to inappropriate development and cattle grazing. The impacts of both modification and loss of this habitat are thus considered severe. It is likely that this habitat type will continue to be modified, degraded and lost by 2020 due to inappropriate development, poor agricultural practices and back-flooding by the construction of reservoirs.

Marshes

Marshes, or vleis as they are commonly known in the region, are regionally important as they are the most common form of wetland found in the wetter parts of the region). The GIWA Experts estimate that at least 75% of marshes in the region have been destroyed through landfill and development. Of those that have not been destroyed, the remainder are all modified. The impacts of modification and loss of marshes are thus rated as severe in the region. An increased awareness of the importance and sensitivity of this habitat, together with improved technology to restore, rehabilitate, and even recreate, these habitats is likely to stem the loss and lead to some reduction in their modification and degradation in the future.

Riparian belts

Very few intact riparian belts remain in the region and the GIWA Experts estimate that almost 80% of this habitat has been lost. Reasons for this loss include; aforestation, deforestation, agricultural encroachment onto the river banks, overgrazing in riparian zones, river regulation and overabstraction of water leading to reduced water supply for riparian vegetation, plantation encroachment, invasive alien plants, canalisation, and inappropriate development. The exception is in the northern Angolan part of the region, where the ongoing war has reduced these types of activities. The impacts of modification and loss of riparian belts are collectively considered as severe in the region. Of those riparian belts that remain, the majority are within conservation areas. However, the continuous nature of riverine systems results in the spread of invasive alien vegetation even into these areas, causing further loss of this habitat by 2020. However, growing public awareness and campaigns such as the Working for Water project are moving in the right direction to reduce and reverse the modification of these habitats. The results of such initiatives are, however, not likely to be felt within a near future.

Endorheic pans

Endorheic pans are habitats with periodically standing waters with large amplitude fluctuations. These periodic standing waters are almost vegetation-less. They allow water in, but not out, and remain dry during the dry season. In southern Africa, they are a dominant feature of the landscape between southern Angola and the western Cape. In the highly arid regions, they are the only form of standing water. Although species richness in these pans is low, endemism is high, and they contain unique faunas. Overall, modification and loss of this habitat is considered severe in the region. Major problems include; infilling, overgrazing by cattle and associated faecal contamination, and reduction in stream flow into these systems by upstream river regulation. The GIWA Experts consider that the intensity of the problem does, however, vary with an aridity gradient in the region according to the following. In the hyper-arid areas (<50 mm rainfall) where population density is low, approximately 5 to 10% of this habitat has been lost. In arid areas (<200 mm rainfall) approximately 30% has been lost. In semi-arid areas (<400 mm rainfall) where population density is far higher, there is a 100% loss of this habitat type. It is envisaged that modification and loss of this habitat type will continue by 2020, although there is uncertainty about the rate at which this will happen.

Floodplains

The area is naturally poor in floodplain habitat and there is only one floodplain in the entire region – that of the Berg River in South Africa. Among other things, this floodplain serves a very important function as a feeding ground for a huge density of palearctic migrant waders. According to the GIWA Experts the floodplain has experienced a loss of >30%, due to overabstraction of water upstream leading to reduced flooding, reduction of peak flows, grazing pressure and crop farming on the floodplain, pollution from agricultural and industrial sources, and stabilisation of the estuary mouth which reduces vital back-flooding into the floodplain. Because the Berg River floodplain is the only one of its kind in the region, its long-term survival is vital and modification or loss is considered a severe impact. Its future deterioration is predicted for two reasons. Firstly, the surrounding area is a growth point of development, and is unlikely to remain in its current state without intervention. Secondly, a proposed new dam upstream will reduce stream flow even further, also reducing the frequency and intensity of flood events. It is envisaged that the floodplain will no longer operate with current capacity, and this system will thus be entirely lost, and this habitat type will cease to exist in the region.

Rivers

The majority of rivers in the region are intermittent rivers (>65%) and flow only periodically (Figure 7). Some of these rivers flow annually, while others flow less frequently or predictably. All intermittent rivers in the region are dammed (all have multiple impoundments along their length, mostly in the form of farm dams) and suffer from overabstraction of water. This has resulted in massive changes in the temporal flow regimes of these systems. In extreme cases, these rivers have ceased to flow, as all the water is captured in impoundments. This has lead to loss of species, and modification and loss of these ecosystems are thus considered severe in the region. Increased regulation of flow and abstraction of water for agricultural purposes (which may lead to 100% reduction in flow) are likely to result in further modification and loss of these river systems by 2020. New laws regarding ecological flow requirements of rivers in South Africa may slow down the process in this country, but it is unlikely that they will have any effect in the near future.

Figure 7 Dry river beds are a common feature in the arid Benguela Current region.
(Source: B. Davies)

The permanent rivers are limited to the less arid parts of the region. Although they suffer from a range of problems, the most important are changes in river flow, impoundments and overabstraction. In South Africa and Namibia many rivers have ceased to flow permanently and have become intermittent, resulting in temporal rather than spatial fragmentation of the habitat (Department of Environmental Affairs and Tourism 2000). This has lead to loss of biodiversity and ecosystem functioning. Salinisation, pollution, riparian destruction, sedimentation and invasion by alien vegetation exacerbate the problems. In Angola, the major problems are siltation and impoundments. Modification and loss of this ecosystem type is severe in the whole region. Increased regulation of flow and abstraction of water for agricultural, industrial and domestic purposes are likely to result in continued modification and loss of these river systems.

Marine habitats

The overall environmental impacts in marine habitats are considered moderate in the region.

Sandy foreshores

Sandy foreshores cover more than 50% of the coastal length of the region. The impacts of modification and loss of sandy foreshores in the region is considered moderate due to land reclamation, port development, coastal diamond mining in South Africa and Namibia which has lead to both erosion and accretion of sandy foreshores, and some sand mining in Angola. Possibly the largest contributor is beach accretion related to diamond mining activities on the Namibian coast. Since the coastline is highly dynamic and exposed, the few suitable sites have already been reclaimed, and thus no future deterioration is envisaged by 2020. This carries only medium confidence as it is possible that engineering technology may find a way to reclaim sites which were previously regarded as unsuitable. As diamonds become depleted, mining is moving further offshore, thus lessening the pressure on this habitat type, and leaving these areas to revert back to their natural state. However, it is likely that sand mining will increase in Angola, although there is a lot of uncertainty as to the extent of this.

Lagoons

There are only a few lagoons in the region and most of these are nature conservation areas, and all are important feeding grounds for birds, including palearctic migrant waders. Local deterioration of these sites may thus have far-reaching implications for bird populations. Several of these lagoons have been designated as Ramsar sites. The impacts of modification and loss of this ecosystem type are considered moderate. The Luanda Lagoon is of particular concern. The ecological functioning of this system has become entirely lost due to blocking of the connection between the lagoon and the sea. The lagoon is silting up rapidly, and is highly polluted. Lagoons on the Namibian coast are naturally relatively short-lived systems and are characterised by natural siltation processes. The process of siltation, however, is being exacerbated and accelerated by human activities. It is likely that lagoons will experience further modification and loss by 2020 as increasing population densities result in increasing development around lagoons, and a resultant increase in exploitation and disturbance. Luanda Lagoon is already almost lost. Of the Namibian lagoons, Sandwich Harbour is silting up naturally, while Walvis Bay is experiencing siltation exacerbated by human activities. It is unlikely, however, that Walvis Bay Lagoon will be lost entirely within the near future. In South Africa, Langebaan Lagoon is protected as part of a national park, and thus unlikely to be lost in the future.

