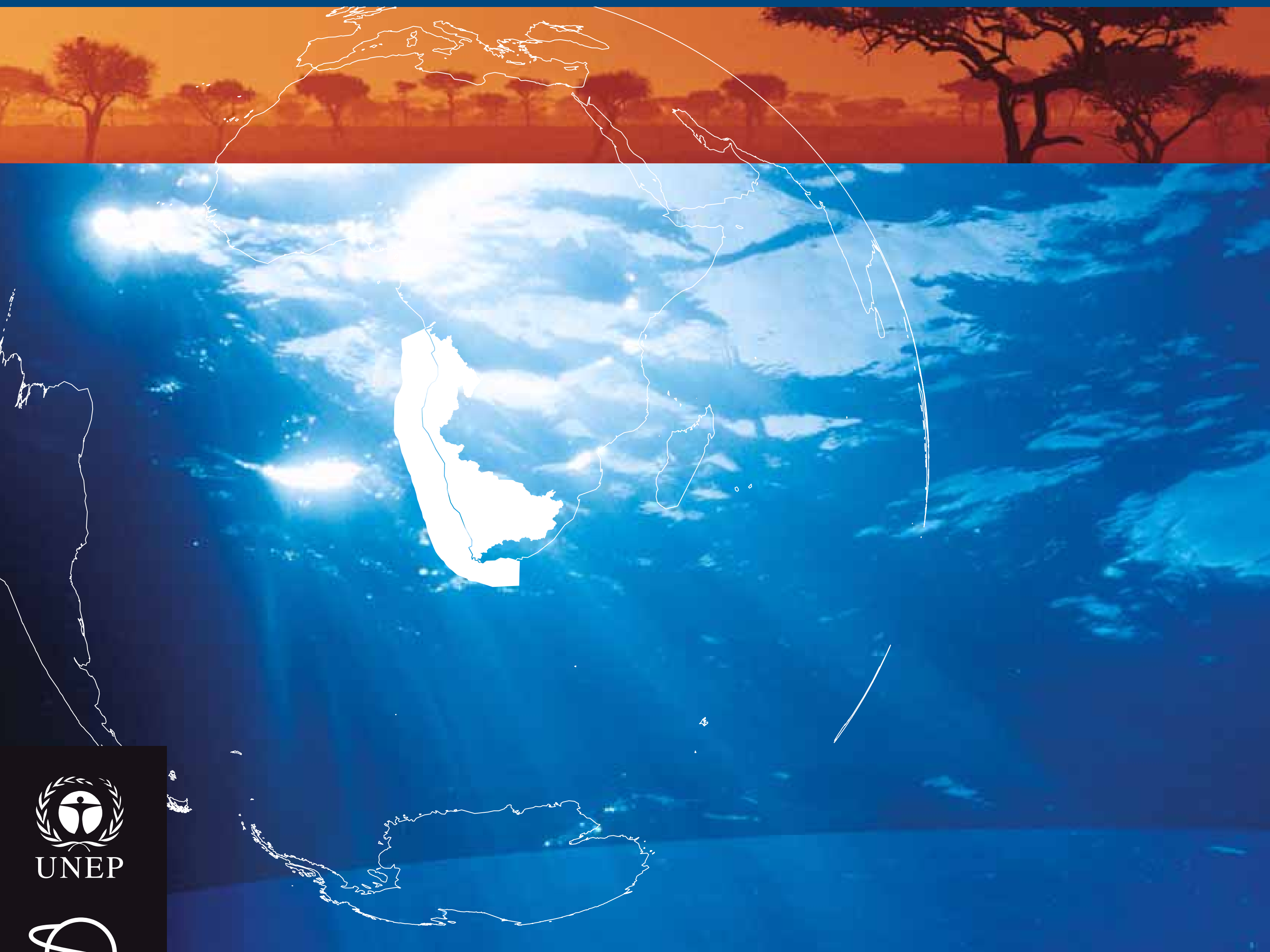
Global International Waters Assessment



Benguela Current

GIWA Regional assessment 44

Prochazka, K., Davies, B., Griffiths, C., Hara, M., Luyeye, N., O'Toole, M., Bodenstein, J., Probyn, T., Clark, B., Earle, A., Tapscott, C. and R. Hasler

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Regional assessment 44
Benguela Current

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Contents

Executive summary

The Benguela Current region (GIWA region 44) includes the entire extent of the Benguela Current system and the freshwaters that drain into it. The region spans five countries, including Angola, Namibia, Botswana, South Africa and Lesotho. The total coastline of the region extends some 4 590 km from the Angolan enclave of Cabinda in the north to Cape Agulhas at the southern tip of the African continent. The combined Exclusive Economic Zones of the three coastal states covers some 1.9 million km^2, with an estimated 1.4 million km^2 falling within the Benguela Current region.

The cold, northwards-flowing Benguela Current system to a large extent controls the climate of the region, which is for the most part arid or semi-arid. The climate in turn influences the human dimensions of the region, with the drier western areas being more sparsely populated than the wetter eastern parts. The region is characterised by high variability, both in natural processes such as rainfall and upwelling, and also in socio-economic processes, with the highly industrialised Gauteng Province of South Africa contrasting dramatically with subsistence-based activities in Angola. The variability in the human dimensions translates into differing anthropogenic activities in different parts of the region, and hence into differing environmental impacts across the region. A major difference in the environmental impacts is evident between the freshwater and marine systems of the region, and these systems were therefore assessed separately.

Environmental impacts surrounding the unsustainable use of freshwater resources are severe in the region, while the impacts of this environmental degradation on the social and economic dimensions are considered moderate to severe. This, together with the backdrop of the natural aridity of the area, resulted in the GIWA concern of Freshwater shortage being highlighted as a priority for further analysis. Modification of stream flow through the construction of dams and the overabstraction of water for agriculture and industry was considered to be the major contributor to Freshwater shortage in the region. Pollution of freshwater resources through a number of avenues is also considered to be severe in the region, as are the impacts of changes in the water table due to overabstraction of aquifers with long replenishment times. Although some measures are in place to address the problems of freshwater shortage in the region, the outlook for 2020 remains poor.

Almost all forms of pollution of freshwater systems are assessed as being severe, resulting in the overall assessment that the GIWA concern Pollution is severe in the freshwater systems of the Benguela Current region. The primary issue of concern related to pollution of the marine environment is that of oil spills, which have profound environmental and economic impacts. Microbiological pollution, and pollution by solid waste are considered to be moderate, although highly localised, while pollution by suspended solids as a result of marine mining activities is also considered moderate but more diffuse. The prognosis for 2020 is of further deterioration of all types of pollution across the region.

The modification and loss of freshwater habitats and communities of the Benguela Current region is assessed as severe. All major freshwater habitats are considered to have undergone some form of transformation, and much loss of habitats and ecosystems was also evident. In the marine environment, modification and loss of ecosystems and habitats is assessed as moderate. Of particular concern are coastal lagoons, estuaries and mangroves. The projection for the future is that habitats and communities within the Benguela Current region will continue to be transformed, and that further losses of habitats and ecosystems will occur.

Due to a low level of activity related to freshwater fisheries in the Benguela Current region, and the overwhelming importance of marine fisheries, the GIWA concern of Unsustainable exploitation of fish and other living resources was assessed only in the marine environment. Overall the impacts of the concern are assessed as being moderate in the region. Overexploitation was by far the most important contributing issue, with stocks of many marine resources being considered overexploited at present, and with resultant declines in catches having been documented. As a general overview, it would appear as if the larger commercial fisheries are more sustainably managed at present, than are the smaller, and particularly the artisanal, fisheries. The future outlook is of sustainable commercial fisheries, but of a worsening of the current unsustainable exploitation in the smaller and less valuable fisheries by 2020.

The impacts of the GIWA concern of Global change are assessed as moderate in freshwater systems and slight in marine systems. The assessment of global change should be treated with some caution, as this is an area where data are not readily available. Thus, in several cases, although impacts may currently exist, no direct evidence could be found for these, and it is thus likely that the assessment may have underestimated the impacts. The environmental and socio-economic impacts of all issues related to Global change are expected to worsen by 2020.

Two case studies were selected for more in-depth analysis of the root causes of environmental degradation, and for analysis of policy options to address these. The two case studies were selected so as to represent both the freshwater and marine environments of the Benguela Current region. The case study of Freshwater shortage in the Orange-Vaal transboundary river system highlighted modification of stream flow through dam construction and overabstraction of water as immediate causes of the environmental impacts. Root causes of this issue include political decisions such as prioritisation of industrial water use, lack of coordination among departments, demographic considerations, economic policies, and improvements in technology, particularly irrigation technology. A suite of policy options for addressing these root causes was developed. This revolved around the three thematic areas of changing the way water is perceived and used, effecting holistic planning, and improving existing management of water resources.

The case study of Unsustainable exploitation of inshore finfish in the Benguela Current transboundary system highlighted overexploitation due to excessive fishing effort and degradation of critical habitats such as estuaries and mangroves as immediate causes of the environmental impacts. The root causes of these were identified as political encouragement of small-scale fisheries, governance failures and difficulty of regulation of inshore finfish fisheries, a number of economic considerations, improved capture technology, and poor voluntary compliance. A suite of policy options was developed to address the root causes of overexploitation around the two major themes of reducing access to the fisheries and improving voluntary compliance with existing regulations. A suite of three thematic options was developed to address the root causes of degradation of critical habitats, including introduction of holistic management of these habitats, creation of alternative economic activities in coastal areas, and improved voluntary compliance with existing regulations.

Abbreviations and acronyms

BCLME	Benguela Current Large Marine Ecosystem Programme
CFCs	Chlorofluorocarbons
CIA	Central Intelligence Agency (USA)
CPUE	Catch Per Unit Effort
CSIR	Council for Scientific and Industrial Research (South Africa)
DDT	Dichlorodiphenyltrichloroethane
DWAF	Department of Water Affairs and Forestry (South Africa)
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization (United Nations)
GCM	Global Climate Model
GDP	Gross Domestic Product
GEO	Global Environment Outlook
GGP	Gross Geographic Product
GIWA	Global International Waters Assessment
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
IUCN	The World Conservation Union
LORMS	Lower Orange River Management Study
MARPOL	International Convention for the Prevention of Pollution from Ships
NCAR	National Centre for Atmospheric Research (USA)
ORASECOM	Orange Senqu River Commission
PBMR	Pebble Bed Modular Reactor
Ramsar	Convention on Wetlands of International Importance
SADC	Southern African Development Community
SEAFO	South East Atlantic Fisheries Organization
SST	Sea Surface Temperature
TAC	Total Allowable Catch
UN	United Nations
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency

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Regional definition

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

Boundaries of the region

The Benguela Current region (GIWA region 44) includes the entire extent of the Benguela Current system and the freshwaters that drain into it. The northern boundary extends to include Cabinda, a province of Angola which is entirely enclosed within the Democratic Republic of the Congo, and which represents the most northerly influence of the Benguela Current system on the marine environment and the socio-economic climate (Figure 1).

Further landward, the region includes most of the western parts of Angola. The rivers draining into the Congo Basin are specifically excluded from this region, as they are being dealt with as part of the Congo Basin in the Guinea Current region (GIWA region 42). Also included in the region is most of Namibia, with the exception of the rivers that drain into the Okavango system, as the Okavango is being considered as a discrete system within the Agulhas Current region (GIWA region 45a). The boundary of the region extends east to include the hyper-arid southwestern parts of Botswana. Since this includes such a small area of the country, Botswana will not be discussed in any detail in this report. Within South Africa the region includes the entire catchment of the Orange-Vaal drainage basin, and thus includes the large and industrialised urban centres of Johannesburg and Pretoria. Although not strictly falling within the boundaries of the Orange-Vaal Basin, the Gauteng Province is nevertheless an important recipient of water from this catchment, and for this reason is considered as part of the region. The country of Lesotho is also included within the region as it falls entirely within the Orange-Vaal drainage basin. The region does not include the rivers draining off the eastern escarpment of South Africa, nor the rivers draining onto the south coast of the country, as these are included in the Agulhas Current region. The easternmost boundary on the landward side is at Cape Agulhas.

For the purposes of this assessment, the oceanic boundary of the region is taken as the limit of the 200 nautical mile Exclusive Economic Zone (EEZ). Use of the 200 nautical mile EEZ as a boundary delimiter is partially as a matter of convenience, but also to ensure that all economic activity associated with the transboundary waters of the Benguela Current region are included in the assessment. For the convenience of this assessment, the northern boundary is considered as a line drawn from the northernmost landward point (the northern tip of Cabinda Province) and extending out to the 200 nautical mile limit. In the southeast the region includes the entire Agulhas Bank as there is significant biological interaction between the Agulhas Bank and the Benguela Current, and this area is thus of transboundary significance within the Benguela Current region.

