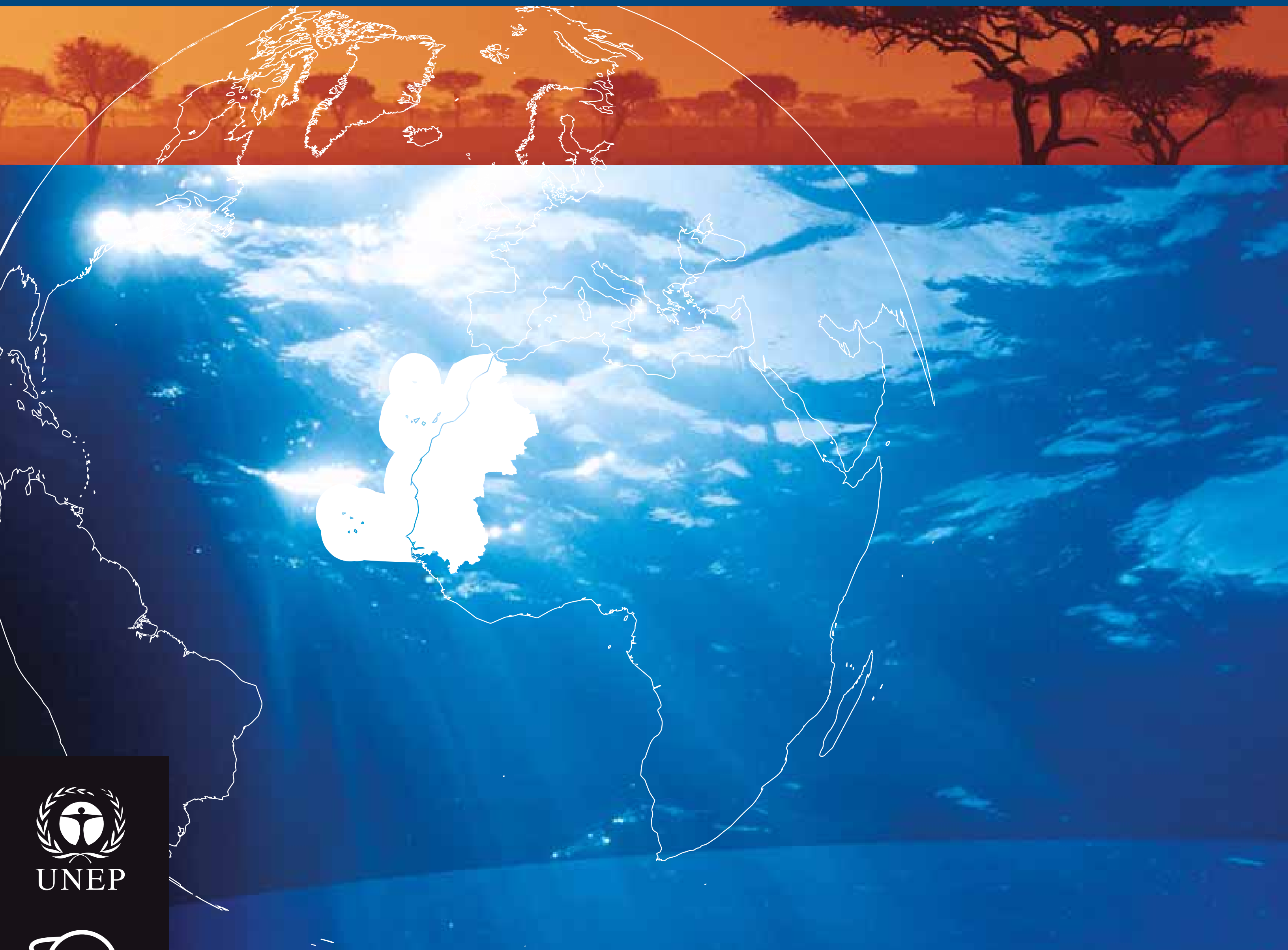
Global International Waters Assessment



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Canary Current

GIWA Regional assessment 41

Tayaa, M., Saine, A., Ndiaye, G. and M. Deme

Global International Waters Assessment

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Canary Current

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Executive summary

The GIWA region Canary Current encompasses Cape Verde, the Canary Islands, Mauritania, Senegal, The Gambia, Mali, Guinea, Guinea-Bissau and the western part of Morocco that drains into the Atlantic Ocean. In order to conduct a suitable assessment, the region was divided into two sub-systems in recognition of significant ecological, climatic and cultural differences. The northern sub-system covers part of northern Mauritania and the western part of Morocco. The southern sub-system includes the southern part of Mauritania, Senegal, The Gambia, Mali, Guinea, Guinea-Bissau, Cape Verde and the Canary Islands. The boundary between the two sub-systems is at Cape-Timiris at approximately 19° N.

The population in the region totals approximately 45.2 million people, out of which an estimated 70% are directly dependant on international waters for their livelihoods. The growth rate fluctuates between 0.8% and 3.03% with an average of 2.3% for the region. This population is engaged mostly in marine fisheries, agricultural production and tourism activities.

Mean annual rainfall ranges from 10 mm to more than 2 000 mm. The total annual renewable water resource in the region is on the average about 342 km^3 per year and average freshwater is approximately 15 km^3 per year. It is estimated that more than 80% of all water withdrawals are for agricultural use.

Based upon the assessment, the main tranboundary GIWA concerns in the region are Freshwater shortage and Unsustainable exploitation of fish and other living resources. In the northern sub-system, a declining groundwater base flow is a major issue linked to the long dry periods that the region as a whole has experienced for more than 30 years. For the last two to three decades, the average aquifer draw down in the Souss River Basin has varied from 0.5 to 1.5 m per year. The southern sub-system has been suffering from water shortage problems for the last three years and will most likely suffer in the next 20 years. The regime flow of Senegal River in particular has been significantly modified by the construction of the Manantali and Diama dams, which has altered the River's hydrological regime and has consequently caused transboundary problems.

The environmental impacts of stream flow modification and changes in the water table have led to serious socio-economic impacts that often have significant transboundary implications. These socio-economic impacts include the loss of agricultural income and potential, increased costs associated with the construction of dams and inter-basin transfer schemes to supply water, the costs of alternative sources of water, the cost of deepening wells and pumping, increases in water-borne diseases and conflicts about water supplies.

Unsustainable exploitation and particularly the overexploitation of fish stocks is another major issue in the region. Most if not all the coastal countries have already taken steps in terms of regulating fisheries at the national an international level, as demonstrated by discussions with the European Community over the renewal of fishing agreements with the different countries in the region. All these countries are aware that a moratorium on certain fish stocks is needed and that there is a need for conserving and improving fisheries management overall. In addition, specific policy measures intended to control industrial fishing pressures have been instituted.

Causal chain and policy options analyses were conducted for three issues:

- Stream flow modification for the Senegal River Basin;
- Lowering of the water table in the Souss-Massa River Basin;
- Overexploitation of fish in the Canary Current.

The Senegal River Basin actually experiences two types of stream flow modification: the reduction of discharges to the River due to the drought, leading to an intrusion of seawater; and a reduction of stream flow due to damming. The first type of modification is natural, while the second one is artificial and superimposed on the first one and characteristic of the Senegal River Delta. Therefore, while the focus was on the damming of the River, reduced precipitation has been considered as an immediate cause. Three major root causes were identified:

- Demographic growth, urbanisation and poverty;
- Lack of appropriate governance;
- Inefficient irrigation technology.

Within the existing regional organisations such as the Organisation for the Development of the Senegal River Basin (OMVS, Organisation pour la Mise en Valeur du Fleuve Sénégal) immediate policy options can be implemented for the Senegal River Basin. The consolidation of OMVS assets is one option that can be pursued. Institutional instruments such as the Environment Observatory would be a way to ensure monitoring and management of the River Basin. The Standing Committee of Water constitutes a framework for dialogue regarding the technical aspects of water resources management; the committee can formulate and present recommendations to the Ministers' Council. The role of these two bodies should be reinforced. Capacity building of the institutions in charge of water resources management must accompany all good governance measures, such as implementation of laws and regulations at the local, national and regional level. It is also essential to determine the implications of recommendations on stakeholders, and to make certain stakeholders are informed.

The main issues addressed in the causal chain and policy options analysis of freshwater shortages in the Souss-Massa Basin concerned lowering of the water table. Five major root causes of the lowering of the water table in Souss River Basin were identified:

- Demographic growth and population changes;
- Socio-cultural constraints;
- Governance and enforcement of water regulation;
- Technological changes;
- Economic causes.

The policy option concerning lowering of water table in the Souss-Massa River Basin is proposed to be of a holistic approach. The general framework of this scenario assumes a clear understanding of an integrated system (technical, institutional, political and economical settings) and full stakeholder participation through consultation and education. A new water pricing policy in combination with institutional changes are part of the proposed option.

Overexploitation of fish has been analysed for marine fisheries. Two immediate causes were identified to explain the overexploitation; excessive fishing efforts and unsustainable fishing practices. Both the industrial and artisanal fisheries are sectors responsible for the overexploitation. One of the root causes for industrial overfishing is that all countries of the region, except The Gambia have ongoing fishing agreements with the European Union. The agreements target on already highly treated species. Another root cause is the discard of small juvenile fish by industrial freezer trawlers. Examples of root causes from the artisanal sector are lack of enforcement of regulations and fuel subsidy for artisanal canoes. Policy options identified in the analysis are:

- Artisanal fishing licence system;
- Regulation of access to resources;
- Banning use of the beach seine;
- Joint negotiation of fishing agreements.

The current rate of water usage in the region is unsustainable if no drastic water policy changes are made. Overpumping of the Souss aquifer has resulted in significant water level declines and deserves special attention. Governance measures in the Senegal River Basin will have to be accompanied by capacity building in order to facilitate the implementation of the applicable laws, agreements and regulations at the local, national and regional level. The establishment of Marine Protected Areas form a key step in the preservation of the coastal area and is of crucial importance for the restoration of fish stocks and biodiversity.

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Finally, in writing this report, reference has been made to a number of publications as well as unpublished material. We are highly indebted to all the authors.

Abbreviations and acronyms

ACP	African, Caribbean, Pacific countries
AUEA	Water User Associations
CCS	Senegalese Sugar Company
CSRP	Subregional Fisheries Commission
COSEC	Senegalese council of shippers
CPE	Standing Water Committee
CRODT	Centre for Oceanographic Research of Dakar-Thiaroye
CSEC	Moroccan High Council for Water and Climate
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organisation of the United Nations
FCFA	Franc CFA, the basic monetary unit of UEMOA
GAIPES	Association of Vessel Owners and Industrial Marine Fisheries of Senegal
GDP	Gross Domestic Product
GNI	Gross National Income
GIWA	Global International Waters Assessment
GRT	Gross Registered Tonnage
IMROP	National Mauritanian Institute for Oceanographic and Fisheries Research
ITF	Intertropical Front
ISRA	Agricultural Research Institute of Senegal
MCS	Monitoring, Control & Surveillance
MPA	Marine Protected Area
NORAD	Norwegian Agency for Development Cooperation
ORMVA	Regional Agricultural Development Authority
OMVS	Organisation for the Development of the Senegal River Basin
ONAS	Senegal National Sanitation Board
ONEP	Drinking Water Agency
ORVASM	Souss-Massa Irrigation Agency
RAMSA	Agadir Municipal Authority
RBA	Souss-Massa River Basin Agency
SAED	Management and Exploitation Society for Senegal Delta River
SDE	Water Supply Company
SEMOS	Gold Mining Company of Sadiola
SOCAS	Senegalese Canned Food Company
SOGED	Diama Dam Company
SOCU	Surveillance Operations Co-ordination Unit
SPO	Socio-Professional Organisation
SRFC	Sub-Regional Fisheries Commission
UEMOA	West African Economic and Monetary Union
UPAMES	Union of Fishermen and Export Traders of Senegal

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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 GIWA Canary Current region covers the Canary Current Large Marine Ecosystem, and the river basins flowing in to it. The region extends from 36° N, 5° W at Strait of Gibraltar to 11° N, 16° W in Guinea-Bissau. The estimated coastline of the region is 3 900 km (Morocco 1 300 km, Western Sahara 1 110 km, Mauritania 754 km, Senegal 531 km, Guinea-Bissau 125 km, and The Gambia 80 km). The region also includes the Canary and Cape Verde Islands and Madeira situated off the coast of Senegal. These islands have a coastline of 3 505 km and total land area of approximately 12 300 km^2. Administratively, the region covers the Islands of Cape Verde and the Canary Islands, as well as the countries of Mauritania, Senegal, The Gambia, Mali, Guinea, Guinea-Bissau and the western part of Morocco (Figure 1).