Estuaries

Because of the arid nature of large parts of the region, there are relatively few estuaries. These become more numerous, however in the wetter northern parts, with Angola having approximately 20 estuaries formed by perennial rivers (UNEP 2005). The Benguela coastline is highly exposed to wave action, and is dominated by high wave conditions and strong winds for most of the year. There few sheltered embayments and estuaries that do exist represent much of the only sheltered marine habitat along this coastline, with the result that they are important both for biodiversity and the focus of coastal development. They represent important feeding areas for birds (including palearctic and intra-African migrants) and are nursery areas for many exploited fish species. Many estuaries also contain species that are endemic to only one or two estuarine systems within the region. Almost all of the estuaries in the region have been altered from their original state. Reduced freshwater inflow due to water extraction for human usage is a major factor that has caused this change. Most of the larger estuaries have some degree of built environment along the shoreline, e.g. marina developments that contribute to the alteration of some estuaries (CSIR 1999).

The ecological functioning of many estuaries in the region has been destroyed by alteration and reduction of flow in the catchments, affecting the frequency, intensity and timing of flood events which perform a number of vital functions, including scouring, ensuring natural mouth opening and the provision of vital environmental cues to recruits of marine fish and other organisms. Modification of estuary mouths and their functions by closure and inappropriate timing of artificial mouth breaching, inappropriate development, pollution from a number of sources, and overexploitation all contribute and will continue to contribute to the modification of these systems. In the cool temperate region of South Africa which falls within the Benguela Current region, 50% of estuaries are considered to be in a poor condition (Table 13) (Whitfield 1995). The impacts of modification and/or loss of estuarine systems are considered to be severe in the region. It is likely that the degradation will continue by 2020 due to, among other things, a growing desire for waterfront property particularly within the southern part of the region.

Rocky foreshores

There is some loss of rocky foreshores in the region due to port construction, seawalls and resort development, and the impacts of modification and loss of rocky foreshore is considered moderate in the region. Major contributing factors to modification of this habitat type include overexploitation, which has altered community structure on the shore, and the invasion of a significant stretch of coastline of the region by the alien Mediterranean Mussel (*Mytilus galloprovincialis*). This invasion has drastically altered community structure and functional group composition on the shore. In addition, pipeline discharges of sewage, industrial waste and stormwater run-off at urban nodes has resulted in changes to community structure and functioning. Complete loss of rocky foreshores is a result of inappropriate coastal development. It is likely that this will continue by 2020. Rocky foreshores will also continue to be modified through exploitation of certain species, invasion by alien species, and through point source pollution from pipeline discharges around urban nodes.

Table 13 Condition of estuaries in South Africa's cool temperate biogeographic province.

Condition	Comment	Number of estuaries
Excellent	Estuary in a near pristine state	1
Good	No major negative anthropogenic influences on either the estuary or the catchment	2
Fair	Noticeable degree of ecological degradation in the catchment and/or estuary	2
Poor	Major ecological degradation arising from a combination of anthropogenic influences	5

(Source: Whitfield 1995)

Mangroves

Mangroves are confined to the more northerly, tropical areas of the region between Lobito and Luanda in Angola, where they cover some 700 to 1 250 km^2 (UNEP 2005). Exploitation of the mangrove fauna occurs, but of greater concern is the exploitation of the mangroves themselves for building materials. Exploitation of the mangroves and their associated fauna has lead to changes in community structure. No data exist on the extent of the damage to mangroves in this area, but the GIWA Experts suggest that not more than 30% of the mangroves in this area have been destroyed to date. The impacts of modification and loss of mangroves is therefore considered moderate in the region. As coastal populations in Angola increase (through immigration and growth), so exploitation of the mangrove fauna and flora will escalate, resulting in further modification and loss of this habitat by 2020.

Kelps

Exploitation of kelp systems does occur within the region. This is primarily related to the harvesting of kelp for feed in abalone (*Haliotis* spp.) farms. There is, however, no evidence that kelp systems are suffering fragmentation or loss in the region with the current levels of exploitation of this resource. Severe exploitation of particular species associated with kelp beds has, however, lead to changes in community structure within these systems. The major species exploited include rock lobster, abalone, and linefish. The impacts of exploitation of these species are dealt with under the concern Unsustainable exploitation of living resources, and will not be repeated here. Because of the contribution of the exploitation of these species to the modification of kelp systems, the impacts of modification and loss of this ecosystem type are slight in the region. It is likely that harvesting of kelp for alginates will increase in the future both in Namibia and South Africa. The exact effects of this cannot be predicted at this stage, and it is uncertain what the long-term impacts of kelp harvesting will be. A project is currently underway through the Benguela Large Marine Ecosystem Project to assess the effects of kelp harvesting (Project BEHP/CEA/03/04).

Mud bottoms

Mud bottoms are important off both South Africa and Namibia as they constitute a large proportion of the sea bottom. Many mud bottoms in this area are anoxic, but have a rich surface layer which helps to support a healthy pelagic system. There is no evidence of long-term fragmentation or loss of mud bottom habitat in the region due to human activities. Trawling does, however take place over muddy ground, and the extensive diamond-mining in the region moves and remobilises sediments, resulting in changes to species composition. These mud bottoms are, however, generally anoxic and naturally poor in species, and the communities recolonise quickly. Modification and loss of muddy substrata is therefore considered slight in the region. It is unlikely that there will be any change in the status of mud bottoms by 2020.

Sand and gravel bottoms

The GIWA Experts considered there being no evidence of fragmentation or loss of sand and gravel bottom habitats in the region. Although trawling creates some physical disturbance to the substratum, probably the greatest contributor to community change is through removal of the abundant fish predators inhabiting the above water mass. For this reason, modification and loss of this habitat type is considered slight in the region. It is unlikely that there will be any change in the status of sand/gravel bottoms by 2020.

Rocky bottoms

There is no evidence of fragmentation or loss of rocky bottom in the region, but the exploitation of rock lobster, abalone and large fish has changed the community structure of this habitat. The impacts of exploitation of these species are discussed in detail under the concern Unsustainable exploitation of living resources and will not be repeated here. Because of the impact of the ecosystem effects of the heavy exploitation of these species, modification and loss of rocky bottom habitats is considered slight in the region. It is envisaged that this exploitation will continue, resulting in further modification of this habitat type by 2020.

Socio-economic impacts

Economic impacts

The economic costs associated with loss and modification of ecosystems and habitats are moderate and include; agricultural losses, costs of water supplies, losses associated with tourism, lowered fishery yields (particularly with regard to estuaries), and coastal erosion.

Health impacts

There is no strong link between habitat modification and human health. The major problems revolve around modification of freshwater habitats, including decreased dilution potential for contaminants, increase in water-borne diseases by creation of impoundments, salination, and respiratory problems associated with desertification and the creation of high-dust environments. The overall assessment of health impacts associated with modification and loss of ecosystems and habitats is considered to be moderate.