A number of aquatic systems within the region are regarded as international waters due to their transboundary linkages, and their locations are marked on the map (Figure 1). The Benguela Current system itself forms part of the South Atlantic gyre system, and flows northwards along the west coast of southern Africa, from South Africa to Namibia and Angola. This system is transboundary by its very nature, and a large proportion of the associated living resources are shared across the entire system, and hence between the three coastal countries. To the south of the region, the Agulhas Bank, which falls entirely within the South African portion of the region, nevertheless has transboundary significance, as there are strong biological interactions

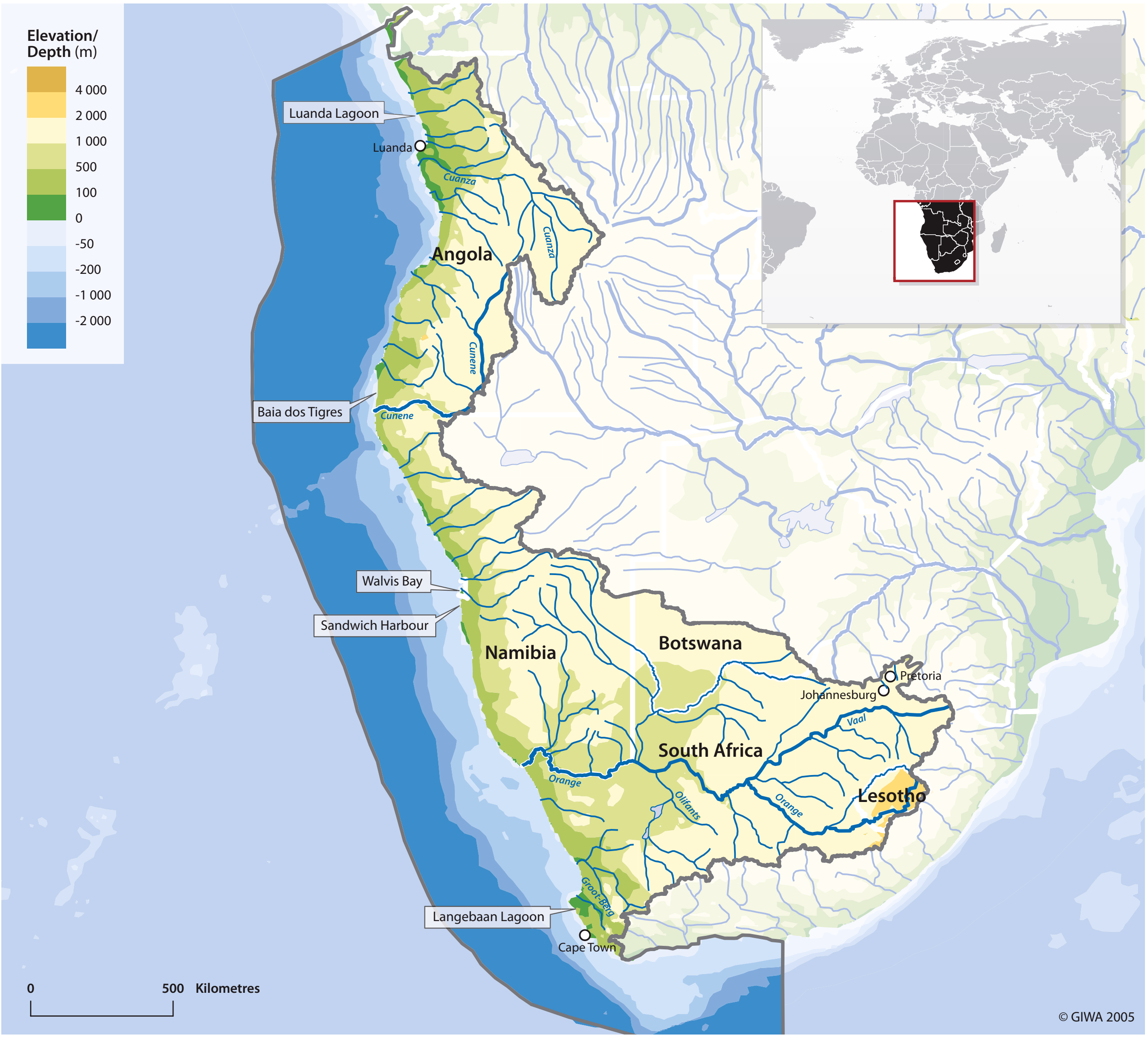

Figure 1 Boundaries of the Benguela Current region.

with transboundary implications between the Agulhas Bank and the Benguela Current.

Two major transboundary river systems are identified within the region. These include the Cunene River, which runs along the national border between Namibia and Angola, and the Orange-Vaal drainage system. The Orange-Vaal system contains several transboundary features. Lesotho, entirely enclosed within South Africa, falls entirely within the drainage basin of this system, and is the source of several of the tributaries of this system. This system has further transboundary significance in that the Orange River runs in part along the national border between South Africa and Namibia. The geo-political boundary currently runs along the northern (Namibian) bank of the river, a situation which results in constant conflict between the two countries regarding "ownership" and use of the River. In a region where water is scarce, the transboundary implications of these shared watercourses are profound.

Five estuaries in the region are considered to be of transboundary significance. These include the Berg River Estuary (South Africa), the Olifants River Estuary (South Africa), the Orange River Mouth (South Africa and Namibia), the Cunene River Mouth (Namibia and Angola), and the Cuanza River Mouth (Angola). These estuaries provide nursery areas for a number of fish stocks which are shared between the coastal countries of the region, and are thus of transboundary significance within the region. The transboundary significance of these estuaries is, however, even more geographically far-reaching, as they provide critical feeding grounds for migratory palearctic wading birds.

In addition to the estuaries, five coastal lagoons in the region are considered of transboundary importance. These include Langebaan Lagoon (South Africa), Sandwich Harbour and Walvis Bay Lagoon (Namibia), and Baia dos Tigres and the Luanda Lagoon (Angola). The primary justification for including these as transboundary waters is that they support large numbers of palearctic migratory birds which use these as feeding grounds during their non-breeding seasons. Five ephemeral pans were also considered to be of transboundary importance, as they provide important feeding areas for both Greater and Lesser Flamingos, which are inter-African migrants. These include Rocher Pan, Wadrif and Brandvlei pans in South Africa, and Sossusvlei and Etosha pans in Namibia.

Physical characteristics

The Benguela Current region is characterised by the presence of flat coastal plains ranging in width from approximately 50 to 150 km. Further inland, the coastal plains rise abruptly up a mountainous escarpment to an inland plateau with an average elevation of between 1 000 and 1 500 m (Encarta 2004).

The Benguela Current is one of the world's four major coastal upwelling systems (BCLME 1999). This highly productive, cold-water system is bounded at both its northern and southern extremities by warm-water systems (BCLME 1999). To the south the Benguela interacts with the warm Agulhas Current, and to the north with the Angola Current at the Angola/Benguela Front which typically migrates between 14° and 17° S on a seasonal basis. The northern extremity of this interaction is approximately at the northern border of Angola (Hampton et al. 1998). Upwelling in the Benguela reaches its greatest intensity near Lüderitz in southern Namibia, but a number of smaller upwelling cells are also recognised.

The climate of the region is influenced primarily by the cold, northwards-flowing Benguela Current, and the geo-morphology. Onshore air flow accumulates little moisture from the cold Benguela Current. The coastal plains consequently receive very little rainfall and are arid or semi-arid. South Africa's western coastal plains, which constitute approximately 21% of the country's land area, receive less than 200 mm of rainfall annually (Encarta 2004). In Namibia, rainfall in the coastal Namib Desert is even lower, reaching only less than 50 mm annually. The Namib Desert extends into southern Angola, and rainfall in this country ranges from less than 50 mm in the south to approximately 300 mm/year in the wetter northern coastal areas around the capital of Luanda (Encarta 2004). Rainfall on the coastal plain is characterised by high inter-annual variability. This low rainfall results in desert and semi-desert conditions on the coastal plains. Vegetation is generally sparse and low, and adapted to xeric conditions (Figure 2). There is almost no natural standing water on the coastal plains. Few permanent rivers traverse the coastal plains to enter the Benguela Current, and those that do have their origins in the wetter escarpment and/or plateau regions.

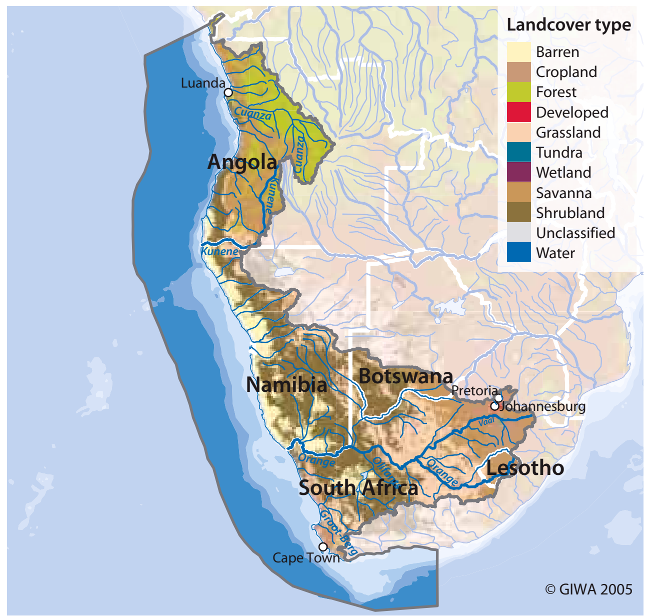

Figure 2 Land cover in the Benguela Current.
(Source: based on USGS 2002)

A mountainous escarpment rises from the coastal plain to the plateau. On the plateau, average annual rainfall is in the region of 200 to 600 mm, decreasing dramatically along an east-west gradient (Encarta 2004). Much of the plateau area falling within the Benguela Current region is arid and/or desert, including the Karoo basins of South Africa, and the Kalahari Basin which spans South Africa, Botswana and Namibia (none of the plateau areas of Angola are represented in the Benguela Current region). The major permanent and transboundary rivers of the region, including the Cuanza River, Cunene River, Orange River and Vaal River, arise in the wetter easterly areas of the plateau (Figure 3).

The coastline of the region is highly exposed to wave action from the prevailing southwesterly, wind-driven swells of the Benguela Current, and few natural sheltered bays exist. Where these are present (including, but not exclusively, False Bay, Table Bay and Saldanha Bay in

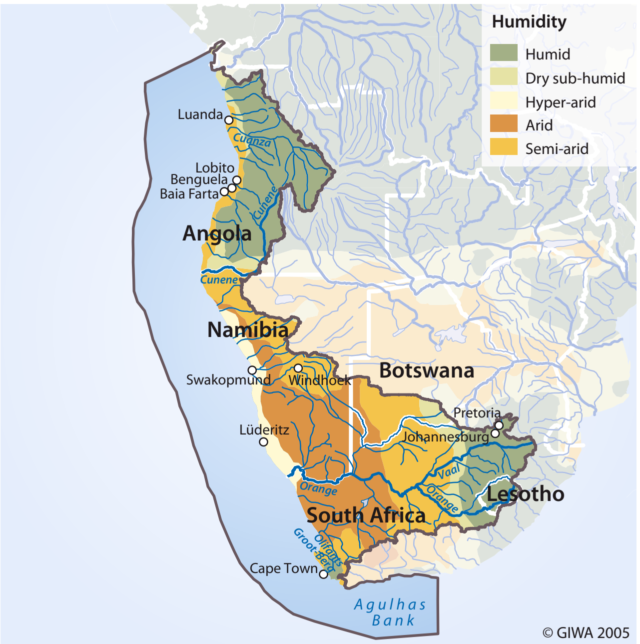

Figure 3 Humidity in the Benguela Current.
(Source: Deichmann & Eklundh 1991)

South Africa, Lüderitz and Walvis Bay in Namibia, and Namibe in Angola) they act as nodes for urban development. The south is characterised by alternating rocky shore and sandy beaches, giving way to almost entirely sandy shore in Namibia and along the Angolan coast. Along the coast of the Namib Desert, the combination of wave and wind-action results in migrating sand-spits which form unstable sheltered bays or lagoons, of which Walvis Bay in Namibia is an example.

The three coastal countries of the Benguela Current region have an estimated total coastline of some 6 030 km, and EEZ of 1.9 million km^2. Assuming that approximately half of the coastline and EEZ of South Africa fall within the region results in the estimated total coastline of the region being 4 590 km, and the EEZ being 1.4 million km^2 in extent (Table 1).

Table 1 Geographical characteristics of the coastal countries in the Benguela Current region.

Country	Coastline (km)	Continental shelf (km^2)	EEZ (km^2)
Angola	1 650	51 000	330 000
Namibia	1 500	111 000	504 000
South Africa	2 880	143 400	1 050 000
Total for the countries	6 030	305 400	1 884 000
Total for the Benguela Current region *	4 590	233 700	1 359 000

*Note: * The estimated total for the Benguela Current region includes the entire coastline, continental shelf and EEZs of Angola and Namibia, and half of each of these for South Africa.*
(Source: SADC 2002)

Socio-economic characteristics

The Benguela Current region contains four countries, including Angola, Namibia, South Africa and Lesotho. Each of these countries has distinct socio-economic characteristics, and the countries are thus presented individually. The population density in the region is shown in Figure 4.