The region has several drainage systems of both national and international significance that are highly dependant on rainfall patterns, and given the significant variability, some of these rivers flow only during the rainy season. The main river systems in the Canary Current South sub-system are Senegal and Gambia rivers, in the the Canary Current North it is the Sebou and Souss rivers (Figure 2).

The region has limited mineral resources and has reached low to medium levels of industrialisation. Hence, the drainage systems contribute significantly to rural as well as urban development. Waterways are exploited for crop and livestock development, rural as

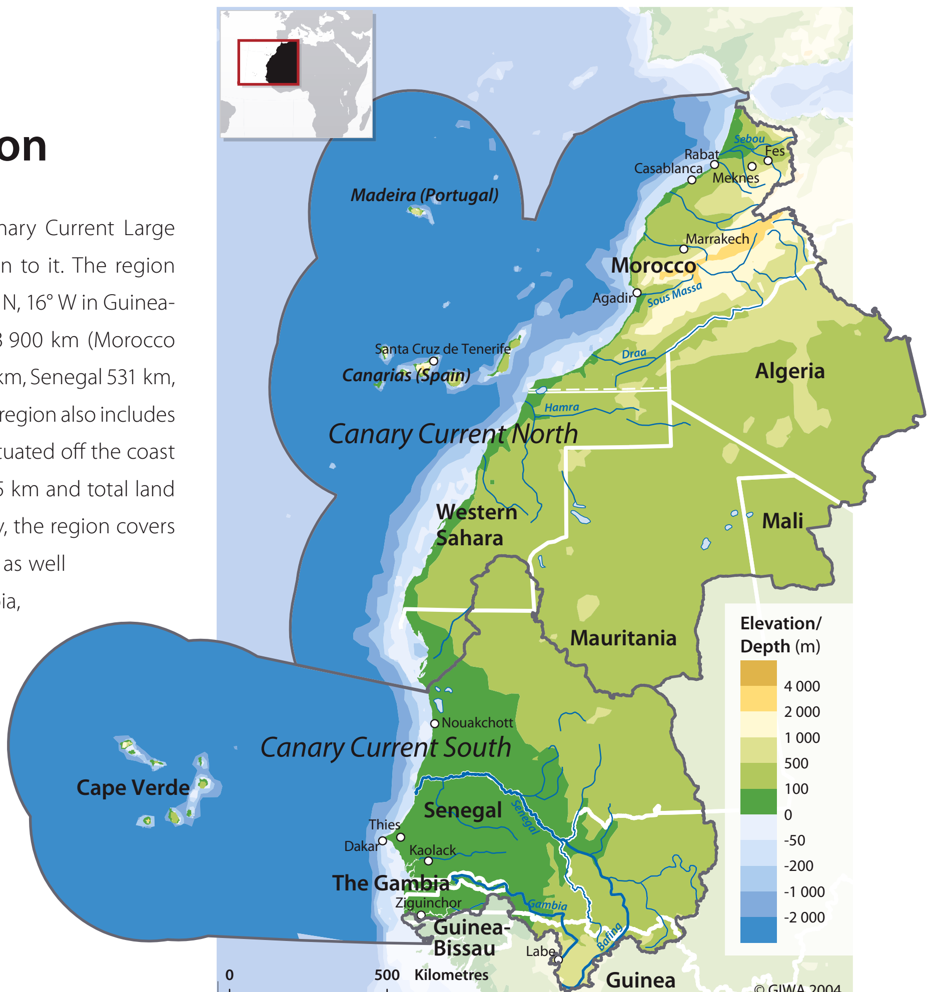

Figure 1 Boundaries of the Canary Current region.

Note: Western Sahara is a disputed territory. The depiction and use of boundaries, geographic names and related data shown on maps are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the UNEP.

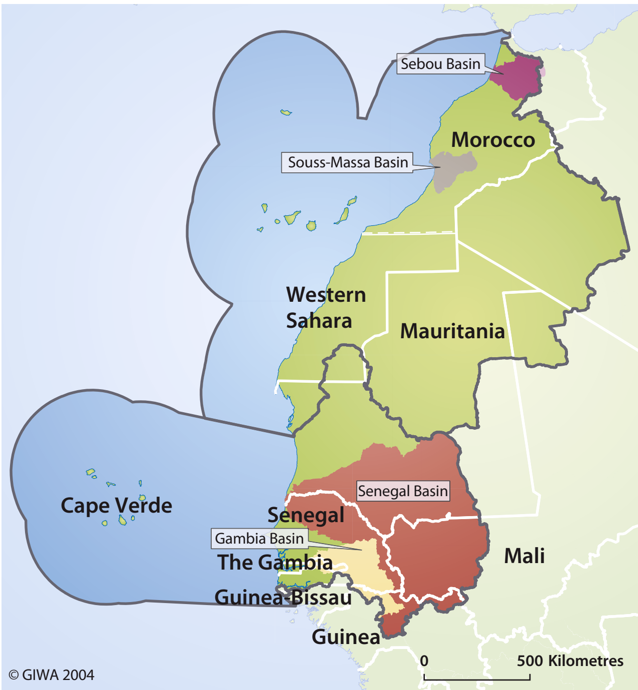

Figure 2 Major river basins in the Canary Current region.

Note: Western Sahara is a disputed territory. The depiction and use of boundaries, geographic names and related data shown on maps are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the UNEP.

well as urban domestic water needs and industrial development. In the majority of cases, the natural vegetation has been overexploited. In order to conduct a suitable assessment, the Canary Current region was divided into two sub-systems in recognition of the area's significant ecological, climatic and cultural differences. The northern part of the region has a Mediterranean climate, with areas that are arid and semi-arid, while the southern part is dominated by savanna and rainforests. These differences have a significant impact on patterns of resource use. The Canary Current North sub-system covers northern Mauritania and western Morocco, while the Canary Current South sub-system covers southern Mauritania, Senegal, The Gambia, Mali, Guinea, Guinea-Bissau, Cape Verde and the Canary Islands. The boundary between the two sub-systems is at the Cape-Timiris approximately 19° N (Figure 1).

Physical characteristics

The physical characteristics of the countries of the region are shown in Table 1. In the Canary Current North sub-system, the topography of the area features the Atlas Mountain range and vast plateaus, bordered by the Atlantic, with narrow coastal plains widening in the lower reaches along the Atlantic coast, and low-lying areas towards the southern parts most of which fall within the Sahelian zone. The high and middle Atlas ranges have summits exceeding 3 000 and 4 000 m.

The Canary Current South sub-system is generally low-lying. Mauritania has flat plains with a few hilly outcrops, Senegal has low, rolling plains with some foothills in the southeast, with the highest point at 581 m above sea level near Nepen Diakha. The Gambia is dominated by the

Table 1 Physical characteristics of the countries in the Canary Current region.

Country	Area in the region (km^2)	Area in the region (%)	Area total (km^2)	Continental Shelf (nm)	Exclusive Economic Zone (nm)	Contiguous Zone (nm)	Territorial Sea (nm)
Algeria	359 561	15	2 381 740	-	32-52	-	12
Cape Verde	4 031	100	4 033	-	200	24	12
Guinea	43 570	18	245 857	-	200	-	12
Guinea-Bissau	633	2	36 120	-	200	-	12
Mali	231 972	18	1 240 000	-	-	-	-
Mauritania	841 205	81	1 030 700	200	200	24	12
Morocco	303 741	75	446 550	200	200	24	12
Portugal (Madeira)	774	1	-	200	200	24	12
Senegal	190 521	97	196 700	200	360	24	12
Spain (Canary Islands)	7 556	1	-		200	24	12
The Gambia	10 721	100	11 300	200	200	18	12
Western Sahara	269 067	100	266 000	-	-	-	-
Total	2 263 351						

(Source: EROS Data Center 2003, ESRI 2002, CIA 2003)

Gambian River floodplains flanked by some low hills; the highest elevation is 53 m above sea level. Guinea-Bissau is dominated by coastal low plains rising to savanna in the northeast corner that reaches approximately 300 m above sea level. Guinea is also generally low-lying with a few hills and a mountainous interior rising to approximately 1 752 m above sea level at Mount Nimba. Most of the terrain of Mali is low-lying, with rolling northern plains and rugged hills in the northeast rising to approximately 1 155 m above sea level at the Hombori Tondo. The Cape Verde and Canary Islands both feature steep, rugged, rocky volcanic terrain.

Canary Current Large Marine Ecosystem

The marine ecosystem of the region is considerably influenced by the Canary Current, which flows along the West African coast from north to south between 30° N and 10° N and offshore to 20° W (Fedoseev 1970). Like other eastern boundary currents, it is wide (1 000 km) and slow (10-30 cm/s), and it flows year-round towards the Equator (Wooster et al. 1976, Batten et al. 2000). Its surface waters are relatively cool because as it flows southwards, it entrains water that has upwelled from the coast (Mittelstaedt 1991).

On average, the Current is about 500 m deep (Wooster et al. 1976) and flows at a speed of 10-15 cm/s (Zhou et al. 2000). The Canary Island archipelago forms an obstacle to the flow of the Canary Current (Batten et al. 2000). The Canary Current system contains coastal upwelling, filaments, and eddies (Johnson & Stevens 2000) with length scales of 100 to 300 km from along the coastal boundary of the current (Mittelstaedt 1991). The eddy kinetic energy values are less than 100 cm^2/s^2 (Zhou et al. 2000).

The Canary Current LME is classified as a Class I, highly productive (> 300 g C/m^2/year) ecosystem, based on global primary productivity estimates from SeaWiFS (LME 2004). The region supports fish and also millions of migrating birds. Sardines, pilchards, Horse mackerel, Chub mackerel and Hake are some of the commercial species found in the region.

In the last three or four decades there has been an increase in catches of the European pilchard *Sardina pilchardus* as a result of increased fishing pressure. Additionally, due to collapsing fishing stocks in Europe, European countries are transferring their fishing efforts to the waters of the region as a result of a bilateral fishing agreement. Among the species threatened are the Sea bream (*Dentex canariensis*), along with certain pelagic species such as the Chub mackerel (*Scomber japonicus*) (LME 2004).

Climate and renewable water resources

There are significant climatic variations among the North and South sub-systems and the Atlantic Ocean archipelago. The Canary Current North sub-system features a Mediterranean type of climate, primarily in Morocco, with a desert climate in Mauritania. The latter is constantly hot, dry and dusty most of the year. In the Canary Current South sub-system, Senegal, The Gambia, Guinea-Bissau and Guinea have a tropical climate, while Mali has a tropical and arid climate. Senegal in particular experiences a hot and humid rainy season from May to November accompanied by strong southeast winds. Senegal's dry season extends from December to April and is dominated by hot and dry harmattan winds. The Gambia is generally hot with a rainy season during the months of June to November and a cooler and drier season during November to May. Guinea-Bissau and Guinea are generally hot and humid with a monsoon-type rainy season during the months of June to November with southwesterly winds, and a dry season during December to May with northeasterly harmattan winds. In Mali, the months of November to June are generally hot and dry. However, June to November are characterised by some rainfall with humid weather. Both the Canary Islands and Cape Verde have a temperate climate with a warm, dry summer; precipitation tends to be meager and very erratic.