Other social and community impacts

Habitat and community modification has lead to loss of sustainable livelihoods, particularly related to the collection or use of natural resources such as fish, wood, water, thatch, etc. and is considered moderate in the region. Women are the worst affected, as it is usually they who are involved in these activities (Figure 8). This means that more effort must be expended on these activities, which reduces opportunities for other activities such as education.

Conclusions and future outlook

Habitats and communities will continue to become transformed and lost as a result of urbanisation, pollution, etc. Of particular concern are

Figure 8 Women collecting water.
(Photo: B. Davies)

the cumulative effects of such habitat modification and loss. As more habitats and/or communities are lost, what is left behind becomes more important. The environmental impacts of the concern Habitat and community modification will thus increase by 2020, and become more severe than at present. Since the environmental problem is increasing, so the costs must necessarily increase, with the cumulative effects of this resulting in the impact becoming severe. In fisheries, for example, as stocks decrease, so effort must increase to compensate, and costs increase as a result. Similarly, it is predicted that there will be further deterioration in health by 2020. It is also likely that, as habitats are increasingly modified and resources become correspondingly more scarce, so the social and community impacts will increase.

Unsustainable exploitation of fish and other living resources

Marine component

The high productivity of the Benguela Current supports abundant fish stocks. Pelagic fisheries in the region target Anchovy (*Engraulis capensis*), Sardine or Pilchard (*Sardinops sagax*), Cape and Cunene Horse Mackerels (*Trachurus trachurus capensis* and *T. trecae*), Round Herring (*Etrumeus whiteheadi*), while Angolan fisheries additionally target Sardinellas (*Sardinella aurita* and *S. maderensis*). The demersal fisheries of Namibia and South Africa are largely based on Cape and Deep-water Hakes (*Merluccius capensis* and *M. paradoxus*). A number of by-catch species are also important components of the hake fisheries, including adult Horse Mackerel, Monkfish (*Lophius vomerinus* and *L. vaillanti*), Kingklip (*Genypterus capensis*), West Coast Sole (*Austroglossus microlepis*) and Snoek (*Thyrsites atun*). On occasion, some of these by-catch species, notably Monk and Kingklip are also targeted. There is also an important demersal fishery in Namibia for Orange Roughy (*Hoplostethus atlanticus*). Angolan demersal fisheries are largely based on Cape and Benguela Hakes (*M. capensis* and *M. polli*), *Dentex* spp. and Red Pandora (*Pagellus belloti*). Many of these species are shared between two or all three of the coastal countries in the Benguela Current region (Members of the GIWA Task team pers. comm.). Red Crab (*Chacean maritae*), Deep-water Rose Prawn (*Parapenaeus longirostris*) and Striped Red Prawn (*Aristeus varidens*) are important components of the Angolan crustacean fishery. Red crab is also taken in Namibian waters. A large fishery exists for West Coast Rock Lobster (*Jasus lalandii*) in Namibia and South Africa (Members of the GIWA Task team pers. comm.).

The linefishery in the Benguela Current region includes an enormous array of species, from highly resident and range-restricted reef associated fishes to large, highly-migratory species such as tunas and billfishes. The linefishery contains a number of "sectors", ranging from subsistence and artisanal fisheries to recreational and fully commercial fisheries (Members of the GIWA Task team pers. comm.).

Total fish catches in the Southeast Atlantic over the last 30 to 40 years have declined from a peak of more than 3 million tonnes in 1968 to around 1 million tonnes per year in the 1990s (Hampton et al. 1998). Much of this is associated with overexploitation of key resources in the region. Some of the most pronounced features associated with the decline in catches include a major decline in catches of South African and Namibian Sardine in the mid- and late 1960s, a major decline in the West Coast Rock Lobster resource (particularly off Namibia), a major reduction in hake catches off Namibia in the 1990s, and a sharp reduction in industrial catches of all the most important species (e.g. Sardinellas, Horse Mackerels and prawns) in Angola (Hampton et al. 1998). The latter two trends are not purely a function of overexploitation, and are due, at least in part, to the major reduction in foreign fishing effort from 1985 onwards.

The socio-economic value, national importance, and the balance between the various sectors (industrial, artisanal, recreational etc.) varies considerably between the coastal countries in the region. In Angola and Namibia fisheries are nationally important, making a substantial contribution to employment in these countries. Fisheries provide a valuable source of local food production in Angola, while in Namibia the value of exports of fishery products contributes substantially to the national economy, at approximately 225 million USD per year (Hampton et al. 1998). The South African fishing industry is not as important on a national scale, although earnings are similar to those of the Namibian fishery. The fishing industry, however, remains an important source of food, income and employment for many coastal people.

Because of the relative scarcity of permanent surface freshwater in the region, marine fisheries far outweigh inland fisheries in importance. As a consequence, the GIWA concern of Unsustainable exploitation of fish and other living resources is assessed only for marine fisheries.

Environmental impacts

Overexploitation

Overexploitation of fish and other living resources is considered severe in the region, as many fishery resources are overexploited. The Southern African Development Community (SADC) recognises overexploitation of fisheries resources as a concern for the southern African region as a whole (SADC 2002). Historical catch records indicate a past drastic decline in catches of Sardine (*Sardinops sagax*) in South African waters. In the early 1950s catches were approximately 100 000 tonnes per year. With increased fishing effort, these rose to a maximum of 400 000 tonnes in the early 1960s before a steady decline to below 100 000 tonnes per year from the late 1960s until the mid-1990s. Acoustic surveys conducted since 1984 indicate a steady increase in spawner biomass (Hampton et al. 1998), suggesting an increase in the Sardine stock in South African waters. Namibian Sardine catches show a similar pattern, with catches increasing from around 200 000 tonnes per year in the early 1950s to a high of almost 1.4 million tonnes in the late 1960s. A dramatic decline followed this peak, with a subsequent slight increase in catches again until the stock collapsed dramatically to below 50 000 tonnes in the late 1970s (Hampton et al. 1998). There are no signs of recovery in catches. It is considered that the stock collapse was primarily due to overfishing of the resource (Hampton et al. 1998).

Historical catch figures for Anchovy (*Engraulis capensis*) indicate a strong stock decline in the Namibian fishery. Since its beginnings in 1966, the fishery landed approximately 200 000 tonnes per year. In 1987 the total catch in Namibian waters was approximately double the previous annual average, and this has been attributed to an anomalous influx of recruits from the South African stocks (Hampton et al. 1998). During the 1990s, however, catches declined to below 50 000 tonnes per year, with almost no catches being recorded in 1996 and 1997. Acoustic survey estimates of Anchovy in Namibian waters indicate a decline in the stock from approximately 200 000 tonnes in the early 1990s to less than 100 000 tonnes since, and the stock is considered to be in a depleted state (Hampton et al. 1998).

Catches of Horse Mackerels (*Trachurus* spp.) in South African waters have also shown marked declines. After reaching a maximum catch of 118 000 tonnes in 1954, catches declined steadily until the 1970s when they became negligible, never reaching more than 10 000 tonnes per year (Hampton et al. 1998). The results of acoustic biomass surveys of Horse mackerels in South African waters are currently unreliable due to spatial and temporal discrepancies in the availability of the stock to sampling (Hampton et al. 1998).