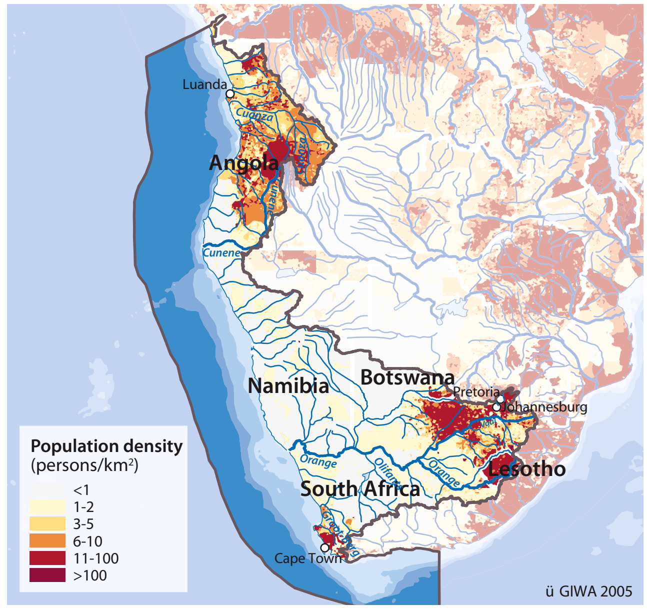

Figure 4 Population density in the Benguela Current region.
(Source: ORNL 2003)

Angola

The socio-economic climate of Angola has for the past 30 years been heavily influenced by continual civil war since its independence from Portugal in 1975. The long-standing civil war had profound negative effects on all aspects of human life in Angola, and this legacy continues. Approximately 6 million people live in the coastal area (UNEP 2005). Populations of the three cities of Lobito, Benguela and Baia Farta, situated on the coast, trebled in the 20 years between 1970 and 1990, while the population in Namibe in the south more than doubled in just six years between 1984 and 1990 (UNEP 2005). The capital city of Luanda, situated on the coast, is home to some 20% of the estimated total population of 13.7 million people (SADC 2003). The portion of the country that lies within the Benguela Current region houses approximately 48% of the total population (Table 2). Population density is 11 people/km^2. Of the four countries in the region, Angola has the highest population growth rate at 1.97%, and the lowest literacy rate, estimated at only 40%. The population consists primarily of Africans (75%), with small portions of the population being made up of Europeans (1%), people of mixed African and European background (2%), and others (22%) (CIA 2003). In addition to the indigenous population, Angola also provides a haven

Table 2 Socio-economic characteristics for the Benguela Current region.

Country	Population in the country (million)	Population in the region (million)	Population of the country in the region (%)	Population growth (%)	Country area (km^2)	Population density (people/km^2)	Urbanisation (%)	Literacy rate (%)	GDP per capita (USD)
Angola	13.7	6.6	48	2.0	1 247 000	11	ND	40	656
Namibia	1.9	0.6	32	1.5	842 269	2	27	76	1 667
South Africa	44.9	15.5	34	0	1 221 000	37	30	82.2	3 714
Lesotho	2.2	1.8	80	0.2	30 355	72	17	78	368

Note: ND=No Data.

(Source: SADC 2003, CIA 2003, Landscan 2001)

Table 3 GDP by sectors in Angola 2001.

Sector	GDP (%)
Oil and gas	54
Trade and commerce	15
Non-tradable services	10
Agriculture, forestry and fishing	8
Diamonds	6
Manufacturing	4
Construction	3

(Source: SADC 2005)

to refugees from its neighbouring country, the Democratic Republic of the Congo. At the same time, many Angolans live as refugees in neighbouring states.

The economy of Angola has been severely disrupted by 30 years of civil war, and GDP per capita is estimated at 656 USD (Table 2). By far the largest contributor to the economy is the production of oil and gas off the coast, contributing 54% of the total GDP in 2001 (Table 3). Agriculture, forestry and fishing contributed 8% in 2001, and of total agricultural production, fisheries accounts for only a few percent, and is thus not an important component of the Angolan economy (SADC 2003, 2005).

Namibia

Namibia is primarily a desert country, and has the lowest population density (2 people/km^2) of the four countries within the Benguela Current region (Table 2). An estimated 27% of the total population of 1.9 million people live in urban centres, with some 10% of the population residing within the capital city of Windhoek (SADC 2003). An estimated 32% of the total population resides within the area defined by the Benguela Current region. The literacy rate is estimated at 76%. The population consists primarily of Africans (87.5%), with small portions of the population being made up of Europeans (6%), and people of mixed African and European background (6.5%) (CIA 2003). Namibia gained independence from South Africa in 1990.

Namibia has a relatively diverse economy that does not rely heavily on only one sector as does that of Angola. Fishing and fish processing contribute a total of 4% to the GDP (Table 4). GDP per capita is estimated at 1 667 USD (Table 2).

Being largely a desert country, water is an important resource for Namibia. Namibia has no permanent rivers entirely her own - all are shared with neighbouring countries (UNEP 2005). Not surprisingly, there are currently several water-related disputes between Namibia and her neighbours. There is currently some dispute between Namibia and Botswana over the construction of the Okavango hydroelectric scheme at Popa Falls, with Angola over the construction of an additional dam on the Cunene River which forms a boundary between these countries, and with South Africa regarding the exact location of the boundary between the two countries in the Orange River. There are also ongoing discussions between Namibia and South Africa regarding the exact location of the boundary between their maritime zones.

Table 4 GDP by sectors in Namibia 2003.

Sector	GDP (%)
Government services	21
Taxes less subsidies	13
Manufacturing	11
Wholesale and retail trade	10
Real estate and business services	9
Transport and communications	8
Mining and quarrying	7
Agriculture and forestry	5
Fishing and fish processing on board	4
Construction	3
Financial intermediation	3
Electricity and water	2
Other	2
Hotels and restaurants	2
Private and community services	<1

(Source: SADC 2005)

South Africa

South Africa has an interesting socio-economic history, having recently become free of the apartheid regime which effectively excluded the majority of the population from being active, participating citizens. Since the change to democracy in 1994, many reforms have taken place in attempts to normalise the country. These reforms are still taking place and South Africa can still be considered a country in transition.

Of the four countries in the region, South Africa has the largest population, estimated at 44.9 million people of which 15.5 million in the region (Table 2). The population is spread over an area of

1.2 million km², resulting in a population density of 37 people/km². Urbanisation is estimated at 30%. Of the urbanised population, approximately half reside in the two major coastal cities of Cape Town and Durban, while the other half reside in the two major cities of Pretoria and Johannesburg, located within the catchment of the Orange-Vaal drainage basin (SADC 2003). Population growth is low, at only 0.01%. This figure includes an adjustment made for the effects of early deaths caused by the severe HIV/AIDS situation in the country. The literacy rate is relatively high, at 82.2%. The population consists primarily of Africans (75.2%), with smaller proportions of the population being made up of Europeans (13.6%), people of mixed African and European background (8.6%), and Asians (2.6%) (CIA 2003).

South Africa has the strongest and most diverse economy of the four countries in the Benguela Current region. GDP per capita is estimated at 3 714 USD (Table 2), and a number of sectors contribute to the GDP (Table 5). Agriculture, forestry and fishing contribute a total of 4% to the GDP. Fisheries are largely marine, producing an estimated 600 000 tonnes of fish each year, and employing some 27 000 people (SADC 2003, 2005).

Table 5 GDP by sectors in South Africa 2003.

Sector	GDP (%)
Manufacturing	20
Finance, real estate, business activities	20
Trade, hotels and restaurants	14
General government	13
Transport and communications	12
Mining and quarrying	5
Agriculture, forestry and fishing	4
Electricity, gas and water	3
Construction	3
Imputed financial service charges	3
Other producers	3

(Source: SADC 2005)

Much of South Africa is arid and semi-arid, and water is thus an important natural resource. Not surprisingly, there are several water-related disputes between South Africa and its neighbours as mentioned above. There are also disputes within the country over water resources.

Lesotho

Lesotho is the smallest country within the Benguela Current region, and is totally surrounded by South Africa. The total estimated population of 2.2 million people live within and area of 30 355 km², resulting in the highest population density of the four countries in the region, 72 people/km² (Table 2). Almost the entire population lives within the catchment of the Orange-Vaal drainage basin. Urbanisation is estimated at 17%, with only 7% of the total population (or 150 000 people) living in the capital and major city of Maseru (SADC 2003). The literacy rate is relatively high, at 78%. The population consists almost entirely of Africans of the Sotho nation (99.7%), with the remaining 0.3% being made up by Europeans, Asians and others (CIA 2003).

Table 6 GDP by sector in Lesotho 2003.

Sector	GDP (%)
Government and services	33
Manufacturing	18
Agriculture	17
Building and construction	17
Wholesale and retail trade	8
Electricity and water	6
Mining and quarrying	<1

(Source: SADC 2005)

The economy of Lesotho has experienced some setbacks in the last decade due to civil unrest since its return to democracy in 1993. The situation does, however, appear to have stabilised over the last few years, and the nation is working to rebuild its economy and to reduce poverty. GDP per capita is the lowest of the four countries in the Benguela Current region, estimated at 368 USD (Table 2). One of the largest contributors to the GDP in 2003, and previous years, was the building and construction sector (Table 6), much of which is related to the Lesotho Highlands Water Project (SADC 2005).

International agreements, national policy and legal frameworks

A number of international agreements relating to the environment and its protection are in place in countries within the Benguela Current region (Annex III). There are also substantial national policies and legal frameworks aimed at protection of the natural environment in place in these countries (Annex IV). This national legislation covers broad issues surrounding healthy and unpolluted natural environments, water and sanitation, but also covers more specific issues such as the exploitation and management of fish and other living resources, mandatory environmental impact assessment, and protection of the environment from pollution, oil and gas exploration and exploitation, and mining activities.

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	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	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

IMPACT **Freshwater component** IMPACT **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

IMPACT **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 CentrÈs 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 CentrÈs 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.

Causal chain analysis

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

Freshwater shortage in the Orange-Vaal River Basin

The Orange-Vaal is the largest transboundary river system in the Benguela Current region. Its catchment covers some 1 million km^2 (Department of Water Affairs and Forestry 2005), almost 10 times as large as the second-largest system in the region, the Cunene River, which covers an area of 106 500 km^2 (Pallett 1997). The Orange-Vaal system stretches over four countries within the region, namely South Africa, Lesotho, Botswana and Namibia, with the Orange River itself forming part of the political border between South Africa and Namibia. Water from this system is the primary supply for more than half of the population of the Benguela Current region. The scarcity and unequal distribution of freshwater resources is considered one of the fundamental factors posing a threat to the economic and social development of the southern African region. The situation is particularly acute in the Orange-Senqu River Basin as it supplies water to the industrial heartland of South Africa, while having to provide livelihoods for people downstream in the arid western part of the drainage basin.

The headwaters of this system arise in the Drakensberg Mountain range in the east of South Africa and in Lesotho (Figure 10). In these eastern parts of the region, rainfall is high (2 000 mm), and exceeds the annual evaporation (1 200 mm). The drainage basin is highly populated and urbanised, with 48% of the population of South Africa living in the catchment and relying on its water. Most of South Africa's heavy industry and mining activities are also situated within the catchment, with more than half of South Africa's wealth being supported by water supplied from the Vaal River (Department of Water Affairs and Forestry 2005). Much of the catchment is heavily modified by impoundments and water transfer schemes both removing and augmenting the natural water supply (see Assessment, Freshwater shortage).

By contrast, at its western extreme, the Orange River flows through hyper-arid areas where the annual evaporation of 3 000 mm greatly exceeds the limited rainfall of 50 mm (Davies & Day 1998). This leads to a mean annual precipitation and to mean annual run-off conversion rate of less than 10% for the drainage basin as a whole and a rate approaching 1% in some of the drier lower reaches. Population density in these areas is correspondingly far lower than in the upper reaches. Agriculture is the major economic activity, with livestock being kept in the drier areas, and grapes and vegetables being farmed in a narrow riparian strip supported by intensive irrigation drawn from the River. The river estuary is a Ramsar site.

Figure 10 Drakensberg mountains at the border between South Africa and Lesotho.
(Photo: M. Karlsson)

Immediate causes

Modification of stream flow is the key issue surrounding the concern of Freshwater shortage in the transboundary Orange-Vaal system within the Benguela Current region. Annual flow data indicate a reduction in flow of at least 50% since 1935 (Department of Environmental Affairs and Tourism 2000). The two principal immediate causes of modification of stream flow are the construction of dams and impoundments, and the overabstraction of water from this system (Figure 11). These two causes are so closely linked, and have such similar root causes that they are treated together for the purposes of the root cause and policy options analyses.

Sectors

Dams have been constructed primarily to supply water to developing urban areas, to mining and industry, and to agriculture (Department of Environmental Affairs and Tourism 2000). Irrigation is by far the largest sectoral user of water from the Orange River, using 54% (Table 15). Data indicate, that in South Africa as a whole, the storage capacity of large and small dams together had already exceeded the maximum usable mean annual run-off in 1990 (Department of Environmental Affairs and Tourism 2000). Overabstraction of water is connected to inappropriate agriculture practices, wasteful use of water, and inappropriate water rights.

Table 15 Water demand from the Orange River by sectors.

Sector	Demand (%)
Irrigation	54
River losses	32
Environmental demands	10
Urban/industrial	2
Consumptive canal losses	2

(Source: Department of Water Affairs and Forestry 2005)

Root causes

Political

Political decisions that promoted development by prioritising industrial use of water, inappropriate irrigated agriculture, and also a low level of political will to implement existing legislation have contributed to problems of freshwater shortage in the region. Decisions to maintain the trend of development, particularly surrounding the highly industrialised Gauteng Province in the catchment of the Orange-Vaal system, made necessary the construction of dams to supply water not only to the industries, but also to the ever-increasing population in the catchment (Department of Environmental Affairs and Tourism 2000). Mining and industry in the catchment of the Orange-Vaal system were encouraged in order to generate employment, bring about economic growth and generate foreign earnings. Water was supplied to industry and mining preferentially (Department of Environmental Affairs and Tourism 2000), with these sectors being favoured as users of water above the environment or even the local inhabitants.

Some political decisions, including schemes to protect the northern borders of South Africa by actively encouraging settlement and farming in these marginal areas, and promoting inappropriate irrigated agriculture, also contributed to cause freshwater problems. Political causes also include the development of irrigation schemes for the thinly-disguised purpose of vote-gaining, and the creation of sheltered employment.