The total annual renewable water resources in the region is about 342 km^3/year, with a maximum of 226 km^3/year for Guinea and a minimum of 0.3 km^3/year for Cape Verde (Gleick 1998) (Table 2). The total freshwater withdrawal is approximately 15 km^3/year for the whole region, with Morocco having the highest withdrawal. On average, agriculture accounts for more than 80% of the water withdrawals in the region.

Generally, rainfall over the region exhibits high spatial and temporal variability. The mean annual rainfall ranges from as low as 10 mm in

Table 2 Renewable water resources and freshwater withdrawal in the Canary Current region.

Country	Renewable water aesources (km^3/year)	Total freshwater withdrawal (km^3/year)	**Use** (%)		
			Domestic	Industrial	Agricultural
Cape Verde	0.3	0.03	10	19	88
Gambia	8	0.02	7	2	91
Guinea	226	0.74	10	3	87
Guinea Bissau	27	0.02	60	4	36
Mauritania	11.4	1.63	6	2	92
Morocco	30	11.05	5	3	92
Senegal	39.4	1.36	5	3	92
Total	342	15	-	-	-
Average	-	-	15	5	83

(Source: Gleick 1998)

the innermost core (Mali and Mauritania) of the Sahara to more than 2 000 mm in parts of the equatorial regions (Guinea, Guinea-Bissau and The Gambia) and other parts of West Africa. The coefficient of rainfall variability in the region exceeds 200% in the deserts, whereas it is about 40% in most semi-arid areas, and between 5 and 20% in the wettest areas (IPCC 2001).

Biodiversity

The African Environmental Outlook (UNEP 2002) reported that habitat diversity in Africa ranges from desert, semi-desert and savanna to tropical forest, mangroves, freshwater lakes and inland and coastal wetlands. The upper Guinea forests are a biologically unique system that is considered one of the world priority conservation areas because of its high endemism, with nearly 200 plants, 4 mammals, 20 000 butterfly and moth species and 15 species of even-toed ungulates. The northern section of Senegal, which is part of the Sahel, consists largely of savanna grass, trees and spiny shrubs. The Gambia River lowlands are mostly composed of woodlands. In the extreme south are mangrove swamps and dense forests of mangroves, teak and bamboo. Wildlife is diverse but larger mammals such as lions, cheetah and antelopes are largely confined to the less-populated eastern half of the country. Hippopotamuses, crocodiles, cobras and boar snakes can also be found. The upper part of Mauritania has little plant life and few animals. However, in the south there is a strip of steppe with acacia and commiphoa trees, which are home to lions and monkeys.

The southern Sahara zone of Mali has mimosa and gum trees. Thorny desert trees are common in the central region and in the south kapok, baobab and shea trees are common. Common animal species include the cheetah, oryx, gazelle, giraffe, warthog, lion, leopard, antelope and jackal. Mangroves and rubber vine are common tree species in The Gambia, while cedar and mahogany trees abound. Wildlife includes leopards, wild boars, crocodiles, hippopotamus and several species of antelopes. Game birds such as guinea fowls and grouses are plentiful.

In Morocco, the mountainous regions contain extensive areas of forest, including large stands of corks, oak, evergreen oak, juniper, cedar, fir, and pine. Except for areas under cultivation, the plains are usually covered with scrub brush and alfa grass. On the plains of Souss near the southern border a large forest of Argan (*Argania spinosa*) can be found. These thorny trees are found principally in Morocco. The wildlife population is a mixture of European and African species. Of the animals characteristic of Europe, the fox, rabbit otter, and squirrel can be found in large numbers, while the African animal species are dominated by the gazelle, wild boar, panther, wild goat, baboon, and horned viper.

River basins

The region has several drainage basins of both international and national importance. The four major river basins in the region are (Figure 2):

- Senegal River Basin
- Gambia River Basin
- Souss-Massa River Basin
- Sebou River Basin

Senegal River Basin (Canary Current South sub-system)

The Senegal River is a transboundary water system shared by the four West African countries of Mali, Guinea, Mauritania and Senegal (Figure 3). It is 1 800 km long, has an area of 475 000 km^2 and has an annual average flow of 23 billion m^3, 45 million m^3 of which is used (Finger & Teodoru 2003). The source of the River is in Mali at the confluence of the Bafing and the Bakoye rivers, 1 000 km inland from its outlet to the Atlantic Ocean.

Figure 3 Senegal River Basin.

The Senegal River flows across the western part of Mali, Guinea, and downstream the River defines the border between Senegal and Mauritania before discharging into the Atlantic Ocean near Saint Louis in Senegal. Other significant tributaries include the Falémé, Kolimbiné, Karakoro, and Gorgol rivers, all located south of the Manantali Dam.

The Senegal River is navigable from the Atlantic Ocean to Podor, Senegal, and to Kayes in Mali during the rainy season. Grassland covers 68% of the Basin, 4.8% is in crop production, 3.6% is wetland and 0.1%

is forest. About 82% of the surface area is desert; arid and virtually unproductive. Water availability is estimated to be 5 775 m^3 per year (Finger & Teodoru 2003).

The Senegal River is quite important to the countries it flows through, because its waters are used for crop and livestock production, and irrigated farming is an important economic activity along the River. Pastoral and nomadic inhabitants who herd livestock, particularly in Mauritania, are highly dependant on this river. Fishing is also an important economic activity along the river course. There are 115 fish species in the river system, 26 of which are endemic.

Gambia River Basin (Canary Current South sub-system)

The Gambia River (Figure 4) is another transboundary river in the Canary Current region that is shared among the three West African countries of The Gambia, Senegal, and Guinea. From its source in the Fouta Djallon (Futa Jallon) in Guinea the River flows west through Senegal and The Gambia before draining into the Atlantic Ocean near Saint Mary's Island.

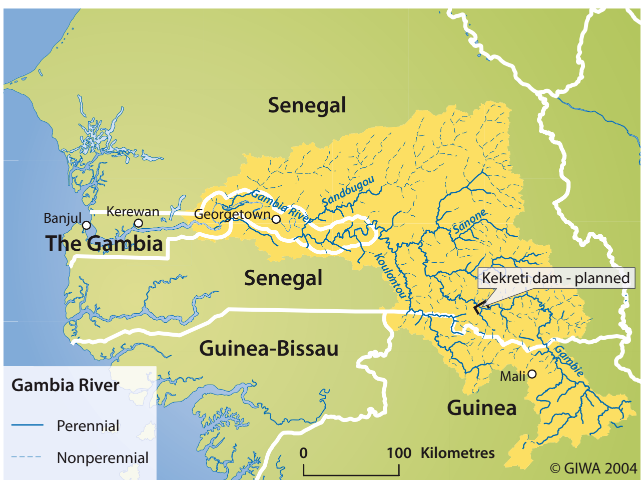

Figure 4 Gambia River Basin.

The Gambia River is approximately 1 120 km long with a catchment area covering approximately 490 000 km^2. Its major tributaries are the Sandougou and the Sofianiama rivers. The total quantity of water leaving Guinea for Senegal is estimated at 3 km^3/year. The River then flows northwards to enter The Gambia in the extreme eastern part of the country. An average of 4 km^3/year (average of 1951-1990) to nearly 10 km^3/year enters The Gambia from Guinea (Saine 2001). The flow of the River is reported to be highly seasonal, with a peak discharge of about 2 000 m^3/s, but for six months the inflow at the Gambian border is less than 10 m^3/s (Saine 2001).

In May, the river discharge falls below 0.5 m^3/s. Because of the flat topography of The Gambia and the low river discharges during the dry season, saltwater moves up about 70 km upstream in the wet season and 250 km upstream in the dry season. The tidal variation at the river mouth is about 1.6 m.

Dense mangrove swamps fringe the lower river as far as 97 km inland, after which freshwater swamps and salt flats on low-lying stretches alternate with dense clumps of small trees and shrubs. On the higher slopes of the riverbank, swamps and shrubs give way to parkland and tall grass with wild oil palm grows found along the valley bottom. The vegetation of the River and of its creeks provides a favourable habitat for insects, animals, and birds. The swamps encourage mosquitoes and tsetse flies to breed. The river system abounds in fish and river creatures, including the hippopotamus and the crocodile. Among the 400 bird species that have been recorded are Kingfisher, Cuckoo, Swallow, Heron, Sunbird, Hawk, and Grass warbler. The annual flooding of the fertile alluvial loams of the middle flats makes them especially suitable for intensive rice cultivation. On the light sandy and well-drained soils of the higher slopes, peanuts (groundnuts) grow particularly well. Cultivation and settlement have therefore taken place in the middle flats and on the higher slopes, with many villages being located on the borderline between the flats and the plateau.

Approximately 20 million inhabitants in the region depend on the Gambia River for their livelihood, making it one of the most important rivers in the area. The River is used for irrigation downstream, where the potential has been estimated at 20 000 ha, with enormous potential for additional 60 000 ha of suitable soils in the Senegalian part of the Basin (Saine 2001).

There are about 10 4200 ha of swamps in the Basin, of which 33 500 ha are cultivated. Mangroves account for an additional 67 000 ha. In the dry season, the saltwater moves upstream at a rate of 15-20 km per month. It is thought that an additional withdrawal of 1 m^3/s would increase the penetration of saltwater by 1 km per month during the dry season (Saine 2001). The safe limit for irrigation from the Gambia River without a major dam construction is estimated to be no more than 2 400 ha in the dry season. However, if the planned Kekreti Dam on the Gambia River in Senegal is constructed, it is expected that 15 000 ha can be irrigated in Senegal and 55 000 ha in The Gambia. Moreover, this dam could prevent salt intrusion during the dry season. The development of these 55 000 ha would require 0.275 km^3 per year of water. A further 25 000 ha of mangrove cultivation would require 0.125 km^3 per year of water (Saine 2001).

Patterns of settlement in The Gambia reflect three habitats, found on both banks of the River, consisting of the swamps adjacent to the River (and not extending above Kaur), the riverine flats known as banto faros (from a Malinke word meaning "beyond the swamp"), and the sandstone uplands. Most rural settlement is concentrated on the uplands, which have the best-drained soils. A number of settlements are located in the banto faros on the middle course of the River, where there is less danger of flooding than in the swamps. Many villages are built on the boundary between the uplands and the riverine flats. The River is navigable for the entire length of The Gambia; oceangoing vessels can reach Georgetown 280 km upstream. The River is the main transportation artery for The Gambia and provides access to interior sections of Senegal and Guinea.

Souss-Massa River Basin (Canary Current North sub-system)
The Souss-Massa River Basin is located in the southwestern Morocco between the Atlantic Ocean and the high Atlas Mountains. It encompasses the Souss River and all its tributaries, the Massa River and all its tributaries, and the coastal river basins of Tamri and Tamraght (Figure 5). The Souss River Basin covers a total area of 27 000 km^2.

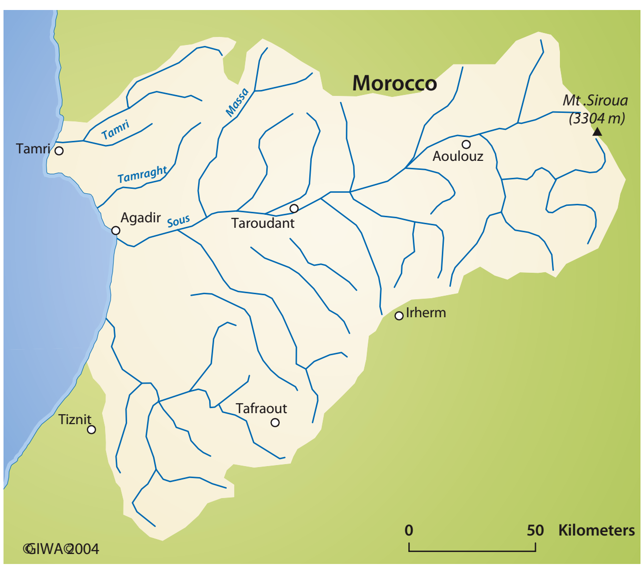

Figure 5 Souss-Massa River Basin.