Although past declines in catches of Hakes (*Merluccius* spp.) have been documented in the Benguela, the introduction of strict controls on these species appear to be working and the stocks appear to be stable (Hampton et al. 1998). Biomass survey estimates support the catch data in suggesting that the stocks are stable, and even indicate that there may be an increase in the biomass of Hakes in the Benguela in more recent years (Hampton et al. 1998). Stocks of Kingklip (*Genypterus capensis*), a by-catch species and sometimes target of the demersal trawl fisheries is considered to be overexploited (Punt & Japp 1994).

Catches of West Coast Rock Lobster (*Jasus lalandii*) have declined in both Namibia and South Africa. South African catches were stable at around 9 000 tonnes per year during the 1940s and 1950s, but declined to around 1 500 tonnes per year from the 1960s to the mid-1990s, with sharp catch declines having been noted in the late 1960s, and early 1980s and 1990s (Hampton et al. 1998).The Namibian catch records show the same pattern of decline, with only a few hundred tonnes being landed per year in the mid-1990s. The Namibian stock is estimated at a total of approximately 3 000 tonnes, while South African stocks are estimated to be at approximately only 35% of their pristine levels (Hampton et al. 1998). Over the last 15 years, a decrease in the abundance of an important food source of rock lobsters, unfavourable environmental conditions (i.e. El Niño) and a recent increase in the occurrence of red tide events, have caused a decrease in the growth rates of the West coast rock lobster (Cockroft & Payne 1999, Pollock et al. 1997). These low growth rates have resulted in decreased recruitment into the harvestable component of the population and decreased spawning biomass (Cockroft & Payne 1999). This reduced recruitment to the fishery, coupled with unsustainable fishing pressure (SADC 2002), has resulted in the rock lobster resource being considered heavily depleted (Cockroft & Payne 1999).

Many of the region's linefish stocks are rated as overexploited or collapsed (Griffiths 1999, Griffiths et al. 1999, Mann 2000, SADC 2002). The overexploited or collapsed stocks include, among others, the Geelbek (*Atractoscion aequidens*), Silver Kob (*Argyrosomus inodorus*), Roman (*Chrysoblephus laticeps*), Seventy-four (*Polysteganus undulosus*) and Red Stumpnose (*Chrysoblephus gibbiceps*) (Griffiths 1999, Griffiths et al. 1999, Mann 2000) in South Africa, and Silver Kob (Holtzhausen et al. 2001) and Orange Roughy (*Hoplostethus atlanticus*) (Boyer et al. 2001, McAllister & Kirchner 2001) stocks in Namibia. The principle target species of the South African gill and beach seine fisheries, Harders or Mullet (*Liza* and *Mugil* spp.), also appear to be overexploited in the most heavily fished areas (Hutchings et al. 2000, Hutchings & Lamberth 2002).

The Abalone (*Haliotis* spp.) stock has been declining since 1996 and is considered to be on the brink of collapse as a result of illegal fishing linked with an ecological shift in species abundances (Tarr 1998, 2000, Tarr et al. 1996, 2000).

Excessive by-catch and discards

By-catch is a feature mostly of the large fisheries, especially the pelagic and demersal fisheries. By-catch is controlled by strict laws, including observers in some fisheries and self-policing where the by-catch is used as a luxury product. South Africa initiated observer programmes for the trawling industry in 1955 (Hart et al. 1998). In the demersal trawl fishery of South Africa, 10% of the total catch by mass is composed of discarded fish (Walmsley-Hart et al. 2000). Both the South African and Angolan purse seine fisheries yield a by-catch of between 10% and 20% of the total catch by mass (calculated from Tables III and VII of Crawford et al. 1987). Overall, the impacts associated with by-catch are considered slight in the region.

Destructive fishing practices

The impacts of destructive fishing practices are assessed as moderate in the region. Destructive fishing practices include primarily trawling, but there is also some dynamite fishing (artisanal fisheries) in Angola. No documented quantification of either the extent of damage caused by destructive fishing practices or the impacts on fish stocks is available.

Decreased viability through pollution and disease

There are no known impacts of decreased viability through pollution and disease in the region. There is no evidence, and there are no data directed at this issue. It is however suggested that the introduction of alien parasites (e.g. sabellid worms which bore into mollusc shells) through aquaculture operations may have some effect on local stocks, but there is no evidence to support this.

Impact on biological and genetic diversity

A few introduced species are known from the Benguela Current region. The major impacts stem from the Mediterranean Mussel (*Mytilus galloprovincialis*) and are considered moderate. *M. galloprovincialis* has largely displaced the indigenous Intertidal Mussel, *Aulacomya ater*, (Griffiths et al. 1992), but since both mussel species grow in multi-layered and structurally heterogeneous matrices, they support similar interstitial communities (Hockey & Van Erkom Schurink 1992). *M. galloprovincialis* has competitively excluded the large individuals of the limpets, *Scutellastra granularis* (Griffiths et al. 1992) and *Scutellastra argenvillei* (Steffani 2001), from the primary rock space. The *Mytilus* beds have, however, provided a large smooth substratum for juvenile *Scutellastra granularis*, which has prevented the build-up of epiphytic macroalgae such as *Gigartina* and *Pterosiphonia* spp., thus affecting the algal communities (Hockey & Van Erkom Schurink 1992).

Socio-economic impacts

Economic impacts

The economic impacts of the concern Unsustainable exploitation of fish and other living resources is assessed as moderate in the region. In the case of fisheries, a decrease in Catch Per Unit Effort (CPUE) translates into increased costs, or decreased profits, for commercial fishers. Indeed, although the catches of certain linefish in the region, such as Yellowtails (*Seriola* spp.) and Snoek (*Thyrsites atun*) have increased over the past decade, current catch rates are less than 60% of historical rates (Griffiths 1999). For other linefish species, catch rates have declined far more dramatically, with catch rates of under 5% of historical catch rates for over half of the 25 stocks investigated (Griffiths 1999), and nearly all under 25%.

Despite such heavily depleted stocks and declining CPUE, the number of participants in the linefisheries remains high, and applicants by potential new entrants continue unabated. This does however not mean that there has been no significant economic impact of overexploitation on these fisheries. The reason for this phenomenon can largely be explained by the concept of "effort subsidisation", which can happen in three ways, as follows (Griffiths 1999):

- Part-time commercials: Fishers who have commercial access to the fishery but generate income elsewhere. These are effectively recreational fishers who cover the costs of their sport by selling part of their catch. In fact, less than 20% of boats catch more than 80% of the reported catch.
- Multiple access: Participants who have access to more lucrative resources (e.g. tuna and rock lobster), and only focus on linefish when they are abundant or when other target species are unavailable.
- New entrants: Permit holders that are unable to make a profit sell within a couple of years to optimistic new entrants, who follow a similar cycle. It is estimated that as many as one third of commercial linefish permits change hands each year.

Thus, the economic impacts of overexploitation in the linefish sector are subtle, but would probably be measurable in terms of decreased incomes to individual participants. This is also supported by the continuing reduction in the number of active commercial vessels since 1989 (Griffiths 1999).