Governance

Failures in governance are primarily related to a lack of coordination between different interests and to conflicts between government departments at the policy level. This has frequently left the South African Department of Water Affairs and Forestry in the position of having to supply "extra" water to new industrial, mining or agricultural developments in the drainage basin, without due consideration of the water resource available in the area. Water management in the Orange-Vaal drainage system is highly fragmented, and there

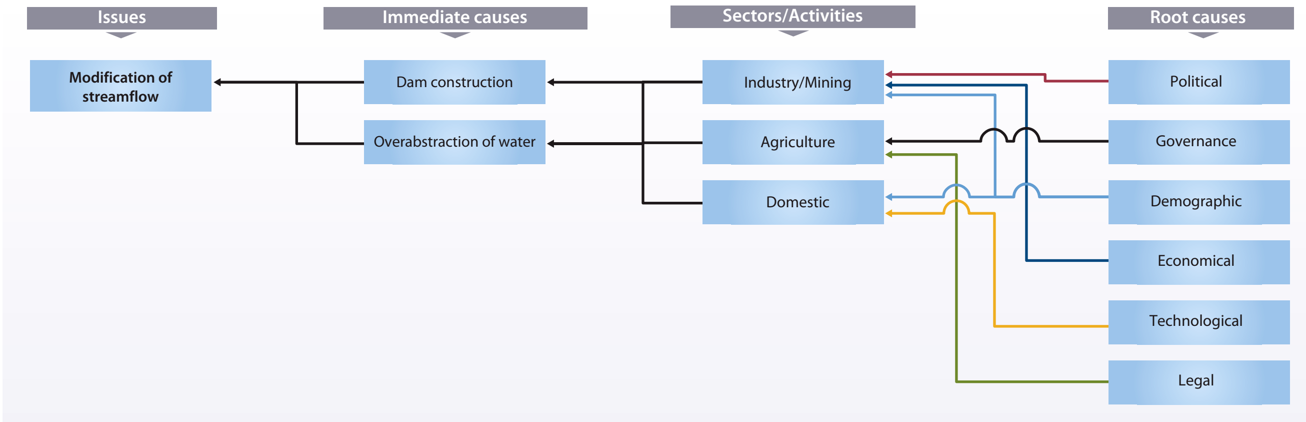

Figure 11 Causal chain diagram illustrating the causal links for freshwater shortage in the Orange-Vaal River Basin.

is no basin-wide planning to support an efficient management of water supplies. South Africa's National Water Act (36 of 1998) does, however, attempt to address several of these problems, although poor implementation and enforcement remain serious constraints to the effectiveness of this legislation. Additionally, in 2000 the four basin states of the Orange River formed the Orange Senqu River Commission (ORASECOM), tasked to serve as a technical advisor to the countries on the use, development and conservation of the River. As an organisation, ORASECOM has a legal personality and is founded on the principles of the Revised SADC Protocol on Shared Watercourses as well as the UN Convention on the Non-navigational Uses of International Watercourses. These principles commit signatories to manage shared waters in a "fair and equitable" way and "not to cause significant harm" to downstream riparian states. Although the Commission is newly-formed it is starting to make progress towards its goal to promote the equitable and sustainable development of the resources of the Orange River.

Many of the decisions to supply water preferentially to mining and industry are historical, born from the political and economic desire for South Africa to achieve self-sufficiency at almost any cost during the economic sanctions of the Apartheid era. In a region where the water supply is generally low and highly variable, until recently surprisingly little effort has been put into managing the demand for water, rather than managing the supply thereof. This is not true only in South Africa, but also in Namibia (International Rivers Network 2004).

Demographic

The political decisions to promote development have resulted in an influx of people to the highly industrialised areas of Pretoria and Johannesburg in the form of both migrant labourers and hopeful immigrants from rural areas seeking jobs. This, together with population growth, has resulted in the catchment of the Orange-Vaal becoming heavily populated, with a concomitant enormous demand for freshwater. The response to this has been attempts to capture as much water as possible, hence the construction of dams and impoundments.

Economic

The dependency of a large and growing urban population on food from rural areas has made the economic incentives associated with water-thirsty commercial agriculture highly attractive. The enormous economic incentives associated with export agriculture, which is often highly inappropriate in relation to local water supplies, have led to a high demand for water for agriculture. Economic causes are also connected to the preferential tariffs given to agriculture, industry and mining (Department of Environmental Affairs and Tourism 2000), to try to achieve the self-sufficiency desired by South Africa. In the past, water has not been considered as an economic good in South Africa, and was available free to agriculture while other users paid only low tariffs (Department of Environmental Affairs and Tourism 2000). This has resulted in a low value being placed on water.

Technological

Improved technology, and in particular irrigation technology, has played an immense part in the development of commercial farming, and in particular in the expansion of inappropriate agriculture, and hence the high demand for water for agricultural purposes. Agriculture is considered to be an inefficient user of water in this system (Department of Environmental Affairs and Tourism 2000). There is the potential for an increase in irrigated agriculture demand, with studies such as the Lower Orange River Management Study (LORMS) projecting an increase in irrigated water use in the common border area of the Orange River between South Africa and Namibia of over 100% by 2025 (Department of Water Affairs and Forestry 2004). Much of these lower reaches of the River have to contend with low quality water, with a high salt content, a problem compounded by the high rates of evaporation in the area.

Deficiencies in the maintenance and upgrading of water supply equipment result in much water being wasted due to avoidable leakages from water reticulation systems such as irrigation canals, storage dams and pipelines, making it a wasteful and inefficient use of water.

Legal

The prevailing water rights in the Orange-Vaal system stem from South Africa's colonial history, with landowners also holding ownership over water on their property. This riparian-rights system of almost private ownership of water resources has allowed the wholesale building of farm dams and concomitant overabstraction of water for agricultural purposes. Until the shift to democracy in 1994, this system of water rights was defended by the South African government in order to protect a limited number of individuals. Under the South African National Water Act all prior rights to water are to be revoked, with water being brought under the curatorship of the state to manage in a sustainable and equitable fashion. However, this shift towards a system which takes into account the needs of the riverine ecosystem will need to be consolidated with the need for regional economic development of the catchment as a whole.

The fragmentation of water policy leads to a fragmentation of water management, which ultimately results in the wasteful or inefficient use of water in the region. The traditional approach of managing water supply rather than water demand has also resulted in wasteful or inefficient use of water by providing as much water as users request, rather than attempting to encourage an increase in the value added to each unit of water consumed. Such an approach gives users the impression that there is an inexhaustible supply of water, and consequently no need for water demand management measures. Placing inappropriately low tariffs on water results in a lack of understanding on the part of users of the value of the resource. Water is thus perceived by users to be a cheap and abundant resource and is consequently used inappropriately and wastefully.

Unsustainable exploitation of inshore finfish in the Benguela Current

The inshore finfish fishery in the Benguela Current region is a multi-species transboundary fishery which is active in all three coastal countries. It is a multi-user and multi-stakeholder fishery, with participation ranging from full-time commercial to part-time semi-commercial, recreational (including tourism) and subsistence users. Stocks of individual species are shared between the three countries, and between the different user groups. In the South African and Namibian portions of the Benguela Current region the commercial, semi-commercial and recreational sectors form the majority of users with the subsistence sector being very small, while in Angola the subsistence sector is a significant user. A variety of capture methods are employed, including boat-based angling and handlining, shore-based angling, beach seine and gill netting, and spearfishing, as well as illegal methods such as the use of explosives (Figure 12).

Figure 12 Beach seines used by traditional fishermen, False Bay, South Africa.
(Photo: C. Griffiths)

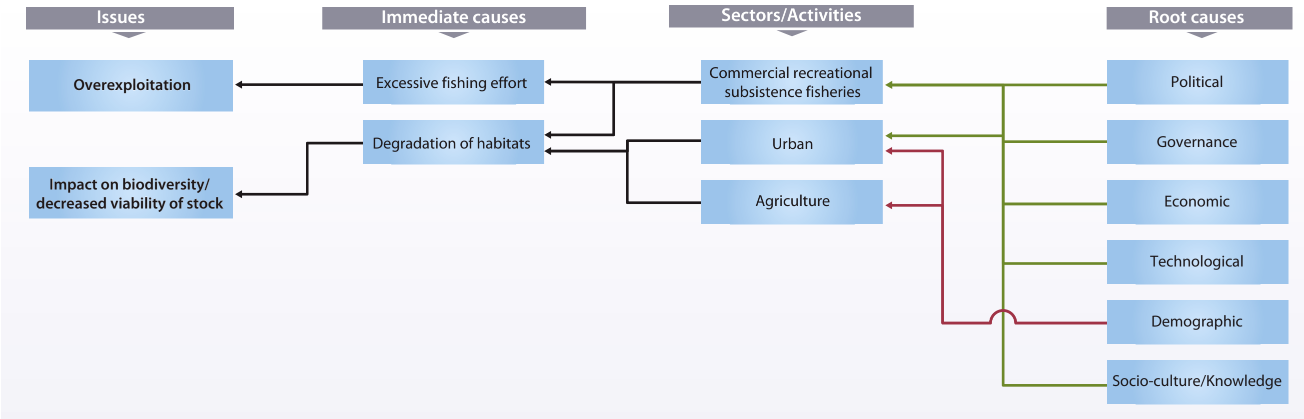

Figure 13 Causal chain diagram illustrating the causal links for unsustainable exploitation of inshore finfish in the Benguela Current.

The majority of the species involved are endemic to southern Africa, and occur only in association with particular habitat types in relatively shallow water close inshore. Some species are long-distance migrants while others may be highly range-restricted and remain resident within a few kilometres of shore for their entire lives. Most are slow-growing species which mature fairly late so that only very large individuals are reproductively mature, and many undergo sex changes as they mature. A host of management measures are currently in place in attempts to manage the fish stocks in a sustainable manner. Nevertheless, there is overwhelming evidence of major catch declines to the extent that numerous stocks are considered to be in a critical condition. This, together with the complex, multi-faceted nature of this fishery makes it an ideal case study for further analysis. Root cause analysis for four other Benguela fishery resources (Hakes, Horse mackerels, Sardine and Anchovy, and Deep-sea red crab) are provided in Hampton et al. (1998).

This case study was chosen in preference to other fisheries in the region because of its highly complex multi-species nature, with many participants falling into a number of "sectors", and with an attendant complex array of causes behind the unsustainable exploitation of these marine living resources. It was also chosen as a case study in preference to some of the more commercially important pelagic, demersal or crustacean fisheries in the region as the majority of the latter fisheries are already receiving much attention in the region through the Benguela Current Large Marine Ecosystem Programme (BCLME) and its attendant projects, and from the governments of the three coastal countries concerned.

Issues

Unsustainable exploitation of inshore finfish in the region was connected mainly to the issues of overexploitation and degradation of habitats (Figure 13).

Overexploitation

Overexploitation has been implicated as the key factor in the reduction and collapse of many inshore fish stocks in the southern African region (Griffiths 1999, Griffiths et al. 1999, Mann 2000). Most species targeted by the linefisheries in this region are rated as overexploited or collapsed (Griffiths 1999, Griffiths et al. 1999, Mann 2000, Holtzhausen et al. 2001, Sauer et al. 2003), as are the principal target species of inshore net fisheries (Hutchings et al. 2000, Hutchings & Lamberth 2002). CPUE for pelagic nomads targeted by the South African linefishery has declined to less than 60% of historical catches (Griffiths 1999), while CPUE of over half of the 25 more vulnerable linefish species for which data are available has declined to less than 5% of the historical CPUE (Griffiths 1999). In Namibian waters, commercial linefishing reached its peak in the 1980s, but has suffered from declining catches since (O'Toole & Boyer 1998). The GIWA Experts estimate that 80 to 90% of the overexploitation problem can be attributed to an excess of fishing effort, with the remaining 10 to 20% being attributed to a deterioration in environmental quality.

Degradation of habitats

Degradation of habitats in the region, notably estuaries and mangroves, has a negative impact on inshore finfish in the Benguela Current region. Estuaries and mangroves are important habitats for many of the species targeted by inshore finfish fisheries. These habitats provide productive feeding grounds, safe refuge from predators and sheltered environments on an otherwise highly exposed coastline. Many species are either partially or fully dependent on these habitats for the successful completion of their life cycles, either as spawning grounds, nursery areas for juveniles, or feeding grounds. Many human influences have negative effects on the integrity of the functioning of these habitats, including alteration of flow, siltation, development, removal of mangroves, pollution, etc. Such degradation may result in direct destruction of the habitat, as in the case of the removal of mangroves, or may manifest itself in more subtle ways such as through reduction of the environmental signal which guides juvenile fish spawned at sea or returning breeding individuals into these essential habitats. While the dependence of particular species on these habitat types is relatively well known, very little is known of the impacts of degradation of these habitats on populations of these species (with the obvious exception of species which are entirely dependent on estuaries for their survival, and whose distribution is restricted to only one or two estuaries). The high degree of dependence of inshore finfish species on estuaries and mangroves, together with the relative scarcity of these habitat types in the region and evidence of their destruction and/or degradation suggest that the degradation of these habitats is likely to be an important contributing factor to the decline, or the lack of renewal, of these fishes.

Immediate causes

Overexploitation

One of the primary causes of overexploitation of inshore finfish in the region is excessive fishing effort. Commercial fishing effort on stocks of these resources is considered to have reached "dangerous" levels (Griffiths 1999). Effort in the recreational shore fishery on the South African coast was estimated recently at 3.2 million angler days per year, resulting in a total catch of 4.5 million fish per year or almost 3 million kg per year (Brouwer et al. 1997). The total number of shore anglers was estimated at 412 000 in 1995 (McGrath et al. 1997). Estimates of the numbers of gill nets used in coastal areas indicate that in some parts of the Benguela Current region, the density of nets is up to 20 per km of coastline (Lamberth et al. 1997). Recreational fisheries, including both ski-boat fishing and shore angling, attract large numbers of participants on the coasts of both Namibia and South Africa. During the summer months, for example, several thousand fishers partake in recreational angling on the coast of Namibia (O'Toole & Boyer 1998). During the 1996/1997 season, 65% of the total catch of Kob (*Argyrosomus* spp.) were taken by recreational shore anglers, and catch statistics indicate heavy fishing pressure on some species (O'Toole & Boyer 1998). For these participants, however, catch is not the sole incentive for participating, and a good days outing can be had even if very few fish are caught. Recreational participants are therefore still prepared to fish even at extremely low levels of CPUE.