Even though the Souss-Massa Basin is located entirely in Morocco, there are several tranboundary issues that are relevant for this report: (i) a significant portion of the available water resources of the Souss-Massa Basin can be lost to the Atlantic Ocean when a strong flash flood occurs; (ii) a large proportion (roughly 60%) of the national production of fresh fruits and vegetables that are exported from Morocco to international markets originates in the Basin; (iii) a correspondingly large amount of 'virtual water' is exported annually through the export of commercial high-cash crop commodities; and (iv) an equally important amount of irrigation water is currently pumped from the transboundary aquifer, around two-thirds of the total water used for irrigation purposes.

Average rainfall for the Souss-Massa River Basin is about 270 mm per year, making this part of Morocco a semi-arid environment. The rainfall that does occur in the Basin comes in short storm bursts, which creates serious flooding conditions. The high intensity rainfall is not easily used by irrigation because of the short, high intensity duration. Storms in the Basin result in flash floods, which create sediment problems in the River; the sediment is subsequently carried over into the reservoirs. Sediment deposition in the reservoirs has decreased the active storage pool for most reservoirs. Flash floods also pose a danger to the population (CSEC 2001). In 1971 the population of the Souss-Massa River Basin was 938 000 and in 1994 it has grown to 1 541 000 and is expected to almost double by the year 2020 (CSEC 2001). Land use is dominated by forest and pasture land (80%) (Baroud 2002).

Modern irrigation systems are used in 60% of the irrigated area. Citrus and vegetables represent almost 44% of crops grown in the irrigated area (Baroud 2002). The predominant source of water, not only for domestic use but also for irrigated land, is from groundwater. Groundwater levels have been dropping over the years as water is extracted for use.

Sebou River Basin (Canary Current North sub-system)
The Sebou River is one of the largest Moroccan rivers, draining approximately 40 000 km^2 (Figure 6). It runs across some 600 km from its source in the middle Atlas Mountains to the Atlantic Ocean. The upper part of the Sebou Basin rises over 2 800 m and is underlined by

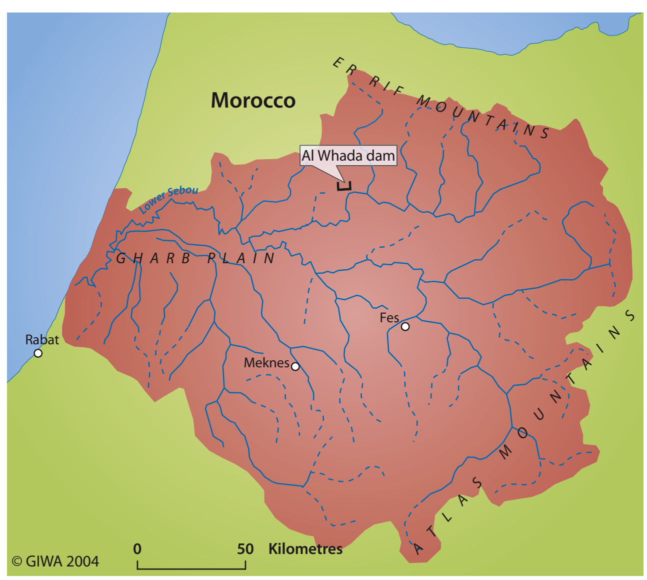

Figure 6 Sebou River Basin.

calcareous rocks. The Basin receives a mean annual rainfall of more than 1 000 mm. The middle part is located mainly in the Rif and the Pre Rif mountains, characterised by a mean elevation of 2 000 m above sea level with relatively steep slopes, bedrock that consists of schist, marl and marly sandstones, and high rainfall averaging 2 000 mm per year. The lower Sebou Basin encompasses a large plain called the Gharb plain. The estuary extends over 90 km of the lower river.

Presently, there are 16 dams constructed along the Sebou River. The most recently constructed dam (the Al Wahda Dam) is the second most important dam in North Africa after the Aswan High Dam. Its storage capacity is 3 800 km^3 with a height of 800 m. The reservoir of the Al Wahda Dam is designed to irrigate 100 100 ha, generate 400 GWh per year of hydroelectricity, transfer 600 million m^3 to the southern region of Morocco, and to protect the Gharb Plain from floods (Arthurton et al. 2002).

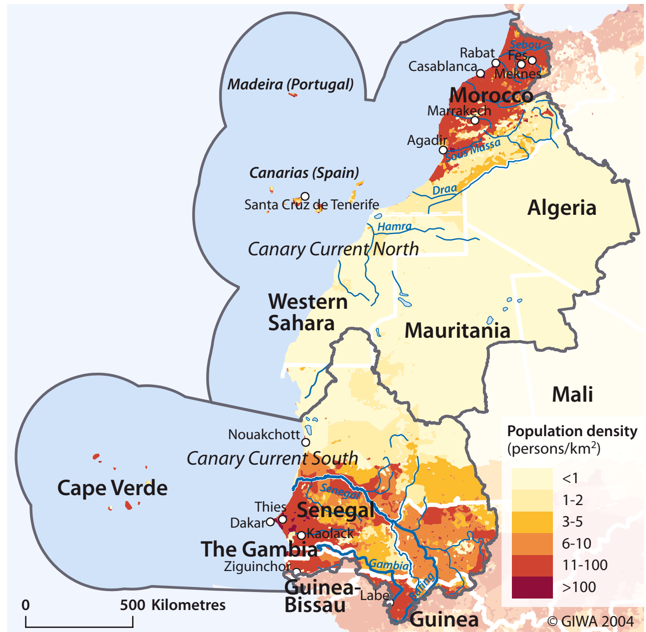

Figure 7 Population density in the Canary Current region.

(Source: ORNL 2003)

Note: Western Sahara is a disputed territory. The depiction and use of boundaries, geographic names and related data shown on maps are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the UNEP.

Socio-economic characteristics

Population

The total population for the region is approximately 45.2 million people (Table 3), of which an estimated 70% are directly dependant on international waters for their livelihoods. Figure 7 shows the population density in the region. Growth rates fluctuate between 0.8% (Cape Verde) and 3.03% (The Gambia) with an average of 2.3% for the region. An average of 54% of the population in the region falls in the 15-64 years age group. Approximately 41% of the population is younger than 15 years of age and only about 3.5% are above 65 years of age (World Bank 2001).

Table 3 Population in the Canary Current region.

Country	Population in the country	Population in the region	Growth rate (%)
Algeria	32 130 000	100 000	1.28
Cape Verde	412 000	400 000	0.79
Guinea	9 030 000	1 400 000	2.37
Guinea Bissau	1 360 000	0	2.02
Mali	11 340 000	2 000 000	2.97
Mauritania	2 910 000	2 600 000	2.91
Morocco	3 1680 000	25 300 000	1.64
Portugal	10 520 000	200 000	0.41
Senegal	10 580 000	10 000 000	2.56
Spain	40 280 000	1 500 000	0.16
The Gambia	1 400 000	1 400 000	3.03
Western Sahara	270 000	270 000	ND
Total		45 200 000	

Note: ND = No Data.

(Source: CIA 2003, ORNL 2003)

The current infant mortality rate is 73 per 1 000 live births on average in the region, with the highest recorded at 120 (Mali) and the lowest recorded at 32.2 (Algeria) (CIA 2003) (Table 4). This is a slight decline from 1997 statistics where the average rate for the region was 86 (World Bank 2001). In the Canary Current region the literacy level is low for the majority of countries (Table 4). The rate of urbanisation is relatively high for all the countries but significantly higher for Morocco, Mauritania and Cape Verde. The average urbanisation rate for the region was 40.2% in 1997 and had slightly increased to 43.6% in 2001 (World Bank 2001).

The majority of the countries in the region are among the poorest countries in Africa. From Table 5 the countries with incomes above the African GNI per capita average of 635 USD are Mauritania, Morocco, Senegal and Cape Verde. Some of the factors contributing to the low GDP in the region are the terms of trade for agricultural products and fisheries, which form the primary backbone of the economy. Furthermore, the industrial sector made a very weak contribution to the GDP for 1999. However, the services sector contribution to the GDP in 1999 appeared to be stronger (World Bank 2001).

Table 4 Population charactersitics of the Canary Current region.

Country	Birth rate (per 1 000)	Death rate (per 1 000)	Migration rate (per 1 000)	Infant mortality rate (per 1 000 live births)	Life expectancy at birth (year)	Total fertility rate (born per women)	Literacy level (%)
Algeria	17.8	4.6	-0.39	32.2	72.7	2.04	70.0
Cape Verde	27.0	6.9	-12.16	50.5	69.8	3.77	71.6
Guinea	42.5	15.7	-3.14	93.3	49.5	5.9	35.9
Guinea-Bissau	38.4	16.6	-1.6	110.3	47.0	5.07	53.9
Mali	48.4	18.3	-0.35	119.6	47.4	6.73	31
Mauritania	42.2	13.0	0	73.8	51.9	6.08	46.7
Morocco	23.3	5.8	-1.03	44.9	70.0	2.89	43.7
Senegal	36.2	10.9	0.21	57.6	56.4	4.93	33.1
The Gambia	40.8	12.4	1.89	74.9	54.4	5.53	47.5

(Source: CIA 2003)

Table 5 Gross National Income and annual growth of GDP in the Canary Current region.

Country	Income per capita 1999		Average annual growth of GDP (%)	
	(USD)	Growth (%)	1980-1990	1990-1999
Algeria	1 550	3.3	ND	ND
Cape Verde	1 174	0.66	ND	ND
Guinea	514	0.92	ND	4.2
Guinea-Bissau	317	4.48	4	0.3
Mali	273	2.16	0.8	3.6
Mauritania	607	3.01	1.8	4.2
Morocco	1 066	-1.74	4.2	2.3
Senegal	820	3.62	3.1	3.3
The Gambia	314	4.06	3.6	2.8

Note: ND = No Data.

(Source: World Bank 2001)

Domestic saving for the countries are far too low to sustain the required investment and growth at the level needed to substantially reduce poverty, especially with the high population growth rates. In general, most African countries with extremely low per capita incomes, as is the case is for this region, cannot promote saving, and instead reliance on subsistence farming reduces household income substantially. Another common factor in the region is the difference in income distribution between and among households, among regions, and among rural and urban populations. Traditional land tenure systems in the region tend to be biased and discriminatory against certain group of people, especially women (World Bank 2001).

Economic activities

The population that lives in the region's coastal areas is engaged mostly in marine fisheries, agricultural production and tourism. In Morocco 80% of the industrial infrastructure of the country is situated along the Atlantic coast and tourism contributes to more than 54% (296 680 people) of the employment (ONEM 2001). In Cape Verde, fisheries contribute only 5% to the GNP and employs around 11 000 people. Fish protein is the main source of animal protein in the diet of residents, and exports of fisheries products are of considerable importance to the economy of the region (Fonseca 2000). The Senegalese fishing industry, which consists of small-scale artisanal fishing and large-scale trawler fishing, employs about 100 000 people (LME 2004). In Mali, where fisheries are primarily inland-based, production is around 99 500 tonnes with a potential yield ranging between 37 000 and 60 000 tonnes (Ticheler 2000).