Net fisheries, while concentrating on Harders or Mullet, generally have relied on a small permissible by-catch of linefish species to turn a good profit. With the overexploitation of these species, it is becoming evident that this fishery is also in economic decline. As is the case with the linefisheries, the small-scale net fisheries appear to support a considerable number of participants despite declining catches. Again, the explanation lies largely in the three types of "effort subsidisation" outlined above. An economic analysis of the fishery reveals that very few participants generate their main income from the fishery, and very few make any significant profit (Hutchings et al. 2000). In effect, as stocks in the line and net fisheries have declined, and effort has continued at a high rate, the profits, or rents of the fisheries have been dissipated by an increasingly high proportion of revenues being spent on fishing effort. Thus, even in the case of linefish where overall catches and landed values may not have changed dramatically, the profitability of these fisheries has been significantly undermined by the escalating costs of the effort per unit of fish caught.

In some of the commercial invertebrate fisheries, on the other hand, overexploitation has reached the level that total landed catches have begun to decline. Stocks of several invertebrate species, especially rock lobster and abalone, have been subject to dramatic local overexploitation, and overall catches have declined markedly in the past 10 years. In the case of the rock lobster, stocks have been "mined" down to a level where they are now sensitive to growth rate changes. When stocks are overexploited to the extent that catches decline, or quotas are reduced, this means that the gross income of the fishery is affected. Prices may increase in response to greater scarcity, ameliorating this effect to some degree. Thus, it is principally the changes in effort that have an economic impact, and secondarily, a reduction in catches.

Overexploitation has quite different types of impacts on subsistence users. Instead of translating to profits and income generated, the costs to subsistence users can be considered in terms of time and nutrition. Subsistence fishers generally live close to where they harvest, and harvest over relatively short sections of coast (<20 km) (Clark 1999). Local overexploitation of stocks results in harvesters having to travel further to search for food, a factor that may have serious time costs for women who also have to devote time to cultivation, fuel and water collection and other household chores. Subsistence fishers do not constitute a major component of fishery users in the southern parts of the Benguela Current region, but form a greater component in the more northerly areas, particularly on the Angolan coast. Subsistence fisheries provide an important source of protein to those households which rely on them, and their depletion may adversely affect the diet and consequently the health of household members. All of these factors contribute to the productivity, and thus the well-being, of rural households, but are difficult to measure in conventional economic terms.

Recreational fisheries are more important in South Africa than the other two countries, but interest in this recreational outlet in Namibia is increasing rapidly. Recreational fisheries generate more income in South Africa than all the other fisheries combined. While the recreational catch is substantial, it is far lower than the commercial catch, although more comparable to the small-scale commercial catches. Recreational anglers target many species in common with the commercial linefisheries, and the recreational CPUE has also undergone a marked decline over the past two decades (Van der Elst 1989, Bennett 1991, Griffiths 1999). In spite of this, recreational angling has been one of the fastest growing sports in the last decade. Although recreational anglers may redistribute themselves to some degree in response to local changes in catch rate due to depletion, the demand for fishing is not greatly affected by overall average stock condition. Recreational anglers quickly adapt to the level of effort required to catch fish, and the value of this fishery is probably the least sensitive to overexploitation of any fishery. The effort, mostly comprising leisure time, carries very little cost to recreational anglers, and thus expenditures cannot be expected to change significantly until catch rates virtually fall to zero.

Health impacts

Overexploitation of fish resources may thus have implications for the diet and consequently the health of subsistence fishers. There are no substantial health issues associated with overexploitation in the region, as there is not a great reliance on fish or other aquatic resources as a protein source. Subsistence fisheries may form an important protein source in those households which rely on them, even though these fisheries do not form a major component of the fisheries of the Benguela Current region as a whole. Although there are no known cases of direct starvation, overexploitation leads to increasing poverty levels of those that depend on the resources. There are also numerous indirect impacts on human health (related to poverty caused by overexploitation). These include alcoholism, family violence, and many others. Health impacts are therefore assessed as moderate in the region (Members of the GIWA Task team pers. comm.).

Other social and community impacts

Other social and community impacts of the concern Unsustainable exploitation of fish and other living resources are assessed as moderate in the region. Overexploitation leads to a decrease in commercial viability of fishing operations, and results in unemployment and increasing poverty. Intermittent employment also results in family disruptions. In addition, overexploitation leading to decreased resource availability results in conflicts between user groups. Existing resource use patterns, although they may be unsustainable, especially in the light of increasing population pressure, are difficult to change as they are seen as a traditional right.

Marine resources form an important protein supplement in a wider southern African context, with land-locked countries depending on the export of marine resources from maritime states, including those in the Benguela Current region in order to supplement their food supply (Hara 2001). The overexploitation of the resources in the Benguela Current region would result in the cessation of this export trade. This would cause an economic loss for the countries within the Benguela

Current region, a loss of employment opportunity for people within the region, and may have adverse effects on health in other southern African countries.

The abalone resource, which is overexploited, has become a lucrative resource. As a result, crime syndicates have become established, illegally fishing already greatly depleted stocks (Hauck & Sweijd 1999). This has led to the oppression of the people in the relevant coastal areas, who live in fear of the syndicates, making cooperation with fisheries management authorities difficult. The collection of abalone became even more lucrative than other employment options (Hauck & Sweijd 1999). In addition, the overexploitation of abalone has led to major conflicts between user groups. This is an extreme case, but shows the indirect socio-economic effects of overexploitation.

In South Africa, the fishing industry is valued at approximately 400 million USD, and employs approximately 26 000 people. The Western Cape Fishing Industry is responsible for 90% of the total value (Western Cape Fishing Industry 2005). The industry is currently being restructured to increase access for previously disadvantaged fishermen and to boost smaller players through the reallocation of fishing quotas. Overexploitation of the South African West coast rock lobster has resulted in fisheries managers adopting a cautious management policy (Cockroft & Payne 1999). As a result the quota system and Total Allowable Catch (TAC) has not yet stabilised and user groups are operating on short-term contracts. This has resulted in instability in the industry.

In December 2000, Mr Vali Moosa, the Minister of Environmental Affairs and Tourism in South Africa, banned the commercial linefishing of 40 fish species that were known to be overexploited. This resulted in the loss of up to 300 jobs. In 2001, it was announced that the application fees for commercial fishing rights would be increased from 13 to 800 USD. This amount would be non-refundable, putting a strain on the applicants (Members of the GIWA Task team pers. comm.). In July 2003, it was announced that the number of fishing licences for the linefishery would be decreased as a result of potential stock collapse due to overexploitation. It was decided that 450 vessels would be allocated rights, maintaining 3 450 crew. There were a total of 742 applications for fishing licenses, and approximately 300 applications were denied. Eight out of 40 vessels in one small harbour (Kalk Bay) and two out of 100 ski-boats in another (Hout Bay) were allocated rights (Figure 9) (Members of the GIWA Task team pers. comm.). This has led to protest meetings by the fishermen who are left without a means to provide an income for their families and has led to illegal fishing by those who were denied fishing rights (Members of the GIWA Task team pers. comm.). Overexploitation of stocks can therefore result in unemployment and increased criminal activity, which in turn has economic implications in terms of increased policing effort.