Fishers who rely only in part on the linefishery for their income may include both part-time commercials, and artisanal or subsistence fishers. Such participants are also willing to fish at low levels of CPUE. Artisanal fishers on the Angolan coast subsidise their income through alternative activities such as agriculture and commerce (Delgado & Kingombo 1998), and are therefore not solely reliant on income generated through the fishery.

Many fishers participate in a number of different fisheries and only target inshore finfish opportunistically, taking advantage of occasions when CPUE for these species is elevated due to the presence of spawning aggregations, etc. Such fishing results in relatively large catches with a high CPUE, creating a false perception that the fish stocks are in a good condition, and further incentive for fishers to continue with this practice.

New entrants enter the fishery annually hoping to make a profit. These participants are prepared to utilise maximal effort in order to try to recoup their investment in the fishery and make a living. Most entrants soon realise, however, that they will not be able to do so, and sell their permits, boats and gear, to the next batch of hopefuls. This results in a constant turnover of enthusiastic new entrants, all of whom are hoping to recoup their investments in the fishery, and who are therefore prepared to fish at very low levels of CPUE. In South Africa, one third of all commercial linefish permits changed hands during each of the 10 years between 1996 and 1997 (Sauer et al. 2003).

The lack of a strong profit incentive makes these fisheries particularly vulnerable to excessive effort, and allows fishing to continue at very low levels of CPUE which would be unprofitable in full-scale commercial fisheries. Despite the obvious evidence of declining stocks of inshore finfish and decreasing CPUE, the numbers of participants in these fisheries not only remains high, but increases continuously.

Degradation of habitats

Many factors, including pollution, siltation, development, alteration of flow regimes, and removal of mangroves, among others, result in degradation of marine habitats, and of estuarine and mangrove habitats in particular (see Assessment, Habitat and community modification). Agriculture is an important contributor to the degradation of estuarine areas. Quite apart from the obvious effects that damming and water abstraction for irrigation have on flow and flooding in the estuaries downstream, agriculture adversely affects estuarine health in a number of other ways. Run-off of fertilisers and animal wastes lead to increased nutrient loads, thus decreasing water quality. The planting of crops right up to the edge of the river bank removes stabilising riparian vegetation, encourages erosion and leads to increased siltation of the estuary (this is further exacerbated if flooding intensity is reduced to a level which is no longer sufficient to remove the excess sediment).

Estuaries provide relatively safe, sheltered harbours on a coastline which is otherwise highly exposed, and are obvious nodes for development. Development which encroaches on the estuary or associated floodplains directly destroys previously productive environment. Furthermore, alteration of the dynamics of the estuary mouth through stabilisation and hardening in order to support mouth developments alters the environmental cues used by adult and juvenile fish seeking to enter the estuary to complete their life cycles, and alters the physical and chemical nature of the estuary. In some extreme cases, development below the natural flood-line of an estuary leads to artificial breaching of the estuary mouth to prevent flooding. In temporarily closed estuaries this alters the natural regime of the opening of the estuary mouth, creating a mismatch in timing between the opening of the mouth and time when juvenile fish are seeking to enter the estuary.

Destructive fishing methods such as the use of small-mesh nets and explosives, which occurs on the Angolan coast, are also important contributors to deterioration in environmental quality which affects the biodiversity and viability of the stocks. The use of explosives is not only devastating to the fish in the area surrounding their deployment, but also causes physical damage to the habitat. Vast tracts of underwater habitat such as reefs which support the food organisms of inshore finfish are easily destroyed forever. Although there is an awareness that this practice is ongoing in Angolan waters, there have been no studies to date which quantify the extent of use of explosives or the magnitude of damage already caused by this practice.

The use of small-mesh nets has a more subtle effect on the quality of the habitat. Such small-mesh nets are non-selective with regard to species. The removal of large quantities of small fishes from the system undoubtedly has an impact on populations of these species, and on the ecosystem as a whole. These ecosystem effects of fishing are, however, extremely difficult to identify and quantify, and no such characterisation has been performed in the region as yet.

Root causes

Political

Political encouragement of subsistence and small-scale commercial fisheries leads directly to an increase in the number of participants in the fishery. In addition to the "natural" increase in the numbers of participants in the inshore finfish fisheries, government policies aimed at poverty alleviation in coastal areas have encouraged the proliferation of subsistence and small-scale commercial fisheries in the region. The artisanal fishery in Angola, for example, is essentially an inshore fishery, with fishers making use of both rudimentary wooden canoes, and more sophisticated boats. The majority of the fleet is not motorised, relying instead on rowing and sail power (Delgado & Kingombo 1998), thus restricting fishing operations to the inshore zone. In 1992 the Ministry of Fisheries created the Fund for Development of Fisheries (FADEPA) to allow fishermen access to cheap credit for the purchase of motorised boats. Between 1991 and 1995, the total number of subsistence fishers on the Angolan coast increased by 55% from 15 114 to 23 364 fishers (Delgado & Kingombo 1998). The FADEPA also offers low-interest loans to encourage and assist potential subsistence fishers to enter the fishery and to purchase fishing gear (Delgado & Kingombo 1998). While nobly aimed at assisting to alleviate poverty in coastal areas, such programmes are not necessarily consistent with sustainability of the resources on which they are based. The vast numbers of participants in these fisheries (412 000 participants in South Africa) (McGrath et al. 1997) results in a reluctance on the part of governments to introduce further restrictions on catches and to tighten regulation of these fisheries, both of which may be perceived as controversial and discriminatory by the fishers.

Governance

The vast number of participants, which span a number of different "sectors" from subsistence to recreational to commercial, and target a wide range of species with very different life histories, make the inshore finfish fishery highly complex to regulate. It is not surprising, therefore, that difficulties are experienced in trying to create good and sustainable governance within these fisheries. For the most part, regulations aimed at sustainable harvests are in place in each of the countries concerned. However, poor enforcement, an active illegal "sector", and a lack of voluntary compliance are all stumbling blocks to creation of good and sustainable governance of these resources.

In a survey of shore anglers on the South African coast, enforcement of regulations was shown to be poor in that part of the coast which falls within the Benguela Current region, with anglers being subjected to inspection of their catches on only slightly more than 1% (1.39%) of fishing occasions (Brouwer et al. 1997). The perception that the probability of being caught and prosecuted for illegal activities is very low (Lamberth et al. 1997) encourages illegal and unsustainable activities. Such a lack of enforcement arises primarily from a lack of financial resources to implement effective enforcement of existing regulations. On the South African and Namibian coasts, shore anglers are required to purchase a fishing license, but this requirement is not in place in Angola.

Governance failures can also be found at the root of degradation of habitats. Governance failures which allow the continuation of the use of destructive fishing methods include a lack of regulation in some

Figure 14 Trawling in the Benguela Current.
(Photo: P. Hockey)

instances and poor enforcement. The relatively ease with which members of the general public have access to explosives, and poor control over the use of these explosives, represents a further failure in governance resulting in destructive fishing methods and deterioration of environmental quality. A lack of awareness of the implications of these actions exacerbates the problem.

Economic

Inshore finfish fisheries can be important to local economies. The direct economic value of the fishery products creates an incentive for greater participation in the fishery and for larger catches. An increased demand and value generates greater incentive to catch. On the Angolan coast, for example, the high demand for species such as Soles, Croakers and White Groupers on the international market (Delgado & Kingombo 1998) make these species particularly attractive targets for fishers. Sauer et al. (2003) provide evidence that the value of six linefish species on the east coast of South Africa increased by an average of 173% between 1990 and 2001. Such increased value and demand is an interesting contributor to an excess of effort in the inshore finfish fishery in the Benguela Current region.

The indirect values of the recreational shore fisheries in Namibia and South Africa are substantial (Holtzhausen 1996, McGrath et al. 1997). The South African recreational shore fishery is estimated to contribute 1.3% to the Gross Geographic Product (GGP) of the coastal provinces and employs approximately 131 500 people (McGrath et al. 1997). This contribution to the economies of the coastal provinces leads to a reluctance to place restrictions on the fishery.

The ability of fishers to "cross-subsidise" between fisheries allows opportunistic fishing, thus increasing the number of participants in the fishery. Such increases may be temporally and spatially sporadic rather than continuous. They are nevertheless significant to the fishery as this greatly increases fishing pressure at times when CPUE is high, thus adding substantial fishing pressure and increasing the total catch.

Technological improvements of fishing equipment are also connected to economics. The increased value of the resource makes fishers more prepared to invest in technology which they perceive will increase their catch and hence their ultimate economic yield. In addition, as technology becomes relatively less expensive, more people can afford to utilise it. Many of the participants in the recreational fishery are wealthy individuals who are both willing and able to purchase the latest available technology, including boats, 4-wheel drive vehicles, fish finders, etc. if they perceive these will improve their catches. A detailed analysis of the influence of technology on overexploitation is given below.

The impact on biodiversity also has root causes related to economics. In the quest for the most cost- and time-effective method of capturing fishes, individuals resort to the use of destructive fishing methods. In some cases this is driven by profit incentives, while in others it is driven merely by the desire to generate a livelihood in areas where few alternatives exist. Such paucity of economic opportunities in coastal areas also results in destruction of mangroves for use as building material and firewood as local communities are faced with a lack of financial resources with which to purchase alternative materials.

Technological

Improvements in technology are a further contributor to overexploitation. Improvements in fishing gear, such as the availability of off-road vehicles, geared fishing reels, nylon line, fibreglass fishing rods and the advent of the prawn pump which allowed easy collection of prime bait organisms have previously been pointed to as underlying an increase in harvest potential and overfishing of inshore finfish by recreational anglers in the region (Bennett 1991, Griffiths 1999). The proliferation of privately-owned small motor boats fitted with modern devices such as echo sounders and GPS has undoubtedly made inshore fishermen far more efficient by allowing them not only to locate the fish themselves more easily, but also to accurately and repeatedly locate reefs and other seabed features where fish aggregate, and to target spawning aggregations, etc.

Not only has the technology to locate and capture fish become more advanced over the years, but it has also become more affordable and hence more available to a wider range of participants. In addition to this, an increase in scientific knowledge of the species involved in these fisheries, accumulated in attempts to better manage them, has also allowed more efficient location and capture of target species, resulting in a form of "arms-race" between fishers and managers.

Demographic

The need for water at growing urban centres results in damming of rivers and abstraction of water, altering flow regimes and reducing the intensity, frequency and timing of critical flood events in estuaries. Population growth also demands an increase of food supply, which implies an increase in agriculture activity which in turn imposes negative impacts on coastal habitats. The civil war in Angola resulted in large-scale migration of people to coastal areas. Faced with limited financial resources and natural alternatives, mangroves became an important source of building materials, with a resultant severe destruction of mangrove forests.

Socio-cultural

Poor voluntary compliance by participants in the fishery exacerbates the problems of inadequate enforcement of regulations to avoid overfishing. Voluntary compliance with management regulations in the South African inshore finfish fishery was found to be poor (Sauer et al. 1997, Brouwer et al. 1997). In the part of the South African coast which falls within the Benguela Current region, between 39 and 44% of 983 anglers interviewed admitted to disobeying the prevailing regulations with regard to size and bag limits and closed seasons (Brouwer et al. 1997). The commercial linefishery in South Africa was found to regularly under-report catches by a factor of three (Sauer et al. 1997), while only a mere 3.6% of catches in the gill net and beach seine fisheries are reported (Lamberth et al. 1997). In those parts of the South African coast which fall within the Benguela Current region, an estimated 23% of the gill nets in operation are being used illegally (Lamberth et al. 1997). To some degree the low level of voluntary compliance may arise from a lack of awareness regarding management regulations. In their studies on the South African coast Sauer et al. (1997) and Brouwer et al. (1997) found that participants in the fishery generally had a very poor knowledge of existing regulations. Much of the lack of compliance, however, also stems from poor attitudes associated with common goods, and the perception that the sea holds an inexhaustible supply of fish on which individuals cannot make a substantial impact, with little thought to or understanding of the cumulative effects of the large number of participants. A lack of visible and effective enforcement certainly also encourages poor voluntary compliance and illegal activity.

As resources in a commons become increasingly scarce, so competition increases between individuals each wanting their share. The heightened competition both within and among user groups targeting inshore finfish leads to the use of more extreme measures by fishers, and the development and purchase of technologically more advanced equipment. This phenomenon is not only created by economic incentives, but is a result of prevailing attitudes to common resources which are becoming increasingly scarce. Each fisher perceives that his/her right to capture fish is being impinged on by others, resulting in a selfish attitude. Participants in the fishery feel that most other participants are "cheating" and that the only means of ensuring his/her own rightful share is to do likewise.

Policy options

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

The suites of policy options presented below were generated by the Benguela Current Task team as a set of responses to the root causes identified during the Causal chain analyses. By their nature, each policy option usually addresses more than one of the root causes identified. Attempting to link the policy options directly to each root cause identified in the Causal chain analyses was not always possible, and would have resulted in much repetition within the policy options, thereby creating unnecessary confusion. The policy options have thus been presented in a more thematic manner.