About 90% of the industries in Senegal are located in the Dakar coastal zone, along Hann Bay, which ranges from the port of Dakar to Thiaroye village, with a 3 km long coastline. These industries employ a substantial number of the population and include fish processing, textile, pharmaceutical, painting, food processing and slaughterhouses (JICA 1999, Arthurton et al. 2002). It is estimated that over 0.5 million people in Mauritania, Guinea-Bissau and Senegal depend directly on fisheries for their income and food supply (IPS 2001).

By 2001 the agriculture sector was still one of the driving forces for economic development in many countries of the region. In Mauritania and Mali, the main crops produced are millet, pulses, rice, dates, yams, watermelons and maize. In the region's savanna areas (The Gambia and Senegal), groundnuts, maize and rice are the major food crops produced (Senegal produced 828 300 tonnes of peanuts in 2000, providing a significant percentage of foreign exchange). The crops grown for industrial purposes are cotton and sugar cane. In the rainforest areas (Guinea and Guinea-Bissau) agriculture production is dominated by subsistence farming, with the main food crops being rice, peanuts, cassava, plantain, maize, vegetables and fruits. While industrial crops include cashew nuts and cotton, the common crops are perennials (vegetables and fruits). In Morocco, the principal crops are cereals, particularly wheat and barley (4.8 million tonnes in 2001),

Table 6 Livestock distribution in the Canary Current region.

Country	Livestock (million)			
	Sheep	Goats	Cattle	Poultry
Mauritania	6.2	4.1	1.3	3.1
Mali	6	8.5	6.1	24.5
Senegal	4.3	3.6	3	45
Morocco	6.3	5.1	2.7	ND

Note: ND = No Data.

(Source: Diop 2001, Tandia & Dieng 2001, ORMVA/SM 2001)

along with roots crops such as potatoes and sugar beets (1.1 million), vegetables including tomatoes and watermelons (3.2 million), fruits, particularly grapes and dates (2.6 million), and sugar cane (1.3 million). A wide variety of other fruits and vegetables are also grown. The livestock industry is also of major importance, particularly in Mauritania and Mali (Table 6).

Water resources

Due to considerable rainfall variability, most of the rivers in the region have been dammed for irrigation and energy production. The Senegal River has been subjected to significant water resources development projects. Two dams have been constructed on the Diama River. One near its mouth, designed to exclude saline water, and the other at Manantali in Mali was designed to provide electricity and water for a potential of approximately 10 000 ha of rice. The latter also provides a potential of approximately 125 000 ha of rice in Mauritania. For the Senegal River valley, there is a potential for 240 000 ha from the Diama and Manantali Dams (FAO 1997, Vincke & Thiaw 1995). In the Souss Basin in Morocco, five concrete dams and nine earthen dams have been constructed and designed to irrigate 134 294 ha and provide drinking water for the city of Agadir and the region (CSEC 2001).

Nearly 80% of the water in the region is used by the agriculture sector for irrigation. The high demand is mostly in arid and semi-arid countries of the region (Morocco, Mauritania, Mali and Senegal). The increasing proliferation of urban centres, particularly along the coast, has led to increased water demand not only for domestic use but also for industrial development. This however, may consume only about 10% of the overall water use.

Legal framework

All of the countries in the region are signatories to various international conventions related to water use such as the United Nations Framework Convention on Climate Change, United Nations Convention to Combat Desertification, Ramsar Convention on Wetlands, Convention on International Trade in Endangered Species, United Nations Convention of the Law of the Sea, and Convention on the Prevention on Marine Pollution (Table 7).

Table 7 Conventions that affect water use in the region.

Convention	Morocco	Mali	Mauritania	Senegal	Cape Verde	The Gambia	Guinea Bissau	Guinea
Convention on Biological Diversity		√[1]	√	√	√	√	√	√
United Nations Framework Convention on Climate Change	√	√	√	√	√	√	√	√
United Nations Convention to Combat Desertification	√	√	√	√	√	√	√	√
Convention on International Trade in Endangered Species of Wild Fauna and Flora	√	√	√	√		√	√	√
Convention on the Control of Tranboundary Movements of Hazardous Wastes and their Disposal (Basel Convention)	√	√	√	√	√	√		√
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)	√				√			
Nuclear Test Ban Treaty	√	√	√	√		√		
Convention for the Protection of the Ozone Layer (Vienna Convention)	√	√	√	√		√		√
International Convention for the Prevention of Pollution from Ships (MARPOL)	√		√	√		√		
Convention on Wetlands (Ramsar Convention)	√	√[2]	√	√		√	√	√
International Convention for the Regulation of Whaling	√			√				√
United Nations Convention of the Law of the Sea			√	√	√	√	√	√
Environmental Modification Convention					√			
Convention on Fishing and Conservation of Living Resources of the High Seas				√				

Notes: [1] Signed and ratified. [2] Signed but not ratified.

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 8.

Table 8 Scoring tables for the Canary Current region.

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

IMPACT: 0 No known impact; 1 Slight impact; 2 Moderate impact; 3 Severe impact

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

Canary Current North	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.5* ↗	2.0 ↗	0.8 ↗	1.0 ↗	1.9	1
Modification of stream flow	1					
Pollution of existing supplies	1					
Changes in the water table	2					
Pollution	1.0* ↗	1.0 →	1.0 →	1.0 →	1.1	3
Microbiological pollution	0					
Eutrophication	1					
Chemical	1					
Suspended solids	2					
Solid waste	1					
Thermal	0					
Radionuclides	0					
Spills	1					
Habitat and community modification	2.0* ↘	1.6 ↘	0 →	0 →	0.7	5
Loss of ecosystems	3					
Modification of ecosystems	1					
Unsustainable exploitation of fish	2.3* ↘	2.0 ↘	0 ↗	1.6 ↘	1.4	2
Overexploitation	3					
Excessive by-catch and discards	2					
Destructive fishing practices	2					
Decreased viability of stock	0					
Impact on biological and genetic diversity	2					
Global change	0.8* ↗	1.0 ↗	0 ↗	1.0 →	1.1	4
Changes in hydrological cycle	1					
Sea level change	1					
Increased UV-B radiation	0					
Changes in ocean CO_2 source/sink function	0					

Canary Current South	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.8* ↗	2.0 ↗	2.2 ↗	1.4 ↗	2.3	1
Modification of stream flow	2					
Pollution of existing supplies	2					
Changes in the water table	1					
Pollution	1.8* ↗	1.0 ↗	1.0 ↗	1.8 ↗	2.0	4
Microbiological pollution	1					
Eutrophication	2					
Chemical	2					
Suspended solids	2					
Solid waste	2					
Thermal	0					
Radionuclides	0					
Spills	1					
Habitat and community modification	3.0* ↘	2.6 ↘	1.8 ↘	1.0 →	1.8	3
Loss of ecosystems	3					
Modification of ecosystems	3					
Unsustainable exploitation of fish	2.5* ↘	2.5 ↘	1.2 →	2.4 ↘	1.8	2
Overexploitation	3					
Excessive by-catch and discards	2					
Destructive fishing practices	3					
Decreased viability of stock	0					
Impact on biological and genetic diversity	2					
Global change	0.8* ↗	1.0 ↗	1.0 ↗	1.0 ↗	1.5	5
Changes in hydrological cycle	1					
Sea level change	1					
Increased UV-B radiation	0					
Changes in ocean CO_2 source/sink function	0					

* 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.

It should be noted that the present assessment is based upon available data. A number of data gaps and an imbalance in the availability of data exist, which makes the assessment speculative in some cases. To adequately address the concerns and issues, empirical evidence from research elsewhere was used and applied to the regional context.

Freshwater shortage

IMPACT **Canary Current North** IMPACT **Canary Current South**

The region has limited mineral resources and has generally attained low to medium levels of industrialisation. Hence, the region's river basins contribute significantly to both rural and urban development. Rivers are exploited for crop and livestock development, rural and urban domestic water needs and industrial development.

A large portion of the region is located in the Sahel region, meaning that surface water is limited to areas with significantly high levels of rainfall. This effectively controls the characteristics of the rivers in the region. Within this context, the uneven distribution of surface waters is quite notable in the region. Mauritania and Mali are characteristically dry countries while substantial parts of Senegal, The Gambia, Guinea and Guinea-Bissau are characterised by ample amounts of annual rainfall. With these characteristics, overextraction of large amounts of water by upstream nations automatically jeopardises the availability of the resource for downstream users. Overextraction also leads to changes in biodiversity.

The primary concern of this assessment is focused on rivers of transboundary nature; the Senegal and Gambia rivers for the Canary Current South and the Souss-Massa and Sebou rivers for the Canary Current North sub-system.

Environmental impacts

Modification of stream flow

Stream or river flow may be altered by natural causes and this is discussed under the Global change concern. However, stream flow modification, particularly in the Canary Current South sub-system, has been caused primarily through damming of rivers that in turn has resulted in changes in flow regimes, losses of flood plains, losses or degradation of wetlands and increased erosion of riverbanks. Many seasonal rivers and streams drain this sub-system and provide support to food production. These seasonal rivers run for a very limited period and their economic impacts are therefore very limited.

Box 1 Impacts of stream reduction in the Souss-Massa Basin.

In the northern part of the Canary region, the Moroccan government has built several dams along the Souss River. Hundreds of small, seasonal springs flow down from the Anti-Atlas Mountains into the Souss. While the construction of dams supports industrial agriculture (citrus and tomato exports) in the region, it has disturbed the ecological equilibrium of Souss-Massa's Natural Reserve. Since less water is able to reach its wetlands, the size of the reserve has decreased dramatically. This lack of free-flowing water affects wildlife in the region. Fewer migratory birds, for example, linger at the reserve, and fewer still select it as their final destination. For the most part modernisation has improved water quality. Wells are all lined and most have a bib or a concrete border on the ground around the well to prevent seepage of contaminants into the wells. Technology has also made it possible to treat wells with bleach and iodine. In some villages more modern methods have made it easier to retrieve water such as a tap system, or electric pump that eliminates the need to use a pulley system. An even more modern washer/wheel method has made drawing water from wells less laborious. However, these modern techniques have not reached Tagmoute and the washer/wheel pump cannot be used to make drawing water easier in Tagmoute because the wells are too deep. So as of 1999, villagers rely on old pulley systems that are quite laborious. The introduction of plastic has made for some lighter water containers that are more hygienic. Unfortunately the increase in garbage caused by packaging and the lack of a suitable garbage site has led villagers to discard trash in the dried up riverbed. Garbage is also found throughout the oasis, which will obviously harm the local vegetation and animals. The water situation is greatly improved by the presence of wells and a piping system that delivers drinkable water to every home. This saves women in the village endless hours when they do not have to spend gathering water from the well. Aside from the saltwater that enters wells due to the ocean's proximity, the problem is drought. In 2002, Morocco's dams were filled to 75% of their capacity. Water shortage is a problem that is mounting with increasing desertification, deforestation, and population growth. Farmers are highly cognisant of the water shortage, as some of their fields depend on rainfall for water. The fields closer to the River have irrigation to help them, but these, too, are affected when the water level drops in the River.

(Source: Powell et al. 2003)

Fundamentally, the hydrological regime of the Senegal, Gambia, Souss and Sebou rivers has been subjected to considerable changes in annual discharge and surface area during the past four decades. While drastic changes in the region's river and stream discharges have occurred due to natural factors (climate change), a significant proportion of the changes are due to dynamic human activities. Increasing demographic characteristics and urban and industrial growth are among the factors that have contributed to the changing landscape and thereby, to modified stream flow (See Box 1).

The regime flow of Senegal River in particular has been significantly modified by the construction in 1987 of the Manantali Dam, which is located upstream in Mali. Similarly, the construction in 1997 of the Diama Dam downstream in Senegal near the river mouth has contributed to coastal erosion. Construction of the Diama Dam helped curb the back flow of saline water (JICA 1999). Small dams on the Gambia River (Kekret and Kouya Dams) have similar impacts on their respective river regimes (Diagana 1994).