Conclusions and future outlook

The large-scale commercial demersal and pelagic fisheries were probably the first to encounter the impacts of overexploitation in the Benguela Current region. These fisheries have experienced dramatic

Figure 9 Fishing vessels in Hout Bay, South Africa.
(Photo: M. Karlsson)

declines in stocks and CPUE, and have experienced years of TACs well below the maximum or optimal sustainable yields that could have been maintained in a well managed fishery. With greatly improved means of stock assessment and quota setting, as well as stricter enforcement, the fisheries are now considered to be well managed, though some are still in a state of recovery and have not returned to their full potential. The catches in these fisheries have been relatively stable over the past 10 years, and these fisheries can be considered to have adapted to, or recovered from the impacts of past overexploitation. Furthermore, it is unlikely that these stocks will be as badly overexploited in the future as some of them have been in the past. The same cannot be said for the smaller, lower value fisheries in the region. Most of these fisheries are not well managed, and continue to operate outside of sustainable limits. This is particularly evident in fisheries with a large number of participants and/or where entry into the fishery does not require a large capital investment. These fisheries require urgent management intervention in order to reduce effort and allow stocks to recover such that maximum benefit can be realised.

South Africa and Namibia have adopted the "user pays" principle but management and enforcement requirements for most of these small fisheries far exceed the tax revenue that can be extracted from the participants. An alarming proportion of inshore species are overexploited, several having collapsed to below 10% of their pristine spawner biomass. Interestingly, however, overall catches of linefish have remained relatively stable over the past 10 years. Catch figures, however, do not reflect changes in CPUE, which generally declines with a decline in stock size. Unless small-scale commercial fishing effort is drastically curtailed, these fisheries may be expected to have virtually no value within the next 10 years. Indeed, it is estimated that an effort reduction of 60% is required to achieve maximum economic yield from the net fishery for example (Hutchings et al. 2000).

Global change

Freshwater component **Marine component**

The Intergovernmental Panel on Climate Change (IPCC) have stated unequivocally that the Earth's climate is changing. Recent temperature trends over the southern hemisphere (1950-1985) indicate a warming trend of 0.1 to 0.5°C per decade in the lower trophosphere, rising to 0.2 to 0.8°C in the latter part of this period (1966-1985) (Tyson 1990, Karoly 1988). Warming in the Benguela Current region (i.e. west coast of South Africa) in this period was about 0.6°C (Tyson 1990). A slight warming trend has also been noted in Sea Surface Temperature (SST) data for the southeast Atlantic, corresponding to an increase of about 1°C in the period 1920 to 1988 (Taunton-Clark & Shannon 1998). No large-scale systematic linear trends are evident in rainfall patterns during the 20th century (Tyson et al. 1975, Tyson 1986), but some evidence is available to suggest that variability and extremes are increasing in the drier western parts of the Benguela Current region (Tyson 1986, Nicholson 1993, Nicholson 1986, Mason et al. 1999).

A trend of increasing upwelling intensity has been observed in the Benguela Current over the last four decades (Shannon et al. 1992), mirrored by similar trends in most of the other major coastal ocean upwelling centres in the world (Bakun 1990). Bakun (1990) believes that these changes are a function of the build-up of CO_2 and other greenhouse gasses in the atmosphere. He argues that the CO_2 build-up has enhanced daytime heating and reduced night-time cooling, and has lead to an intensification of continental lows adjacent to upwelling regions. This in turn, he argues, has increased on-offshore pressure gradients, intensified alongshore winds and hence has accelerated coastal upwelling. With intensified upwelling one would expect an increase in primary productivity, but data from the Benguela Current indicate that, if anything, chlorophyll a concentrations have declined in recent decades (Brown & Cochrane 1991). Abundance of zooplankton, on the other hand, has increased over a similar period (Verheye et al. 1998).

Environmental impacts

Changes in the hydrological cycle

Rainfall at four locations in South Africa during the 1990s was not shown to differ from the average for the period from 1960 to 1989 (Department of Environmental Affairs and Tourism 2000). However, all models predict that rainfall in the region, which already suffers from aridity, will decline. By the 2050s Namibia is expecting a decrease in rainfall of between 2.5 and 7.5%, an increase in evaporation of between 4 and 16%, and an increase in rainfall variability of between 5 and 15% (Ministry of Environment and Tourism 2002). Extreme events such as droughts and floods appear to be increasing in frequency, intensity and magnitude (Ministry of Environment and Tourism 2002) and the impacts of this issue in both fresh and marine waters are considered moderate. There is a lack of data regarding cause and effect in freshwater systems. However, models indicate severe reductions in mean annual run-off and mean annual precipitation in southern Africa, suggesting that an assessment of the impacts as severe may be more appropriate.

Sea level change

There is some evidence of sea level change in the region. Long-term tide gauge records from a number of locations in Namibia and South

Africa indicate that sea levels have risen by approximately 1.2 mm per year over the last three decades (Hughes et al. 1991, Brundrit 1995), a rate consistent with global sea level rise related to global warming (Department of Environmental Affairs and Tourism 2000). No known loss of marine populations of organisms has occurred, however, and the known impacts are thus considered slight in the region. The current trend of rising sea level is thus expected to accelerate in the future, with recent estimates indicating a 12.3 cm rise by 2020, 24.5 cm rise by 2050 and a 40.7 cm rise by 2080 (Nicholls et al. 1999).

Increased UV-B radiation

Measurements of UV-B radiation at Pretoria and Cape Town in South Africa indicate no change between 1994 and 1998 (Department of Environmental Affairs and Tourism 2000). This data set is, however, unlikely to be of sufficient length to indicate any long-term trends in UV-B radiation. However, UV-B, measured as Minimum Erythema Dose (MED), in both cities is sufficiently high to be classified as "dangerous" and "very dangerous" for almost half of the year (Department of Environmental Affairs and Tourism 2000). For these reasons, a moderate impact is assessed for freshwater systems for this issue, while marine systems are assessed as having no known impact.

Changes in ocean CO_2 source/sink function

Scientists in the region suspect that alteration of the ocean CO_2 source/sink function has occurred, but have no direct evidence to support this. The issue is thus assessed as having slight impacts in the region.

Socio-economic impacts

Economic impacts

Costs associated with global change include the costs of managing fisheries to ensure their long-term sustainability, and the costs of damage to infrastructure caused by extreme events. There is a large concern, however, about the links between global change and certain climatological phenomena. This lack of evidence leads to great uncertainty about the economic impacts of global change because, although we may know that these exist at present, we may not necessarily be able to link these directly to global change. The GIWA Experts therefore consider that there is too much uncertainty surrounding the economic impacts of global change to be able to rate the impact as more than unknown.

Health impacts

The number of people currently affected by global change was not deemed to be large. The major health problems associated with global change are skin cancers related to increased UV-B radiation as a result of ozone depletion, and events related to extreme climatological phenomena. These include injury and death, as well as infrastructure collapse leading to increases in water-borne diseases. Health impacts are thus considered slight in the region at present.

Other social and community impacts

There is some social disruption caused by extreme events but, at present, this is considered to be having a very slight impact.