An attempt was made to devise sets of policy options which are practical and realistic, and which together will make a substantial contribution towards improving the situations outlined in the Assessment and Causal chain analysis for the two chosen systems. The policy options should thus preferably not be viewed as individual interventions, but as sets of interlinked interventions which together present an holistic approach.

Addressing modification of stream flow

A suite of three thematic policy options are suggested for arresting the modification of stream flow in the Orange-Vaal river system. These include changing the way water is perceived and used, effecting holistic planning, and improving existing management.

Changing the way water is perceived and used

Most of the Benguela Current region and the drainage basin of the Orange-Vaal system is characterised by naturally highly variable rainfall, and in most parts rainfall is also extremely low. Attitudes of both the general public and managers towards water in the region are, however, not consistent with the reality of this stochastic supply. Domestic, industrial and agricultural users, for the most part, do not take due cognisance of the limited and variable supply of this resource. Where realisation of the natural variability of rainfall has been recognised, it has been met with something of a sense of panic, resulting in a fever of dam-building in the region in order to ensure that as much water as possible is retained for human use. Water which flows down a river and enters the sea has traditionally been regarded as water wasted (for an example, consider the category "River losses" in data published on the official South African Department of Water Affairs and Forestry website, reproduced in Table 15 in the Causal chain analysis section). These attitudes towards water and its management have resulted in major negative environmental and socio-economic impacts in the region.

A further factor influencing how water is perceived and used is related to the low value that is placed on it at all levels, from government to individual users. The perceived low value has been entrenched in users through inappropriately low tariffs, and through government subsidy schemes which have supplied cheap water to farmers. Changing attitudes towards water and encouraging more efficient use of water will require careful consideration of the economics of the resource.

Water management in the Orange-Vaal system has largely been based on managing the supply of water, and little attention has been given to managing water demands. The emphasis on water management has resulted in efforts to retain as much water as possible through the building of dams and impoundments, and to move this water to where the users are through inter-basin transfer schemes. A critical step in changing the way water is used is by shifting the emphasis from managing the highly variable supply towards managing the demand for water. Such water demand management requires a multi-faceted approach, including education and awareness surrounding the limited supply of water, introduction of water conservation measures and appropriate technology, adjustment of water tariffs, and the inclusion of water considerations in town and city planning. For integrated water resources management of an international transboundary river such as the Orange River to be effective, there has to be a "common vision" adopted between the various stakeholders impacted by and impacting on the water resource. This includes inter-governmental organisations such as ORASECOM as well as community and other non-governmental groups in the river system. As the four basin states require an increased amount of water from the river and more pressure is placed on its resources over the coming decades, planning and management system need to be in place to promote science-based decision-making, incorporating as wide a range of involved stakeholders as possible.

For users to change their perceptions of water and how it relates to the natural environment requires recognition of the importance of water and the legitimacy of the environment as a user of water at the government policy level. The South African National Water Act of 1998 is to be commended on doing exactly this, by making provision for the implementation of minimum in-stream flow requirements, referred to as the "ecological reserve", with the intention of giving due recognition to the environment as a user of water and promoting the environmentally sustainable use of water resources. Additionally, it makes provision for the assurance of a "fair and equitable" share of the water for downstream users. However, it is the implementation of the provisions of such legislation which presents problems. Management and development of the resources of the drainage basin has been on an ad-hoc basis with little coordination between geographic areas or between government departments. This is the case both within the largest of the basin states, South Africa, as well as between the individual states. Thus far collaborative planning has only been around specific projects, such as the Lesotho Highlands Water Transfer project.

Effecting holistic planning

Effective integrated water resources management in the Orange-Vaal system requires holistic planning, from implementation of good town and city planning to basin-wide management. Town and city planning must take into account the low and highly variable natural water supply and plan accordingly. The unchecked growth of urban centres which is occurring in much of the region leads to enormous pressure on available water resources. Town and city planning thus needs to take into account the available water supplies in plans for further development and expansion of urban centres. Water conservation measures such as making provision for the re-use of grey water from households, or treated sewage effluents, for example, need to be incorporated into town and city development at the planning stage. Likewise, agricultural developments need to take into consideration the climatic realities of the drainage basin as well as the economic realities of the local and international food markets. Prices of staple foods have, in real terms, been decreasing since the end of the Second World War. Overproduction in the developed world and the opening up of most markets in developing countries has resulted in a drop in average staple food prices in countries of the Orange River Basin. Yet the cost of irrigation schemes has not dropped, with energy costs and other operation and maintenance costs all experiencing real increases over the past half century. These factors have combined as a call by commercial farmers for water charges to be kept low, leading to inefficient and wasteful use of water in the drainage basin.

The Orange-Vaal system is vast and complex, and by the continuous nature of rivers, impacts on parts of the system are translated into cumulative impacts downstream. It is therefore not practical to plan for only one part of the system, but planning must thus be done for the system as a whole. Such planning should not only include the water resources themselves, but should also include land use planning in the entire catchment, including revision and adjustment of current land use policies and practices. Attention should also be paid to the current system of water rights which are closely tied to land tenure and effectively allow private ownership of water.

Improving existing management

Many measures are already in place to manage water in the Orange-Vaal system, and water management could be greatly enhanced merely by strengthening and improving these. A highly practical intervention would be through upgrading and improved maintenance of existing urban reticulation systems to minimise wastage of high-quality water. The same goes for water used in irrigation systems, where much of the infrastructure needs to be converted to incorporate improvements in the efficiency of water application to the root zone.

Much legislation pertaining to the management of water in this, and other, systems is already in existence. There are, however, shortfalls between the existence of legislation and regulations and the implementation of these. If these instruments are to be as effective as they are intended, it is necessary that such legislation is implemented by management, that there is a high level of voluntary compliance with regulations, and that adequate enforcement is in place to act as a disincentive to a lack of compliance. In accordance with the integrated water resources management approach there needs to be a basin-wide management system. However the day to day practical running of the basin resources, taking place according to the principle of subsidiarity, will result in resources being managed at the lowest practical level.

Fragmentation at both policy and implementation levels is one of the major challenges facing sustainable water management in the Orange-Vaal system. Once basin-wide planning is in place, it is also essential to introduce basin-wide management so that the system is managed in its entirety in a coordinated way.

Both good planning and good management require the input of reliable information for decision-making. Both planning and management of the water resources of the Orange-Vaal system could be greatly enhanced by improvement in the supply of such information for decision-support. Improved reliability of long-range forecasting and rainfall predictions are highlighted as critically important for supporting effective planning and management in this system which is characterised by a high degree of stochasticity. Once a reliable information set has been established it needs to be legitimised by the parties involved. The process of contestation surrounding information can be a vital step in generating a shared vision and understanding between stakeholders of each others problems, challenges, pressures and possible solutions.

Addressing unsustainable exploitation of inshore finfish resources

Overexploitation

The inshore finfish fishery in the Benguela Current region is a complex multi-user, multi-species fishery, for which there is no "one size fits all" solution. To effectively address the severe overexploitation problems will require a multi-faceted approach aimed at the key outcome of reducing effort through restriction of effort, effective enforcement of both new and existing regulations, and achieving improved voluntary compliance on the part of fishers.

Reducing access

It is abundantly evident that the current high level of effort expended in the inshore finfish fishery is not sustainable, and there is an urgent necessity to restrict this effort further than is provided for by existing legislation and regulations. Although a contentious and emotional issue, the possibility of restricting access to this fishery may need to be considered. Certainly one intervention that requires consideration is a restriction on access by individual participants to multiple fishery resources in order to reduce opportunistic fishing on inshore finfish at times when CPUE is elevated (e.g. during aggregated spawning events). De-commercialising the fishery entirely is another available option. As we have learned with land mammals, however, this option should be treated with great caution as it may lead to the establishment of an even more lucrative black-market, resulting in even greater illegal activity and fishing pressure.

Decreasing accessibility to these resources (by whatever means) to fishers will result in shrinkage of livelihood and economic opportunities in coastal areas. A key allied intervention will thus be to simultaneously generate attractive alternative livelihood and economic opportunities for those who have previously relied on fishing. Aquaculture offers an obvious opportunity for generation of livelihoods which are not reliant on the capture of wild populations.

Modern technology has improved the efficiency of fishers to access, locate and capture fish. While legislation already exist regarding the use of fishing gear to capture inshore finfish, it may be necessary to impose further gear restrictions, or at least to discourage the use of certain gear by imposing licenses for their possession.

Improving voluntary compliance

The usefulness of legislation and regulations aimed at sustainable management of fisheries is highly dependent on effective enforcement of these. It is clear that current enforcement of the existing regulations is inadequate and requires strong intervention. Given the vastness of the coastline, the number of participants in the fishery and the different user groups involved, this becomes extremely expensive. The economic considerations are undoubtedly the major factor responsible for the current weaknesses in enforcement of regulations pertaining to these fisheries in the region, and it may be naive to imagine that anything will change in this regard. More creative means of enforcement may thus need to be sought, such as community-policing, and improving voluntary compliance.

Improving voluntary compliance with existing regulations and management measures is critical in addressing the current overexploitation in the inshore finfish fisheries in the Benguela Current region. Improving voluntary compliance revolves around changing attitudes of fishers towards the resources they utilise. Such shifts in attitude can only be brought about through generating understanding and a sense of stewardship. Understanding can be enhanced through education and awareness programmes which highlight the nature of the resources and the impacts of exploitation on these. Involvement of a knowledgeable fishing community in management decision-making provides an important basis for the building of a sense of stewardship on the part of these individuals.

Although such changes in attitude are often perceived to be difficult to effect, this is not necessarily the case. One case in particular, on the KwaZulu-Natal coast of South Africa, serves to illustrate just how well interventions to improve understanding and generate a sense of stewardship can work to improve voluntary compliance and self-policing in relation to exploitation of marine living resources (Harris et al. 2003, Sowman et al. 2003).

Degradation of habitats

As has been highlighted in the Causal chain analysis, there are several root causes of degradation of habitats of inshore finfish resources in the Benguela Current region. To address these varied causes will require a relatively broad approach aimed at a range of levels of intervention.

Holistic management

While the necessity for provision of water at urban centres cannot be denied, the impacts of this on estuaries downstream can be mitigated through adoption of "white water to blue water" or "hilltop to oceans" approaches to the management of freshwater basins. Improving agricultural practices in catchments, and regulating minimum flow requirements for freshwater systems, as has been done in South Africa's Water Law of 1998 are highlighted as important interventions in the protection of estuarine health. For the estuary itself, it is critical to prepare management and development plans which incorporate good ecological practice, and which are subject to rigorous environmental impact assessments before implementation.

The establishment of protected mangrove areas may assist as an interim solution to retarding the destruction of mangroves. Strict compliance by the communities will be required for protected mangrove areas to be at all effective. Ensuring strict compliance can be achieved through costly enforcement, or through generating community stewardship of these areas by involving communities in education and awareness programmes, and in the establishment and management of protected mangrove areas.

Creation of alternative economic activities

Much of the destruction of mangroves is brought about by a lack of alternatives for building materials and firewood, and a number of policy options can be considered in addressing this. Government provision of building material and firewood is likely to be an impractical option as it is extremely expensive and unsustainable. Aforestation programme may alleviate the situation somewhat, but bring with them their own negative impacts on the terrestrial environment. The provision of cheap electricity to these coastal communities would not alleviate the problem as it relates to building materials, but would go a long way to alleviating the necessity for using mangrove wood for cooking fires. The only truly sustainable long-term option for alleviating the pressure on mangroves for building materials lies in creating sufficient economic opportunities in these coastal areas so that communities are better able to afford to utilise alternative building materials.

Destructive fishing methods are utilised by fishers because they are time- and cost-effective. Once again, reducing the reliance of coastal people on inshore finfish resources by creating alternative livelihoods and economic opportunities in coastal areas is the one truly sustainable option. In the interim, increasing voluntary compliance through increasing understanding of the resources and the impact that destructive fishing practices have on these, and creating a sense of stewardship will go some way to alleviating the problem, but only in cases in which there is no economic or livelihood reliance on these resources.

Improving voluntary compliance

Deterioration of environmental quality leading to a reduction in inshore finfish and their habitats in the Benguela Current region, can be attributed primarily to the degradation of critical estuarine and mangrove habitats and to destructive fishing practices. Much legislation already exists in the countries involved to protect environmental quality (Annex IV). There are, however, failures in the implementation of this legislation, and environmental degradation continues, in some cases despite the best efforts of enforcement agencies. The option of stepping-up enforcement is an expensive one, and not necessarily sustainable, nor does it address the root causes of the problem. In most instances, the problems exist because local communities have no alternatives to utilising coastal resources, and are unaware of the larger impacts that their activities may be creating. Public awareness of the impacts of particular activities and public involvement in management will be the key to addressing these problems, as will the generation of alternative sustainable livelihood opportunities in coastal areas.

Conclusions and recommendations

Probably the truest generality that can be made about the Benguela Current region is that it is characterised by high variability. This variability is evidenced in environmental processes such as rainfall and upwelling, but also in its highly variable socio-economic processes, with the highly industrialised Gauteng Province of South Africa contrasting dramatically with subsistence-based activities in Angola. This variability presents some challenges in attempts to assess the region as a whole, and where information has permitted these finer-scale differences have been enunciated in the body of this report. Despite the inherent variability, this report contributes a valuable synthesis of the major environmental issues within the region, and attempts to provide some insights into the impacts of these environmental perturbations on the socio-economic environment. It further attempts to elucidate the root causes of environmental issues and suggests possible policy options for addressing these.