The most common impact of damming includes inundation of large areas, siltation, salinisation and other consequences from infrastructure construction, such as, roads, building, and vegetation removal. It is reported that construction of the Manantali Dam changed the pattern of flooding, resulting in severe problems for the agro-pastoral communities (Diagana 1994).

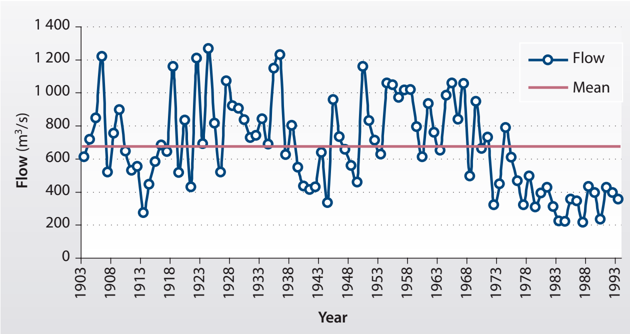

Figure 8 Senegal River discharge variation at Bakel, 1903-1994.
(Source: Diagana 1994)

A standardised time series study of the annual discharge of the Senegal River shows that the River has had a period of significant deficit after 1970 (Figure 8). The percentage of reduction between the mean annual discharge over the years before 1970 and the deficient periods is over 40% (Diagana 1994).

Human activities such as damming, urbanisation, agro-industrial development and settlements along major rivers in the region have caused erosion in coastal areas (Box 2). Deforestation, particularly of native forests, has been very significant in the Senegal Basin. According to the World Resource Institute (WRI 2003) all the indigenous forests along the River have been exploited. Exploitation of exotic forest species is estimated to be about 5% per year. Nevertheless, 6% of the drainage area is designated as protected. Wetlands occupy approximately 4% of the drainage area, some of which are rated among wetlands of international importance under the Ramsar Convention (Vincke & Thiaw 1995). In the Senegal River, the sediment load is as high as 1.18 to 2.86 million tonnes per year, which has threatened lagoon-based cities near the river mouth (Arthurton et al. 2002).

Pollution of existing supplies

For the Canary Current South sub-system, the African Environment Outlook (UNEP 2002) has reported "rising levels of pollution of surface and groundwater resources." Pollution of existing water supplies is attributed to sewage and industrial effluents, agricultural run-off, sedimentation due to poor farming techniques, sand storms (wind erosion), and coastal erosion (JICA 1999).

In Morocco, some rivers and aquifers in contact with saliferous terrains contain as much salt as 320 g/l. In the Tadla area in Morocco, the main river has its source in a saliferous zone and carries 3 g/l during the period of minimum flow. It is estimated that more than 130 000 km^2 of land in Morocco have no outlet to the sea. In these hydrologically closed systems, water is not renewed and the concentration of salts has increased over time. An example of this situation is the in Gharb region (in the Sebou River) where incoming surface waters are of good quality (electrical conductivity of about 1 mmhos/cm) but groundwater frequently contains more than 10 g/l of dissolved salts, especially when water table is shallow (Tayaa & Bazza 1994). Salinisation has also been enhanced through anthropogenic activities such as inadequate irrigation with saline waters and floodwaters. The spreading of flood

Box 2 Transboundary problems resulting from the Diama and Manantali Dams on the Senegal River.

The Diama and Manantali dams were constructed on the Senegal River in 1985 and 1988 respectively. Each of the dams was built for a specific purpose, the Diama was built downstream of the Senegal (around 30 km upstream from the river mouth) for the purpose of preventing saltwater intrusion. It is closed during the dry season from November to June, and is gradually opened during the rainy season, generally around July. The Manantali Dam was built 1 200 km upstream from the river mouth on one of the main tributaries of the Senegal River for hydroelectric power purposes. The main goal of this construction was to provide water for irrigation along the Senegal River valley and a freshwater supply for Lake Guiers, which itself is a water supply for Dakar, the capital of Senegal. The environmental impacts of the dams are:

- Water quality modification, particularly in the delta region, with increased water-borne parasitic diseases (specifically, increased intestinal bilharzia, which had never been observed before the construction of the dam, in the region of Richard Toll, 60 km upstream of Diama Dam). A field survey between 1988 and 1989 of 1 000 randomly selected individuals of all ages showed a prevalence rate of 60% for intestinal bilharzia (Talla 1992). Furthermore, it is reported that dissolved oxygen levels have markedly decreased, with an associated accumulation of nitrate and nitrite (Bâ 1992).
- Reduction of fish yields downstream of the Diama Dam.
- Inundation of certain localities near the main city, Saint Louis, downstream of the dam during particularly rainy seasons.

Detailed studies between 1989 and 1992 (Michel et al. 1993) have shown that, after the construction of the Diama Dam, complex and unstable coastal systems, such as the Senegal River Delta, have undergone profound changes. While the Senegal river mouth is located on a sandy coast with a weak tide, the equilibrium (erosion and sedimentation) of the coastline (the "Langue de Barbarie" sand spit, in particular) and the inner part of the river mouth are both highly dependent on the longshore drift and the transported sand. Therefore, the construction and operation of the Diama Dam greatly affects the river mouth and coastal geomorphology during both the dry and rainy seasons. For example, between 1986 (when the Diama Dam began to function) and 1994, the Senegal River mouth moved southwards more than 3 500 m, and is now located to the extreme south of its former location. Furthermore, a higher sedimentation rate on the marine side as compared to the riverside contributed to reinforcement of the marine side of the "Langue de Barbarie". The Senegal River mouth will certainly be maintained for a while at the southern part of the Delta. Field measurements (including topo-bathymetry transects and sedimentological analysis), spot imagery processing and recent topographical map comparisons have allowed a better understanding of the functioning and evolution of the Senegal River Delta.

Construction of the Diama and Manantali Dams created an additional 240 000 ha of land for irrigation on the Senegalese side of the Senegal River, giving the country the opportunity to diversify its crop base and increase food production, but this was achieved at a cost. The two dams also created controversy by altering the hydrological regime of the River, thus generating transboundary problems. Upon completion of the dams, farmers and fishermen living downstream were exposed to increased health problems from water-borne diseases such as malaria and schistosomiasis. Operation of the upstream dam also reduced annual floods along the floodplain, where an ancient and productive form of recessional irrigation had been practiced for hundreds of years. Recessional irrigation is still practiced along these flood plains on an estimated 50 000 ha, but floodwaters from the Manantali Dam do not carry the same load of nutrient-rich silts which are deposited on the fields after the flood waters retreat.

(Source: Diop et al. 2000)

waters leach some of the salts present in the soil at the time of application but cause actual evaporation to increase and new salts are brought up to the soil surface. Water quality is a problem in some peri-urban areas along the coast, where wastewater has exacerbated problems (CSE 1988).

In Yeumbeul, Senegal, 7 000 households are dependant on groundwater sources that are contaminated by high levels of nitrates over and above the WHO recommendations of 50 mg/l (UNEP 2002). In Dakar, most of the industries discharge raw industrial waste into water-bodies, due to lack of treatment plants. Furthermore, tourist facilities such as hotels also discharge pollutants in water-bodies. Another pollutant source is intensive agriculture, which consumes a great quantity of fertilisers. The Senegal River and Lake Guiers are examples of water bodies polluted by fertilisers. In recent years, the Great Dakar region has experienced chronic water deficits of potable water (JICA 1999). As an example, aquifer waters taken from wells around Dakar showed very high concentration of sodium, potassium, calcium, magnesium, sulfates, nitrates, bicarbonates and chlorides (JICA 1999). The highest bicarbonate concentrations were recorded along the sea front (3.41 mg/l) and an area of unconfined aquifer the least influenced by human settlement (1.32 mg/l). In terms of nitrate, 20 mg/l was recorded in the eastern sector of the peri-urban area, which is less impacted by human settlement. However, excessive concentrations above 200 mg/l were recorded in the peri-urban district of Dakar, which is without sanitation system and is characterised by a predominance of slums. In addition, Niang-Diop et al. (2002) noted that approximately 660 000 ha in Senegal has been affected by salinisation, with 260 000 ha of this area along the coast, and the remaining 400 000 ha found in the Casamance Basin, near the Senegal river mouth.

In summary, pollution of groundwater in the region exacerbates freshwater shortages. Nevertheless, countries from the region in general have experienced considerable improvement in to safe drinking water (WHO standards), particularly for urban populations (Table 9).

Table 9 Access to safe drinking water sources in urban and rural areas in the region.

Country	Access safe drinking water	
	Urban areas (%)	Rural areas (%)
Senegal	90	65
Mali	75	60
The Gambia	95	77
Guinea-Bissau	79	49
Morocco	99	57
Mauritania	33	40

(Source: WHO 2001)

Changes in the water table

The coastal areas of Morocco, Mauritania and Senegal have substantial groundwater aquifers (Senegal-Mauritanian Basin, Taoudeni Basin, Souss-Massa Basin and Errachidia Basin) (ONEM 2001). Major constraints on the use of groundwater arise from the lack of precise data about aquifers, such as capacity, depth and contamination. However, the GIWA Task team recognised that over the past three decades, there has emerged clear evidence of declining base flow in most of groundwater systems in the region. This rapid decline is due to increasing population pressure and the diversification of economic activities. This scenario makes groundwater exploitation very likely in the years to come. Data availability for aquifers in the region is, however, quite limited.

In the Canary Current North sub-system, data from Morocco show that in the Souss-Massa Basin irrigated perimeter, the aquifer drawdown can be as high as 2 m per year and has ranged between 10 to 65 m since 1970 (CSEC 2001). Because of decades of drought, recharge rates are very low and there are problems with overabstraction.

In the Canary Current South sub-system, the decline has been linked to the long dry periods (more than 30 years) and overextraction of groundwater for irrigation (Diene 1995). In Pout and Sébikhotane in Senegal, the aquifer drawdown is 1.5 m per year. There are substantial groundwater aquifers, but because of low precipitation, recharge rates are very low and there are problems with overextraction, especially near Dakar (AWRMI 2001).

Socio-economic impacts

Agriculture, fisheries, industry and tourism are the socio-economic activities most affected by these water problems. The majority of the countries in the region rely heavily on the agricultural sector for food security, raw materials for industrial development and export earnings. Therefore any impact on the productivity of this sector depresses the entire economy of countries involved. However, it should be recognised that the construction of dams on the Senegal and Gambia rivers have also contributed to hydropower generation and irrigated farming.

The inland fisheries is equally important in terms of food security and income generation. The Canary Current South sub-system countries rely on fisheries from the Senegal and Gambia rivers. High fish catches are achieved during high river peak seasons and is lowest with increased catch effort during low flow periods. Therefore, the increasing fluctuation in the river regime, particularly as a result of diversions and climate change, has negative impacts on the fishing sector and in essence contributes to indirect costs in time spent on the activity. ACOPS (2001), reported losses of up to 50 000 tonnes (1972) and 30 000 tonnes (1990) of estuarine fisheries in the rivers due to stream flow modification. Inland fisheries provide regular employment for millions of poor people, and seasonal or part-time employment for many more. This work is closely linked to other activities such as farming, livestock rearing, and fuel wood collection. It has been reported that salt intrusion along the coastal areas of Senegal was partly the reason for the abandonment of the Katakalouss shrimp culture project (Bousso et al. 1993).

Economic impacts of freshwater shortage are also reflected in the high costs associated with the construction of dams and inter-basin transfer schemes to supply water. The Senegal River has a number of large-scale dams, as mentioned above. Morocco has also developed intensive and extensive water resources networks that involve high investment and maintenance costs. Landlocked Mali has a severe shortage of freshwater and has been highly dependent on donor funding to pay for alternative water sources in recent years. Additional economic impacts associated with freshwater shortages are the increased costs from pumping groundwater that results from the need to drill deeper wells. A significant percentage of the population of the Cape Verde Islands depends on groundwater for domestic use, and the increasing costs make this dependency extremely expensive. The same situation applies to Morocco, which relies on groundwater for irrigation development. The majority of the countries in the region are dependant on hydroelectric power for their energy supply, which in turn is directly affected by changes in the water regime. This impact is also reflected in the costs of desertification, and increased effort required for searching for alternative water resources.