Conclusions and future outlook

Relationships between biological and physical environmental processes are not well understood for the Benguela Current. Even greater uncertainty must thus be attached to projections regarding effects of climate change on marine biota, than to the changes themselves. Most scientists are of the opinion, however, that change in wind stress in the Benguela Current region is likely to have more pronounced consequences for marine biota than other effects such as increasing temperature, sea level rise, changing rainfall and river run-off to the coastal zone, because of its influence on large-scale oceanographic processes (Siegfried et al. 1990, Brown & Cochrane 1991, Clark et al. 2000, Lutjeharms et al. 2001). Increases in wind stress over the Benguela Current region (considered to be the most likely outcome of climate change) is expected to result in an intensification of upwelling, increased nutrient availability, enhanced primary production, increased advection of cold upwelled water offshore, reduced rainfall over the adjacent subcontinent, all of which could affect pelagic and demersal food webs and fish production. Pelagic fish recruitment is dependent on a balance between food supply and losses across the open ocean boundary, both of which are a function of wind stress. Best recruitment appears to occur under intermediate conditions and hence may be negatively affected if upwelling intensifies or diminishes.

Another phenomenon of the Benguela Current system that will be affected by changes in wind dynamics is the irregular occurrence of Benguela Niños (Shannon et al. 1986, Crawford et al. 1990, Siegfried et al. 1990, Lutjeharms et al. 2001). These events generally coincide with periods of low or sharply reduced zonal wind stress in the Western Equatorial Atlantic, and are characterised by the sudden collapse of the Angola-Benguela Front and a polewards flow of warm water along the coast from Angola into Namibia. They are usually accompanied by a southward penetration of tropical species such as *Sardinella aurita* and certain copepod species normally only found from Angola northwards, a decrease in primary production off Namibia, southwards displacement of local (Namibian) fish stocks, an influx of low oxygen water from the north and associated mortalities of fish and other organisms. It is believed that changes in the equator-pole temperature gradient and poleward shifts in oceanic and atmospheric systems (considered to be a likely consequence of climate change) may lead to an increase in the frequency and intensity of these events with immediate consequences for the upwelling system, SSTs in the region and biota of the coastal zone (Siegfried et al. 1990, Lutjeharms et al. 2001).

Changes in the influence of the Agulhas Current on the Benguela system, brought on by changes in wind stress, may also be important in the future. The Agulhas Current flows down the east coast of South Africa and terminates in a tight loop south of the African sub-continent, the Agulhas retroflection. The current normally follows an extremely stable trajectory but is periodically (4-6 times per year) interrupted by a solitary meander, the Natal Pulse, that causes the current to shed a ring of warm water when it reaches the retroflection area. These rings then drift off into the South Atlantic or up the west coast (Lutjeharms & Van Ballegooyen 1988, Lutjeharms & Gordon 1987, Gordon & Haxby 1990). These rings have been observed to interact with upwelling plumes and can contribute to the failure of Anchovy (*Engraulis capensis*) recruitment in the southern Benguela and to a tendency for winter depressions moving past the southwestern Cape to intensify (Duncombe Rae et al. 1992, Brundrit & Shannon 1989). Increases in wind stress over the south Indian Ocean (also a projected consequence of climate change) may lead to an increase in frequency of the Natal Pulse and consequently to an increased flux of Agulhas rings into the south Atlantic, with concomitant effects on the biota (Lutjeharms & de Ruiter 1996, Lutjeharms et al. 2001).

Temperature is generally considered to be one of the most important physical variables controlling the life of all aquatic organisms. Changing global temperatures could thus also have far reaching consequences for marine organisms in the Benguela Current region. The most obvious changes that can be expected with increasing SSTs around the country, is that individual species or species assemblages will shift their distribution patterns in response to changing temperature regimes. This is likely to be most pronounced in those species that are most temperature sensitive or whose distribution patterns are strictly governed by temperature. Cold-tolerant species typically found only on the cool temperate west coast are likely to become more restricted in their distribution in the face of increasing temperatures. They may retreat to greater depths or become restricted to the immediate vicinity of the stronger upwelling cells. Some of the warm-tolerant species from the east and south coasts may expand their ranges southwards and westwards, possibly even extending around Cape Agulhas onto the west coast (Members of the GIWA Task team pers. comm.).

Projected changes in stream flow (a function of changing rainfall patterns) are likely to have serious consequences for estuaries of the Benguela Current region. Any reduction in flow, particularly in the frequency or intensity of flooding, has several major consequences for estuaries (Reddering & Rust 1990). These include changes in the erosional capacity and other sedimentary processes, depth profiles, mouth configuration, duration of the open phases and tidal prism within an estuary. Sand shoals situated in the mouths and lower reaches of estuaries will grow larger, constricting the channel and reducing tidal exchange with the sea. Ultimately this will have the effect of increasing the frequency and length of time for which the mouths will close. A change in flow may also be accompanied by changes in nutrient levels, suspended particulate matter, temperature, conductivity, dissolved oxygen and turbidity (Drinkwater & Frank 1994), all of which play a role in structuring biological communities in estuaries. Many estuaries will simply remain closed for much of the year or for several years at a time thereby excluding many marine species. Many marine fish in southern Africa make use of estuaries as nursery and breeding grounds (Wallace et al. 1984), estuaries on the west coast of South Africa being disproportionately more important than in the rest of the country due to the paucity of sheltered embayments along this coast (Bennett 1994). These fish have adapted their breeding habits to take advantage of the seasonal opening and closure of river mouths. Seasonal changes in river flow are likely to alter the timing of the open and closed phases and will impact negatively on recruitment into these systems. A reduction in freshwater run-off is also likely to result in a reduction in the extent to which wastewater discharges are diluted before reaching estuaries. The concentration of pollutants in estuarine waters will increase while levels of dissolved oxygen will decrease, reducing the capacity of these environments to support biological communities.

The potential impacts of sea level rise on the coastal environment of the Benguela Current region include increased coastal erosion, inundation, increased saltwater intrusion and raised groundwater tables and increased vulnerability to extreme storm events (Klein & Nicholls 1999). Several major cities such as Cape Town, Walvis Bay and Swakopmund, are situated at sea level and are thus at risk from some or all of these sources. Lutjeharms et al. (2001) are of the opinion that the impact of sea level rise on the ecological functioning of the Benguela system is likely to be insignificant, except in shallow coastal lagoons and estuaries where much of the marine production is linked to salt marsh ecosystems. In areas where sea levels are rising and a strong supply of sediment is absent, marshes rapidly become water logged or completely inundated and species unable to tolerate these conditions or the increased salinity from marine waters, die back and expose the underlying sediments to further erosion (Beeftink 1979).

Certain minor responses can be expected of marine plants and algae as a result of elevated CO_2 levels in the atmosphere. Some plants (e.g.

seagrasses) are expected to show enhanced photosynthetic rates and growth, while others (e.g. intertidal macroalgae) are already CO_2 saturated and may not show any response (Beardall et al. 1998). Some response can also be expected from increases in ultraviolet radiation reaching the Earth's surface, related to losses in ozone from the upper atmosphere due to human production of chlorofluorocarbons (CFCs). Effects of increasing UV-B radiation are likely to be minor in comparison to other effects of climate change, though. Enhanced UV-B fluxes are likely to favour species with UV-B tolerance or repair mechanisms (Beardall et al. 1998). Intertidal species, for example, generally show less inhibition of photosynthesis by UV-B radiation than their subtidal counterparts. Increases in UV-B fluxes may thus exert some sort of control over species' distribution patterns (Larkum & Wood 1993, Beardall et al. 1998). UV-B radiation can also cause damage to early developmental stages of fish, shrimp, crab and other species (Häder et al. 1995), and may thus disproportionately affect those species with planktonic larval stages.