Both the natural and human environments of the Benguela Current region are strongly influenced by the cold, northwards-flowing Benguela Current. This current and its attendant upwelling are not only responsible for the highly productive fisheries of the marine environment, but to a large extent controls the climate of the region. For the most part the region is arid or semi-arid, with low and highly variable rainfall. The growth of populations, coastal urban centres, irrigation agriculture and industry place increasing demands on limited supplies of water, to the extent that most parts of the region are currently considered to be suffering a water crisis. Sources of water for the most important permanent river basins in the region are shared between a number of countries, and in two cases (Orange River and Cunene River) the rivers themselves form national boundaries. The potential for conflict over water resources in the region is consequently high. For these reasons, Freshwater shortage was highlighted as a priority environmental and socio-economic concern. Many anthropogenic root causes combine to exacerbate the problems of the naturally low and variable supply of freshwater in the region, including political decisions such as prioritisation of industrial water use, lack of coordination among departments, demographic considerations, economic policies, and improvements in technology, particularly irrigation technology. Three major thematic interventions are suggested to alleviate the problems of freshwater shortage in the region:

- Changing the way water is perceived and used. This revolves primarily around perceptions of the value of water as a life-sustaining resource at all levels of society.
- Effecting holistic water planning. Holistic, basin-wide planning is essential to effectively manage the limited supplies of water in the region.
- Improving existing management of water resources. Water management in the region could be greatly enhanced by strengthening and improving existing management at all levels, from policy to implementation to upgrading of supply equipment and introduction of water-conservation measures.

The Benguela Current is one of the most important upwelling systems on Earth. The high nutrient concentration of the upwelled water forms the basis of complex food chains which support highly productive fisheries. The continuous nature of the marine environment ensures that stocks of marine living resources are transboundary in nature, and are shared between the three coastal countries. Despite the high productivity of the Benguela Current, overfishing and the degradation of important habitats have lead to declines in fish stocks in the system. In the case of inshore finfish, most stocks in this multi-species fishery are rated as overexploited or collapsed. Excessive fishing effort is a key contributor towards the decline in these stocks. Degradation of critical habitats such as estuaries and mangroves further compromises the resilience of these stocks to fishing pressure. Anthropogenic factors are at the root of the declines in stocks of inshore finfish, including those of political encouragement of small-scale fisheries, governance failures and difficulty of regulation of inshore finfish fisheries, a number of economic considerations, improved capture technology, and poor voluntary compliance. Interventions around two major themes are offered as suggestions for alleviating the overexploitation of inshore finfish resources in the region:

- Reducing access. Although a contentious issue in the region, limitations on access to inshore finfish fisheries could be an important step in reducing overexploitation of these fisheries.
- Improved voluntary compliance. In this multi-user, open-access fishery spread over thousands of kilometres of coast, stringent enforcement of existing management measures is not practical. Long-term sustainable utilisation of these resources will require large improvements in voluntary compliance.

Interventions around three themes are suggested for reducing the degradation of critical inshore finfish habitats:

- Holistic management. Estuaries and mangroves are key habitats for inshore finfish. Recognition of their role as such, and the introduction of holistic ecosystem-wide management will assist in reducing degradation of these habitats.
- Creation of alternative economic activities. The use of destructive fishing practices and much of the destruction of critical habitats, such as mangroves, are the result of a lack of alternatives. The generation of alternative economic opportunities in coastal areas will reduce economic or livelihood reliance, and hence pressure, on coastal resources.
- Improving voluntary compliance. Existing legislation for the protection of environmental quality is often ineffective due to poor enforcement and a low level of voluntary compliance. Improved enforcement is not necessarily practical for a number of reasons, and long-term sustainability will be reliant on improvements in voluntary compliance.

A number of issues within these themes are currently being addressed by the Benguela Current Large Marine Ecosystem Project (BCLME), and will be the responsibility of the proposed Benguela Current Commission. The objectives of the BCLME are to improve the management of shared resources, and to implement an ecosystem approach to fisheries in the three coastal countries bordering the Benguela Current.

Reflecting the natural systems of the region, much variability also exists in the data, information and expertise available. Strong gradients are present in the distribution of data, information and capacity within the region, these generally decreasing from the south to the north. The text of this report reflects this, with much information available regarding the South African portion of the region, somewhat less concerning the Namibian portion and, not surprisingly after 30 years of civil war, far less regarding the Angolan component.

The quantity and quality of environmental data and information was not evenly spread across the concerns and issues. Data and information relating to specific pollution issues, specific habitats and ecosystems, and to global change issues were either not available, or very little was available. Surprisingly, environmental information was far more readily available than that relating to social and economic processes. The apparent paucity of socio-economic information and expertise does not, however, apply to the fields of social science and economics in their entirety, but rather as they relate to the natural environment. An important consideration in the pursuit of sustainable development will be the fostering of capacity in cross-cutting environmental social sciences and environmental economics.

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Annexes

Annex I
List of contributing authors and organisations

Name	Institutional affiliation	Country	Field of work
Dr Kim Prochazka (Regional Focal point)	International Ocean Institute Southern Africa, Department of Biodiversity and Conservation Biology, University of the Western Cape	South Africa	Marine biology and ecology
Prof. Bryan Davies	Freshwater Research Unit, Zoology Department, University of Cape Town	South Africa	Freshwater biology , ecology and policy
Prof. Charles Griffiths	Marine Biology Research Institute, Zoology Department, University of Cape Town	South Africa	Marine biology and ecology, Benguela fisheries
Dr Mafa Hara	Programme for Land and Agrarian Studies, School of Government, University of the Western Cape	South Africa	Fisheries policy, Fisheries socio-economics
Mr Nkosi Luyeye	BCLME Country Coordinator (Angola), Ministry of Fisheries	Angola	Marine biology and ecology, Benguela fisheries, Benguela dynamics
Dr Mick O'Toole	Chief Technical Advisor, Benguela Current Large Marine Ecosystem Programme	Namibia	Marine biology and ecology, Benguela fisheries, Benguela dynamics
Ms Janet Bodenstein	Enivronmental Evaluation Unit, Department of Environmental and Geographical Sciences, University of Cape Town	South Africa	Socio-economics, Coastal communities
Dr Trevor Probyn	Marine and Coastal Management, Department of Environmental Affairs and Tourism	South Africa	Marine ecology, Oceanography & Benguela dynamics, Marine pollution
Dr Barry Clark	Anchor Environmental Consultants	South Africa	Marine biology and ecology, Benguela fisheries, Climate change
Mr Anton Earle	African Water Issues Research Unit, University of Pretoria	South Africa	Freshwater policy
Prof. Chris Tapscott	School of Government, University of the Western Cape	South Africa	Economics of Benguela coast and fisheries
Mr Richard Hasler	Private consultant	South Africa	Social aspects of freshwater use

Annex II
Detailed scoring tables: Freshwater component

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	3	50	Freshwater shortage	3
2. Pollution of existing supplies	3	25		
3. Changes in the water table	3	50		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	3	33
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33
Weight average score for Economic impacts		**3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	40
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	25
Degree of severity	Minimum – Severe 0 1 2 3	2	50
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	25
Weight average score for Other social and community impacts		**2**	

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	3	20	Pollution	3
5. Eutrophication	3	20		
6. Chemical	3	20		
7. Suspended solids	2	10		
8. Solid wastes	3	10		
9. Thermal	1	5		
10. Radionuclides	3	5		
11. Spills	3	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	3	33
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33
Weight average score for Economic impacts		**3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	33
Degree of severity	Minimum – Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	0	33
Degree of severity	Minimum – Severe 0 1 2 3	0	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33
Weight average score for Other social and community impacts		**1**	

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	3	50	Habitat and community modification	3
Soligenous bogs	3			
Marshes (vleis)	3			
Riparian belts	3			
Endorheic pans	2			
Floodplains	3			
Intermittent rivers	3			
Permanent rivers	2			
13. Modification of ecosystems or ecotones, including community structure and/or species composition	3	50		
Soligenous bogs	3			
Marshes (vleis)	3			
Riparian belts	3			
Endorheic pans	3			
Floodplains	3			
Intermittent rivers	3			
Permanent rivers	3			

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	33
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	2	33
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	33
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	2	33
Degree of severity	Minimum 0 1 2 3 Severe	1	33
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	33
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	1	33
Degree of severity	Minimum 0 1 2 3 Severe	2	33
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	33
Weight average score for Other social and community impacts		**2**	

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	50	Global change	2
20. Sea level change	Not assessed			
21. Increased UV-B radiation as a result of ozone depletion	2	50		
22. Changes in ocean CO_2 source/sink function	Not assessed			

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	0	50
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	0	50
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	0
Weight average score for Economic impacts		**0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	2	33
Degree of severity	Minimum 0 1 2 3 Severe	1	33
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	33
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	0	33
Degree of severity	Minimum 0 1 2 3 Severe	0	33
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	0	33
Weight average score for Other social and community impacts		**0**	

Annex II
Detailed scoring tables: Marine component

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	2	20	Pollution	2
5. Eutrophication	1	20		
6. Chemical	1	20		
7. Suspended solids	2	10		
8. Solid wastes	2	10		
9. Thermal	1	5		
10. Radionuclides	1	5		
11. Spills	3	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	3	33
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	3	33
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33
Weight average score for Economic impacts		**3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small Very large 0 1 2 3	1	33
Degree of severity	Minimum Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small Very large 0 1 2 3	0	33
Degree of severity	Minimum Severe 0 1 2 3	0	33
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33
Weight average score for Other social and community impacts		**1**	

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	1	50	Habitat and community modification	2
Sandy foreshores	1			
Lagoons	2			
Estuaries	3			
Rocky foreshores	1			
Mangroves	2			
Kelp systems	0			
Mud bottom	0			
Sand and gravel bottom	0			
Rocky bottom	0			
13. Modification of ecosystems or ecotones, including community structure and/or species composition	2	50		
Sandy foreshores	2			
Lagoons	2			
Estuaries	3			
Rocky foreshores	2			
Mangroves	1			
Kelp systems	2			
Mud bottom	2			
Sand and gravel bottom	2			
Rocky bottom	2			

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	2	33
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small Very large 0 1 2 3	2	33
Degree of severity	Minimum Severe 0 1 2 3	1	33
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small Very large 0 1 2 3	1	33
Degree of severity	Minimum Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33
Weight average score for Other social and community impacts		**2**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	60	Unsustainable exploitation of fish	2
15. Excessive by-catch and discards	1	20		
16. Destructive fishing practices	2	10		
17. Decreased viability of stock through pollution and disease	0	5		
18. Impact on biological and genetic diversity	2	5		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	33
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	33
Degree of severity	Minimum – Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	33
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	33
Degree of severity	Minimum – Severe 0 1 2 3	2	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	33
Weight average score for Other social and community impacts		**2**	

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	50	Global change	1
20. Sea level change	1	20		
21. Increased UV-B radiation as a result of ozone depletion	0	20		
22. Changes in ocean CO_2 source/sink function	1	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	0	50
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	0	50
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	0
Weight average score for Economic impacts		**0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	33
Degree of severity	Minimum – Severe 0 1 2 3	1	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	33
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	0	33
Degree of severity	Minimum – Severe 0 1 2 3	0	33
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	33
Weight average score for Other social and community impacts		**0**	

Comparative environmental and socio-economic impacts of each GIWA concern

Freshwater component

Concern	Types of impacts								Overall score	Rank
	Environmental score		Economic score		Human health score		Social and community score			
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Freshwater shortage	3	3	3	3	2	2	2	2	2.5	1
Pollution	3	3	3	3	2	2	1	3	2.5	2
Habitat and community modification	3	3	2	3	2	2	2	2	2.4	2
Global change	2	3	0	2	1	2	0	1	1.4	2

Marine component

Concern	Types of impacts								Overall score	Rank
	Environmental score		Economic score		Human health score		Social and community score			
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Pollution	2	3	3	3	2	2	1	2	2.3	2
Habitat and community modification	2	3	2	3	2	2	2	2	2.3	2
Unsustainable exploitation of fish and other living resources	2	3	2	2	2	2	2	2	2.1	1
Global change	1	3	0	2	1	2	0	1	1.3	1

Annex III
List of conventions and specific laws that affect water use in the region

The following table lists a number of international agreements relating to the natural environment in general and aquatic systems in particular, and protection thereof in Angola, Namibia and South Africa. Please note that much of Namibia's legislation is similar to that of South Africa as it has not been changed since gaining independence. Please also note that the table is not necessarily comprehensive.