Health impacts were assessed slight and moderate in the Canary Current North annd South sub-systems respectively. Polluted water supplies are source for microorganisms that can cause water-borne diseases. Reservoirs associated with dams provide a hospitable environment for carriers of water-borne diseases such as bilharzias and guinea worm, which leads to river blindness (Box 3). Against this backdrop, health impacts were ranked based on the effect of these water borne diseases, particularly diarrhoea, cholera and bilharzia and guinea worm, which constitutes a major health problem mainly in Mali, Senegal, Guinea, Guinea-Bissau, Mali, and Niger. Onchocerciasis (river blindness), the world's second leading infectious cause of blindness, is found in 36 African countries. As a public health problem the disease is most closely associated with Africa, where it constitutes a serious obstacle to socio-economic development. A black fly that abounds in fertile riverside areas is the vector that causes the disease.

Box 3 Health impacts due to stream flow modification: Damming of the Senegal River Basin.

Water reservoirs combined with channeling of water for irrigation have created debilitating health problems for the people living in the Senegal River Basin. The permanent presence of standing water in the valley has led to a continuing increase of water-borne diseases that were already common in the area: malaria, diarrhoea, intestinal parasitic diseases, and particularly bilharzias, for which the Senegal valley unfortunately holds the world record (Verhoef 1996). Intestinal bilharzia had never been observed in the Canary Current South sub-system before the construction of the dam 60 km upstream of Diama Dam. A field survey between 1988 and 1989 of 1 000 randomly chosen subjects of all ages showed a prevalence rate of 60% for intestinal bilharzia (Talla 1992). Cholera outbreaks, which typically used to occur only during the rainy season, appear to have become quasi-endemic. The increase in schistosomiasis has resulted from the creation of freshwater bodies, such as irrigation canals and ponds, where disease-bearing snails that were previously controlled by seasonal fluctuations and salt inflows are now able to breed. The mortality rate caused by water-related disease as calculated in 1997 was 8 000 per year. It was estimated that measures to manage flows from the dams could reduce the annual number of deaths by 2 500.

(Source: Finger & Teodoru 2003)

These fertile riparian areas frequently remain uninhabited for fear of infection. Out of some 120 million people worldwide that are at risk of onchocerciasis, 96% are in Africa, and majority of these are in the countries of the Canary Current South sub-system (Tandia & Dieng 2001). In addition, previous surveys have shown that groundwater pumped specifically for drinking in suburban areas is contaminated with the parasites and bacteria that lead to diarrhoea, particularly in children.

Health impacts are relatively small in the Canary Current North sub-system, based on the size of affected population in comparison to the population as a whole. However, in Morocco, water-borne diseases caused by changes in the quantity of freshwater resources affect mainly the rural population. In 1994, it was reported that 206 people had paludism, 3 582 people had epidemic hepatitis and 1 108 people had bilharzia (Table 10) (ONEM 2001).

In the Senegal and Gambia rivers, for example, it has been reported that aquatic weeds have increased due to construction of dams and therefore navigation has been restricted. Habitats for migratory birds have also been affected due to dam construction. Similarly, fish composition has been altered. Conflicts in uses of the resources within the watercourse do occur, but with limited intensity. In Senegal, modification of the hydrologic regime of the Senegal River as a result of

Table 10 Water-borne diseases in Morocco 1990-1994.

Disease	Number of affected people				
	1990	1991	1992	1993	1994
Paludism	838	499	405	198	206
Epedimic hepatitis	2 357	2 286	2 586	2 502	3 582
Bilharzia	3 487	3 705	2 358	1 137	1 108

(Source: ONEM 2001)

damming increased agricultural productivity downstream, but this was achieved at the expense of livestock husbandry that had traditionally been carried out in the flood plains. This upstream-downstream shift in resources also created potential bilateral conflicts between Senegal and Mauritania, as reported by Niang (1999). Persistent conflicts are mostly common among the pastoral and nomadic livestock keepers in Mauritania and Mali. As mentioned earlier, freshwater shortages contribute significantly to economic and health problems. Naturally, these factors are inter-related and in essence, the most common impact on the communities is an aggravation of poverty. People have moved away from traditional lands due to shortages of freshwater, which results in changes in community lifestyles. In Africa, per capita consumption rates of fish are very high, and millions of consumers count on inland fish as a major source of protein, making this resource important for food security (Ticheler 2000). While marine fisheries production is increasingly entering export markets, inland fish production largely continues to feed local populations. However, in the Canary Current region, the assessment showed that the degree of severity of the freshwater shortage is small and localised. The frequency and duration of the impacts is still short term with seasonal variations.

Conclusion and future outlook

The current environmental status of freshwater shortages in the Canary Current region shows that there are significant impacts due to stream flow modification, pollution of existing supplies and changes in the water table. High population rates, urbanisation with limited additional infrastructure, industrialisation and agricultural development are among the major contributors to the problem, as well as the beneficiaries of the resources. Many transboundary rivers have multiple dams that cause environmental problems. Due to shortage of surface water, many countries continue to extract groundwater for various needs. The number of people affected (in terms of economics, and social and health effects) is high particularly in the Canary Current South sub-system.

In the future, an increase in water demand for irrigation, drinking water and industrial water associated with a decrease in water supply due to drought will put pressure on available water resources. As a consequence, more river regulation to provide additional water storage will likely result. In fact, Morocco has already more than 90 large and small dams and the authorities are planning more construction the next 20 years (ONEM 2001). In addition, countries will be more likely to look to redistribute water through inter-basin transfer. Again in the case of Morocco, inter-basin transfer options from north to south have been considered since the beginning of the 1990s (CSE 1988). The water demand for the Greater Dakar region is expected to grow by 30% over the next decade, and triple over the next 30 years (at an annual growth of about 3%) (AWRMI 2001).

In general, in the majority of the countries of the region, there is a growing concern and awareness about water shortage and scarcity as well as about drought and the effects of climate change on water resources. Several measures have been taken since the middle of the 1980s and the beginning of 1990s. Such measures include campaigns aimed at the general public about the importance of conserving drinking water, actions to implement more efficient water use practices in irrigation, development of improved water harvesting methods in rain-fed areas and the use of wastewater for irrigation. In Morocco for example, since the beginning of the 1990s, the General Department of Hydraulics has been developing a comprehensive, flexible water resources master plan for the country's major river basins. Moreover, the institutional framework and setting for water resources management and development such as the creation of river basin agencies, a consultative national council for water and climate, and various water regulations are being launched.

Pollution

IMPACT **Canary Current North** IMPACT **Canary Current South**

Eutrophication due to pollution has been identified as a problem, particularly in the Canary Current South sub-system. Furthermore, chemical pollution and suspended solids were also ranked as a major problem in the Canary Current region as a whole. Microbiological pollution and oil spills were assessed as slight in the Canary Current South sub-system. In the Canary Current North sub-system, the problems encountered are chemical pollution, suspended solids from agriculture (from the use of fertilisers and pesticides in major irrigated perimeters in the major watersheds) and industrial activities. Pollution along and in the Atlantic waters is a transboundary problem and affects all the other Atlantic coast countries in the region (The Gambia, Mauritania and Morocco). The most critical problem in Cape Verde is marine dumping, especially hazardous wastes.

For other GIWA issues, such as thermal and radionuclide pollution, there is no evidence or data concerning these activities in the region. There is some evidence of minor spills of hazardous materials, but these are limited to harbors and fishing ports (UNEP 2002). These issues are therefore not further discussed.

Box 4 Pollution in the city of Dakar.

Senegal's industrial enclave is along the Hann Bay in the capital city of Dakar, which is also the most populated area in the whole country. Some of these industries involve highly toxic chemicals that are used in the production of paint, textiles and pharmaceuticals. There are also fish, slaughterhouses and food processing industries. The 1999 Japanese International Development Cooperation Report on the status of the environment in Senegal noted that raw surface waters were highly polluted. The report noted that this pollution was concentrated along the densely populated Hann Bay in Dakar where 30% of the industries discharge their waste directly into the bay (30%), 12% is discharged through sewers, 12% is discharged after pre-treatment and 4% passes through septic tanks or in open sites. The total amount of wastewater discharged is estimated to be 41 000 m^3 per day. Run-off from agriculture also contributes very significantly to pollution of water, as can be observed in Lake Guiers, and the Senegal and Casamance Rivers. Tourist facilities along the Atlantic coast also discharge to waters, and oil spills can be observed around oil refineries in Dakar

(Source: JICA 1999)

Environmental impacts

Microbiological

Coastal cities in the region such as Dakar, Nouakchott, Banjul, without adequate sanitation and waste treatment facilities, are hubs for microbial pollution. In addition, these coastal cities are primary centres of industrial development and a high population density (Arthurton et al. 2002). According to the African Environmental Outlook (UNEP 2002), microbial and bacteriological contamination is a particular concern in the Hann Bay, near Dakar (Senegal) (See Box 4). Water-borne diseases due to microbiological pollution for the Canary Current South sub-system are listed in the section on health impacts of pollution.

Eutrophication

The assessment of eutrophication is based on the artificially enhanced primary productivity in receiving water basins as related to the increased availability or supply of nutrients. In the Canary Current South sub-system the increasing proliferation and invasion of aquatic species (*Typha australis, Salvinia molesta*) forming green carpets on the water surface along the rivers and particularly in the Senegal River Delta is partly as a result of increased nutrient loading. Under such conditions biological resources (fish and plants, in particular) are affected (Tandia & Dieng 2001). The decay of organic matter depletes oxygen particularly in areas around major cities, the bays and ports, creating anoxia and fish mortality (Tandia & Dieng 2001). In addition, some toxic algae in Lake Guiers have been reported (Tandia & Dieng 2001). The problem of eutrophication has been assessed as having moderate impacts in the Canary Current South sub-system.

For the Canary Current North sub-system, eutrophication effects are to certain degree only found in large dam reservoirs. This is due mainly to pollution loads and the use of fertilisers upstream of reservoirs, which increase the presence of algal blooms that in turn result in a deterioration of the quality of drinking water. As an example, in Sidi Mohammed Ben Abdellah reservoir, which supplies Rabat City in Morocco, 98% of the phosphorus and 85% of the nitrates originate from fertiliser uses upstream of the reservoir (ONEM 2001).

Chemical

Like most rivers draining deserts, the Senegal River contains some salt. The level increases sharply between December and June and drops towards the end of July. There is no regular monitoring of chemical pollutants in the region neither in inland nor in marine waters. However, the intensive use of pesticides and fertilisers in the agricultural and irrigated areas in the region (Morocco and Senegal River valley for example), is a well-known fact. In 2001, the agricultural sector in Morocco used 8 500 tonnes per year of nitrogen as a fertiliser. This use is expected to climb to 15 200 tonnes per year by the year 2015. In addition, it has been reported that nitrate concentrations in several wells in the Oum Errabia Basin are more 50 mg/l with a yearly increase of 5 mg/l. It is also estimated that 0.5 to 1% of the total pesticides used in Morocco reach the country's rivers via run-off (ONEM 2001).

Suspended solids

The region is characterised by desertification, overgrazing of fragile ecosystems, cultivation of crops on steep slopes (Cape Verde), and soil erosion. These anthropogenic activities lead to run-off and increases in turbidity in the major rivers and lakes in the region.