If the current predictions regarding global change (and in particular changes in the hydrological cycle and associated rainfall patterns) materialise, then the environmental impacts of the concern are likely to become a lot worse in the future. Confidence in these predictions is not very high, however, especially in terms of the timescale over which these effects will become apparent. One climate model, for example, predicts a 60% reduction in freshwater flow in the Western Cape alone over the next 20 years (for more information regarding climate models see Box 1). Another factor considered here was that of thresholds, and there was a grave concern that the problem may worsen quickly. A decrease in water availability is also likely to cause major social changes and disruptions in the future, including movements of people, and loss of cultural heritage. Communities who move to wells or taps will give up a nomadic lifestyle and become settled. There will also be important effects on fisheries and agriculture, and by association, with grazing patterns. There is large uncertainty in these predictions, however, due to the large uncertainty of what global change is likely to bring. Baseline data and monitoring are going to be important tools in tracking change and in making forecasts for the future.

Box 1 Climate models.

Numerical models generally referred to as Global Climate Models (GCMs), provide the only quantitative estimates of future climate change. A large number of GCM experiments have been completed recently, employing a variety of different models. It must be acknowledged, however, that the ability of these models to provide accurate predictions is still questionable, particularly with respect to regional level prediction (Michell & Hulme 1999).

Ragab & Prudhomme (2002) provide predictions of changes in land surface temperature and precipitation for southern Africa including the countries bordering the Benguela Current region (Angola, Namibia and South Africa) generated by the UK Hadley CentreÌs global climate model using the IS92a forcing scenario (this assumes an increase in atmospheric CO2 of 1% per year). They predict that by 2050 annual average temperatures will have increased by between 1.0 and 2.75°C. Winter increases (1.0-3.0°C) are projected to be slightly greater than summer increases (1.0-2.75°C). Predicted changes in average annual rainfall in 2050 over the Benguela Current region varies widely, ranging from ñ25 to + 25%. Average rainfall over the South African west coast is expected to decrease by 0 to 15% (slightly worse in summer than winter), to increase on average by 5 to 25% in the southern, central and extreme northern parts of Namibia (summer and winter being similar), to decrease on average (0-10%) in the lower northern parts of Namibia (summer worse than winter), and to increase in southern Angola during winter (5-10%) and decrease in summer (0-20%).

Schulze et al. (2001) provide predictions of changes in annual rainfall and river run-off over southern and eastern Africa for 2050 from the UKTR95 GCM and ACRU agrohydrological modelling system. They predict that both rainfall and annual run-off will decrease by 0 to 30% across the entire Namibian and South African west coast, the hardest hit areas being the extreme northern and southern parts of Namibia and the northern half of South Africa. Arnell (1999) also used data from the UK Hadley CentreÌs global climate model (HadCM2 and HadCM3) together with a macro-scale hydrological model to simulate river flow across the globe at a spatial resolution of 0.5 x 0.5. On this basis he predicts that average annual run-off to the Benguela Current would decrease by 0 to 50 mm per year (from an average of 0-200 mm/year), making the percentage run-off change in southern Africa amongst the highest in the world. These projections correspond closely with those reported by Clark et al. (2000) who estimated that reduction in run-off from four rivers on the South African west coast to be in the region of 35 to 84% if CO2 levels doubled (using the HADCM2 GCM coupled to the ACRU modelling system).

Clark et al. (2000) also provide projections of changes in pressure systems and wind fields over southern Africa for spring and summer under a double CO2 scenario, using data from the National Centre for Atmospheric ResearchÌs (NCAR) Climate System. This period was chosen as it corresponds to the period of most intense upwelling and spawning period for pelagic fish in the Benguela system. The results of this analysis suggest that the South Atlantic High Pressure system will intensify, especially in the late summer months, and will ridge further south and east of the subcontinent than it does at present. Southerly and easterly winds are expected to increase over the Benguela Current region as a result, and upwelling is expected to intensify.

Priority concerns for further analysis

In the region's freshwater the combined environmental and socio-economic impacts of the concerns of Freshwater shortage and Pollution are assessed as severe, while Habitat and community modification is assessed as moderate, and the impacts of Global change as slight. In marine environments, the impacts of Pollution, Habitat and community modification, and Unsustainable exploitation of fish and other living resources are assessed as moderate, and the impacts of Global change as slight (Table 14).

On the basis of the severity of the impacts, two priority concerns were chosen for more in-depth analyses. In choosing priority concerns, consideration was given to choosing one concern which represented

Table 14 Overall score for the five GIWA concerns in the Benguela Current region.

Concern	Score	
	Freshwater component	Marine component
Freshwater shortage	Severe	Not assessed
Pollution	Severe	Moderate
Habitat and community modification	Moderate	Moderate
Unsustainable exploitation of fish and other living resources	Not assessed	Moderate
Global change	Slight	Slight

freshwater environments, and one which represented marine environments. The two concerns chosen were Freshwater shortage and Unsustainable exploitation of fish and other living resources. Further justification for the selection of these two GIWA concerns for further analysis follows.

Freshwater shortage was selected as a priority concern on the basis of the justifications given in the Assessment and for the reasons outlined here. The region is arid in nature, and already suffers from problems of increasing demand and decreasing supply of freshwater. Huge decreases in river flow have already been evidenced in the region, with the result that a number of permanent rivers have become intermittent in nature, while some intermittent rivers have ceased to flow. Microbiological pollution from urban point sources and informal settlements, and overabstraction of aquifers with long regeneration times further reduce the available water supply and compromise the long-term sustainable use of freshwaters in the region. These environmental impacts lead to very serious socio-economic impacts, including the high costs of alternative water sources, increases in water-borne diseases, conflicts over water, relocation of people for dam construction, and loss of nomadism and traditional customs. In addition, impacts on freshwaters often result in downstream impacts on other ecosystems, including estuaries and coasts, and often have significant transboundary implications. For these reasons, Freshwater shortage was highlighted as a priority concern, and within this, modification of stream flow was deemed the most important contributing issue.

Unsustainable exploitation of fish and other living resources was selected as a priority on the basis of the justifications given in the Assessment and for the reasons outlined here. Overexploitation is a widespread problem in the region, and affects a large number of living resources, including several on which local people rely for their livelihoods. The problems are primarily related to marine systems, and have important biological and socio-economic impacts. Despite efforts at management, declines in catches have been documented for many fish and invertebrate stocks. In many cases, and particularly in inshore fisheries, these are exacerbated by illegal fishing. Besides the obvious biological impacts of such overexploitation, there are also profound impacts on the socio-economic environment, including among others, direct economic losses, job losses, and losses of livelihoods for subsistence fishers. While it seems feasible that overexploitation in the large commercial fisheries, which are relatively easily regulated, will improve by 2020, grave concerns remain regarding the future of the smaller fisheries which are not as easily regulated, and it is likely that these will continue to be overexploited.