Agreement	Status
Basel Convention on the Control of Transboundary Movements of Harzardous Wastes and their Disposal, 1989	Ratified by Namibia and South Africa
United Nations Convention on the Law of the Sea, 1994	Not ratified by any of the countries in the region, but many aspects are provided for in national laws of the countries
International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL)	South Africa and Namibia have acceded and enacted domestic legislation
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties	Legislated in South Africa as the International Convention relating to Intervention on the High Seas in Cases of Oil Pollution Casualties Act, 64 of 1987
International Convention on Civil Liability for Oil Pollution Damage	Legislated in South Africa and Namibia as the Prevention and Combating of Pollution of the Sea by Oil Act of 1981
Convention of the International Maritime Organization, 1948	Angola, Namibia and South Africa are all parties to the Convention
International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990	South Africa is a party to this Convention, although Angola and Namibia are not
Convention on Biological Diversity, 1992	Angola, Namibia and South Africa have all ratified the Convention
Ramsar Convention on Wetlands of International Importance	Namibia and South Africa are parties to the Convention
International Convention on the Regulation of Whaling	Ratified by Namibia and South Africa, and legislated through the marine Living Resources Act of 1998 and the Marine Resources Act of 2000 in these countries respectively
Convention on the Ban of Import into Africa and the Control of Transboundary Movement and Management of Hazardous Waste within Africa – Bamako Convention, 1991	Neither Angola, Namibia nor South Africa have acceded to the Convention
Convention for the Prevention of Marine Pollution from Land-based Sources, 1974	Neither Angola, Namibia nor South Africa have acceded to the Convention
Southern African Development Community (SADC) Environmental Policy and Regulatory Framework for Mining	Angola, Namibia and South Africa all require environmental impact assessment. Namibia and South Africa both require monitoring of impacts throughout the lifespan of the mining operation, and South Africa requires provision for rehabilitation and/or ongoing management of impacts
Southern African Development Community (SADC) Protocol on Fisheries	This protocol has not yet come into force
South East Atlantic Fisheries Organization (SEAFO)	Ratified by Namibia, signed but not yet ratified by Angola and South Africa
UN Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks	Signed by Namibia and South Africa, not yet signed by Angola
FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas	
Southern African Development Community (SADC) Protocol on Shared Watercourse Systems in the SADC Region	
Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter (London Convention), 1972	Legislated in South Africa through the Dumping at Sea Control Act, 73 of 1980, not yet legislated for in Angola or Namibia

Annex IV
List of national policy and legislation

National policy and legal frameworks aimed at protection of the natural environment are in place in the countries falling within the Benguela Current region. The following table outlines some of the legislation and policy pertinent to protection of domestic and transboundary waters within Angola, Namibia and South Africa. A brief explanation of the key elements of each, as relates to aquatic environments, is given.

Legislation	Coverage	Key elements
Angola		
Constitution of the Republic of Angola, 1992	Environmental protection in general	Provides the basis for environmental protection and conservation and the right to a healthy and unpolluted environment
Environmental Framework Act, 1998	Environmental protection in general	Provides the framework for all environmental legislation and regulations Incorporates key international policies
Fisheries Act, 1992	EEZ, internal waters and all inland waters	Sustainable management Vessel licensing International and regional cooperation Supply of fisheries data Mariculture Quality and export of fisheries products Monitoring, control and surveillance of fishing activities
Interior and Marine Exclusive Economic Zone Act, 1992	EEZ, internal waters and all inland waters	Use of natural resources Protection of the environment Promotion of scientific research
Petroleum Activities Act, 1978	Oil industry	Exclusive rights to SOLANGOL for exploration, drilling and production of oil products Facilitation of international partnerships to increase local capacity
Petroleum Activities Decree, 2000	Oil industry	Sustainable development of the oil industry Compulsory use of environmental impact assessment
Mining Act, 1979	National	Declares all mineral resources as state property Regulates exploration and mining activities
Local Municipalities Act, 1999	National	Development, sanitation, environmental protection and land management responsibility of provincial and local government
Foreign Investment Act, 1994	National	Regulates foreign investments to ensure compliance with local policies on environmental protection, safety, health and environment of workers
Water Act (Draft)	National	Access to, use and protection of water resources Compulsory environmental impact assessment for all water projects
Environmental Impact Assessment Decree (Draft)	National	Requirements and standards for environmental impact assessment
Namibia		
Constitution of the Republic of Namibia, 1990	Environmental protection in general	Maintenance of ecosystems, processes, biodiversity Sustainable utilization of natural resources Dumping or recycling of foreign nuclear waste
Green Plan, 1992	Environmental protection in general	Sustainable use of living and non-living natural resources Environmental auditing and environmental impact assessment Pollutant treatment and disposal, including hazardous waste Protection of representative landscapes and ecological diversity
Environmental Assessment Policy for Sustainable Development and Environmental Conservation, 1994	National	Sustainable development Compulsory environmental impact assessment Requirements for environmental impact assessment
Environmental Management Bill (Draft)	National	Management of the environment and natural resources Provide mechanisms for implementation of obligations under international conventions Establish institutions for environmental management and protection
White Paper on National Water Policy for Namibia, 2000	Primarily freshwaters	Inter-sectoral coordination Need for realistic water pricing Protection from pollution, and polluter pays principle Water quality monitoring Development of alternative water sources Improvement of knowledge of critical wetlands and management thereof
Water Act, 1956	Freshwater and seawater	Establishes water rights Regulates against pollution of water resources
Health Act, 1919	Sanitation, food and public water supplies	Regulation of pollution from a public health perspective
The Hazardous Substances Ordinance, 1974	Hazardous substances	Regulation regarding import, export, manufacture, sale, use, disposal dumping of hazardous substances Makes provision for appointment of inspectors
Pollution Control and Waste Management Bill (Draft)	Air, water and land	To prevent discharge of pollutants and fulfill international obligations
Prevention and Combating of Pollution of the Sea by Oil, 1981	Oil discharge	Stipulates liability caused by discharge from ships, tankers, offshore installations Exceptions include emergencies and accidental leakage Includes provisions for inspection of vessels and land-based facilities Legislates 'polluter-pays' principle

Legislation	Coverage	Key elements
Angola		
Constitution of the Republic of Angola, 1992	Environmental protection in general	Provides the basis for environmental protection and conservation and the right to a healthy and unpolluted environment
Environmental Framework Act, 1998	Environmental protection in general	Provides the framework for all environmental legislation and regulations Incorporates key international policies
Fisheries Act, 1992	EEZ, internal waters and all inland waters	Sustainable management Vessel licensing International and regional cooperation Supply of fisheries data Mariculture Quality and export of fisheries products Monitoring, control and surveillance of fishing activities
Interior and Marine Exclusive Economic Zone Act, 1992	EEZ, internal waters and all inland waters	Use of natural resources Protection of the environment Promotion of scientific research
Petroleum Activities Act, 1978	Oil industry	Exclusive rights to SOLANGOL for exploration, drilling and production of oil products Facilitation of international partnerships to increase local capacity
Petroleum Activities Decree, 2000	Oil industry	Sustainable development of the oil industry Compulsory use of environmental impact assessment
Mining Act, 1979	National	Declares all mineral resources as state property Regulates exploration and mining activities
Local Municipalities Act, 1999	National	Development, sanitation, environmental protection and land management responsibility of provincial and local government
Foreign Investment Act, 1994	National	Regulates foreign investments to ensure compliance with local policies on environmental protection, safety, health and environment of workers
Water Act (Draft)	National	Access to, use and protection of water resources Compulsory environmental impact assessment for all water projects
Environmental Impact Assessment Decree (Draft)	National	Requirements and standards for environmental impact assessment
Namibia		
Constitution of the Republic of Namibia, 1990	Environmental protection in general	Maintenance of ecosystems, processes, biodiversity Sustainable utilization of natural resources Dumping or recycling of foreign nuclear waste
Green Plan, 1992	Environmental protection in general	Sustainable use of living and non-living natural resources Environmental auditing and environmental impact assessment Pollutant treatment and disposal, including hazardous waste Protection of representative landscapes and ecological diversity
Environmental Assessment Policy for Sustainable Development and Environmental Conservation, 1994	National	Sustainable development Compulsory environmental impact assessment Requirements for environmental impact assessment
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Prevention and Combating of Pollution of the Sea by Oil, 1981	Oil discharge	Stipulates liability caused by discharge from ships, tankers, offshore installations Exceptions include emergencies and accidental leakage Includes provisions for inspection of vessels and land-based facilities Legislates 'polluter-pays' principle
National Oil Spill Contingency Plan (Draft)	Oil spills	Provides a framework for response in the event of a spill
Minerals Policy of Namibia	Mining sector	Ensuring environmentally sustainable exploration and mining activities
Minerals (Prospecting and Mining) Act, 1992	Mining sector	Mineral rights belong to the state Environmental protection within mining operations
Petroleum (Exploration and Production) Act, 1991	Petroleum industry	Rights for exploration, production and disposal belong to the state License holders may not interfere with fishing or navigation, must prevent pollution of any water License holders are required to minimize environmental effects and to undertake environmental rehabilitation if necessary

The Global International Waters Assessment

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

The need for a global international waters assessment

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

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

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

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

The Global Environment Facility (GEF)

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

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

United Nations Environment Programme (UNEP)

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

UNEP work encompasses:

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

University of Kalmar

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

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

International call for action

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

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

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

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

The conceptual framework and objectives

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

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

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

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

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

International waters and transboundary issues

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

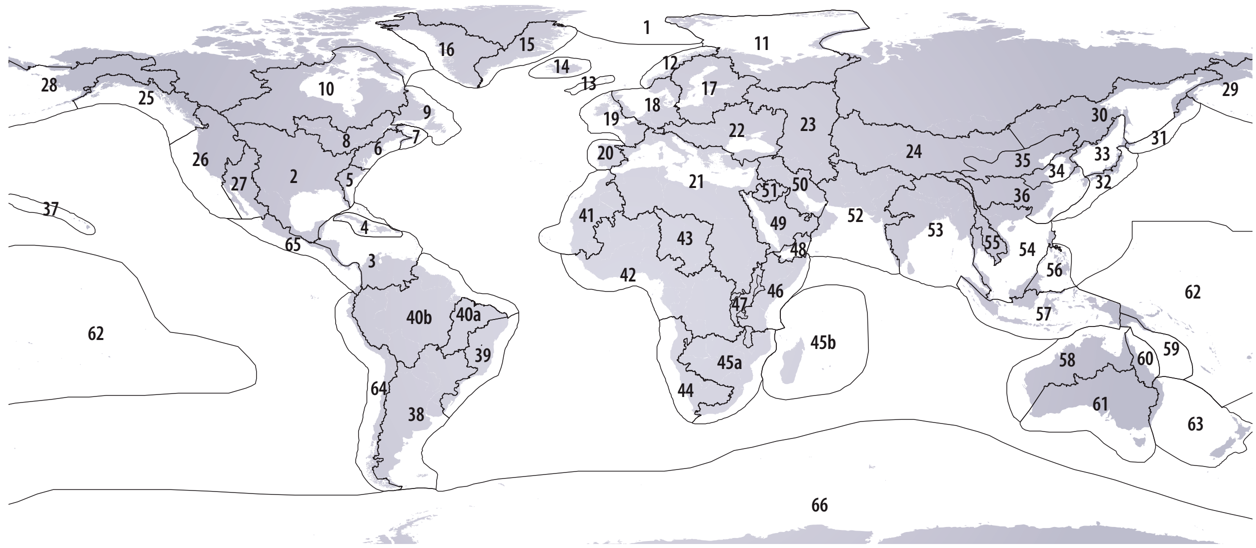
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and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

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

The organisational structure and implementation of the GIWA

The scale of the assessment

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



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

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

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

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

Large Marine Ecocsystems (LMEs)

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

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

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

The global network

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

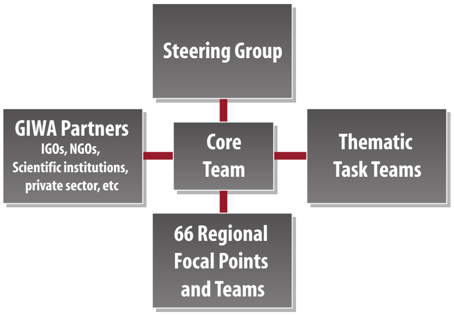


Figure 2 The organisation of the GIWA project.

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

GIWA Regional reports

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

UNEP Water Policy and Strategy

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

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

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

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

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

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

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

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

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The GIWA methodology

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

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

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

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

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

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

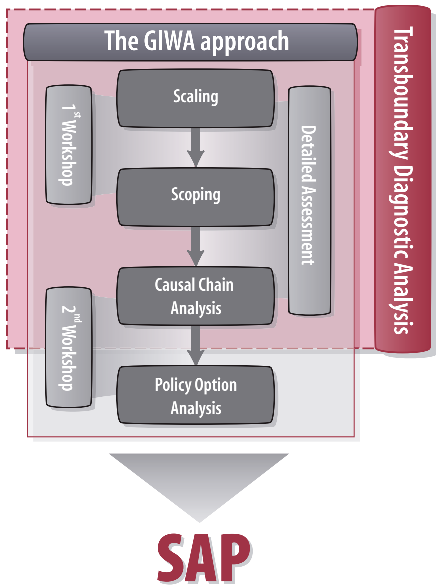

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

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

Scaling – Defining the geographic extent of the region

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

Scoping – Assessing the GIWA concerns

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

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

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

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

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

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

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

Table 2 Example of environmental impact assessment of Freshwater shortage.

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

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

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

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

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

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

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

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

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

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

Causal chain analysis

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

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

Conceptual model

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

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

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

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

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

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

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

Policy option analysis

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

Construct policy options

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

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

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

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

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

Global International Waters Assessment

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

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

Table 5b: Scoring criteria for environmental impacts of Pollution

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

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

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

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

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

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

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

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

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

GIWA

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

Broad Transboundary Approach

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

Regional Assessment – Global Perspective

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

Global Comparability

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

Integration of Information and Ecosystems

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

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

Priorities, Root Causes and Options for the Future

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

This Report

This report presents the GIWA assessment of the Benguela Current region, which includes the entire extent of the Benguela Current system and the freshwaters that drain into it. The environmental and socio-economic problems in the region differ greatly between its freshwater and marine components. A number of anthropogenic activities such as population increase, growth of coastal urban centres, irrigation, agriculture and industry, place increasing demands on the limited freshwater supplies of the region. The potential for conflicts over these resources is also high with large-scale inter-basin transfer schemes and transboundary rivers constituting national boarders. In the marine areas, despite the high primary productivity, overfishing and degradation of important habitats have lead to declines in fish stocks. Freshwater shortage and overfishing were considered priority concerns in the region. The past and present status and future prospects of these concerns are discussed and subsequently traced back to their root causes. Policy options to mitigate these problems are proposed that aims to provide solutions to these fundamental issues in order to enhance the management of the regions aquatic environment.

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