Data on suspended solids for the Gambia and Senegal rivers in the Canary Current South sub-system is shown in Table 11. Fundamentally, these statistics show that the Senegal River has a fairly high concentration of suspended solids (196 mg/l) compared to other major African rivers. In contrast, the Gambia River has low concentrations, amounting to only 19.5 mg/l (Martins & Probst 1991). In terms of total dissolved solids, the two rivers have minimal levels, especially in comparison with other major African rivers.

In the Senegal River and Lake Guiers, total suspended and total dissolved solids are increasing. In particular, total suspended solids are quite significant in the Senegal River and fairly moderate in the Gambia River. The cause for these loads are partly due to increasing

Table 11 Suspended solids in the Gambia and Senegal rivers.

River	Precipitation (mm)	Run-off (mm)	RC (%)	TDS (mg/l)	TSS (mg/l)	Transport (million tonnes)		TSS/ TDS
						TDS	TSS	
Gambia	1 100	219	20	17	19.5	0.08	0.09	1.10
Senegal	650	48	7	42	196	0.4	1.9	2.44

Note: RC = Run-off coefficient. TDS = Total Dissolved Solid. TSS = Total Suspended Solid.
(Source: Martins & Probst 1991)

Box 5 Damming of the Sebou River.

Sediment fluxes of the Sebou River were estimated based the on suspended sediment load transported by the River to the coast. The study reported an exceptionally high sediment yield (850 tonnes/km²/year) before the construction of the dams. The sediment load was due to the combination of steep slopes that generate landslides and mud flows, easily eroded material, high precipitation and human activities such as vegetation removal and change in land use. It was estimated that the sediment load from 1940 to1972 before the construction of dams was about 34 million tonnes per year. After the construction of five dams on the River, the sediment yield was not more than 1.36 million tonnes per year. Thus, more than 95% of the River's sediment load was trapped by these dams. In addition, damming of the Sebou River appears to have had a pronounced effect on the coastal zones, which reached a new dynamic equilibrium in response to the changed sediment regime. The estuarine behavior of the lower stretches of the River downstream of the dams has greatly disturbed the river outlet topography and coastal stability.

(Source: Arthurton et al. 2002)

anthropogenic activities as described earlier, and partly because of the decrease in stream flow following the construction of Manantali and Diama dams.

In Morocco, dam siltation is a problem, where the country's agricultural output is dependent on irrigated farming. Siltation has reduced dam storage capacities and reduced the life span of dams. It is estimated that 50 million m^3 in storage capacity is lost annually, or about 0.5% of the total design storage capacity of the existing dams (Box 5). To date, a total of more than 820 million m^3 of the total storage capacity has been lost (ONEM 2001). Morocco loses an estimated 22 000 ha of arable land annually. Deforestation contributes to this problem with an annual loss of 31 000 ha of forested land, of which more than two-thirds is used for firewood. The impact of soil erosion on water quality is significant (ONEM 2001).

Solid wastes

Household and industrial solids wastes are discharged directly into rivers and the ocean which in turn results in the deterioration of water quality. In Senegal, the amount of solid waste generated throughout the country is estimated to be 744 250 tonnes per year, of which 280 000 tonnes are generated in Dakar (JICA 1999). Due to the lack of household waste collection, most domestic wastes remain in the streets, open canals or illicit dumpsites throughout the city. The problem also affects the coastal beaches, giving rise to public concern about recreational use.

The quantity of municipal wastes generated per inhabitant per day ranges between 0.4 and 0.9 kg/inhabitant/day in Morocco, where solid waste collection ranges from virtually nonexistent in rural areas to as much as 85% in the major cities of Casablanca and Rabat. The rate of waste collection is relatively satisfactory, and could range between 70 to 90% (ONEM 2001).

Even where collection is not a problem, disposal through uncontrolled dumping remains the norm. There are no specific provisions for industrial, toxic, hazardous and medical wastes in the region, although larger medical facilities own and operate incinerators. In Morocco, municipal waste totaled 3.7 million tonnes in 1992, of which 2% is recycled through an informal recycling sector (UNEP 2002).

Socio-economic impacts

The economic sectors affected by pollution in the Canary Current region are agriculture, fisheries and tourism. Impacts on fisheries and agriculture sectors can have severe economic effects beyond direct losses since these sectors contribute very significantly to the overall national product (more than 30% of GDP in the region). Pollution along the coast near densely populated cities such as Dakar are a major cause for losses of up to 40% in tourism industry in this country. Pollution adds additional costs for water purification in major cities, as well as for alternative supplies. In Morocco for example, the increase in suspended sediment concentrations in reservoirs requires the use of primary clarification procedures, which adds to the treatment cost per cubic metre.

In a small fishing village in the district of Hann (Dakar region), 35% of the patients examined by physicians at the university hospital have skin disease. It is believed that the skin disease is from marine water pollution due to industrial activity in the Hann Bay. A limited number of cases of poisoning, mainly in children, have also been reported. These problems were due to the grilled fish consumed by children (Dieng pers. comm.).

The people affected are those who live near polluted water, the people who consume fish or shellfish from polluted water bodies, and the people who swim in these waters. The number of communities affected and their size, the degree of severity and the frequency and duration have been judged to be limited, and were considered slight in both two sub-systems.

Conclusions and future outlook

For the last decade there has been growing concern about water quality and pollution in general in the region. But governmental authorities are to a certain degree much more concerned with water quantity and supply and other social problems. This lack of concern and therefore mitigation will likely lead to the deterioration of water supplies due to urbanisation, migration, a greater concentration of population and industries, intensification of agricultural production, an increase in irrigated areas and poor land use practices upstream of the different major basins in the region. Pollution in the Canary Current region will therefore worsen over the next 20 years. The environment impacts of this pollution will be moderate to severe. It is expected that problems resulting from pollution from eutrophication, microbiological and chemical sources, solid wastes and suspended solids will worsen the most.

Habitat and community modification

Canary Current North **Canary Current South**

There has been considerable loss and degradation of both aquatic and terrestrial habitats in the region during the last two to three decades. The impact has been partly due to natural factors such as drought but significantly due to human activities such as poor and unsustainable agricultural practices, urbanisation, mining, industrial development and other natural resources use.

Environmental impacts

Loss of ecosystems or ecotones

Despite being among the most biologically productive ecosystems in Africa, wetlands are often regarded locally as wastelands, habitats for pests and threats to public health or as potential areas for agriculture. As a result many wetlands are being lost (UNEP 2002). The combined effect of drought and ever-increasing human activities (afforestation, deforestation, alien encroachment, overgrazing, and river regulation affecting and reducing water supply for riparian vegetation) has contributed to the loss of specific types of wetland habitats; marshes, swamps, and mangroves over the past two to four decades.

To date, approximately 30% surface area of these and other wetland habitats have been permanent destroyed in the Canary Current South sub-system (UNEP 2002). Examples of these include: the Niayes wetlands in Senegal, lakes in The Gambia and Senegal, and mangroves in Senegal (Sine Saloum). In Mauritania, wetlands ecosystems such as pools and creeks have disappeared.

The combined impacts of human activities and drought on these types of habitats are quite significant. Due to prolonged droughts in the northern and interior part of the region, open and running water ecosystems have suffered tremendous losses (Tandia & Dieng 2001). Eutrophic lakes in particular, have disappeared. In the Canary Current South sub-system, most eutrophic lakes (except those lakes close to or in contact with Senegal River) have disappeared.

In the Canary Current North sub-system, lakes in the Atlas Mountains, for example, are drying up very fast due to natural and anthropogenic causes (ONEM 2001).

Modification of ecosystem or ecotones

Ecosystems that have not been destroyed are being modified because of continuing human activities. Examples include: modification of the tannes (wetlands) in Senegal, and the proliferation of rodents and aquatic weeds in the Senegal River Basin valley.

The main change recorded for mangrove forests is its reduction in area, which is due to sulfato-acid soils. These soils are responsible for the replacement of mangroves by tannes (salted soils) in the Saloum estuary in southwestern Senegal. This is observed mainly in the central and eastern parts of the estuary where the number of dead mangrove increases until they completely disappear after Foundiougne. Together with this reduction in the area, there is a reduction in tree size (Diouf 1996). The mangrove in Casamance has retreated since 1970, although the figures are different depending on the authors. Sall (1982) observed that between 1973 and 1979 the area of tannes had increased by 107 km^2 while the mangrove area was reduced by 87 km^2. On the other hand, Marius (1985) estimated that 70 to 80% of the *Rhizophora* had disappeared since 1979. Badiane (1986) indicated a reduction of the mangrove area which had occupied between about 1 200 km^2 before 1968-1970 to 930 km^2 in 1973 and 830 km^2 in 1983. The *Rhizophora* were partly replaced by *Avicennia* but this species was finally reduced by hypersalinity.

According to Rue (1994), the observed retreat of the mangroves in Senegal could be related to the weakness of the fluviatile behavior of the rivers (linked to the diminution of freshwater flow, itself induced by the prolonged drought) that induces the growth of sand spits that delimit the estuaries, thus diminishing the entrance of seawater into the estuary. This, in turn, favours salt penetration in the soils thus allowing the development of tannes. It also limits the possible extension of the mangroves as well as the area able to be inundated. This, combined with a lack of pelitic inflow, contributes to the reduction of the area covered by mangroves.

Another modification of the mangrove community in the estuarine system of Senegal was observed due to the breaching of the Sangomar sand spit in 1987. Significant quantities of sands coming from the coastal erosion of the ocean side of the spit accumulated partly in the external fringe of the mangroves, just in front of the new mouth. This substrate change is responsible for the death of the mangroves. In addition, data indicate the extension of water lilies in estuaries and bays, particularly due to flow alteration and reduction, along with the frequency, intensity and timing of flood events, inappropriate development, pollution from a number of sources, and overexploitation, all contribute to the modification of estuarine systems in the region (UNEP 2002).

In the Canary Current North sub-system, continental wetlands in Morocco are being degraded, and marshlands in the northwestern part of the country (the Gharb area) and Sebkha in the southwest (Draa area) have dried up and been cultivated (ONEM 2001). In addition, there is some evidence of change in species composition resulting from species extinction or introduction. Reports indicate the extension in the 1970s of two well-known bird species, one of which is the rosy flamingo (*Phoenicopterus rubber)* in the Iriki water empoundment in the lower Draa River valley due the construction of El Mansour Eddahbi Dam upstream (ONEM 2001). In the case of certain lagoons in the Atlantic Ocean there has been a progressive extinction of certain endemic algae species such as *Psidona oceanica* due to proliferation of *Caulerpa prolifera*. Another example is the introduction of a red algae species *(Antithamnion algeriensis* and *Asparagopsis armata)* in certain lagoons (ONEM 2001).

Because of this ecosystem and ecotone modification, several species are being threatened. Table 12 shows the number of endangered species in the respective countries of the region.

Table 12 Threatened species in the Canary Current region.

Country	Taxonomic group								
	Mammals	Birds	Reptiles	Amphibian	Fishes	Mollusks	Other inverte-brates	Plants	Total
Cape Verde	3	2	0	0	1	0	0	2	8
Guinea	12	10	1	1	0	0	3	21	48
Guinea Bissau	3	0	1	0	1	0	1	4	10
Mali	13	4	1	0	1	0	0	6	25
Mauritania	10	2	2	0	0	0	0	0	14
Morocco	16	9	2	0	1	0	7	2	37
Senegal	12	4	6	0	1	0	0	7	30
The Gambia	3	2	1	0	1	0	0	3	10

(Source: IUCN 2002)

Socio economic impacts

Loss of wetlands usually means the loss of vital functions they play in nature vis-à-vis, spawning areas for fish, improving water quality through the purification mechanisms, and other ecological functions. All these losses translate into high economic costs for the national as well as household economies. Similarly, loss or modifications of wetlands translate to losses of revenue from livestock, wildlife losses, damage to fisheries and tourism, and high costs in terms of loss of water quality. Finally, losses or transformation of wetlands leads to shortage of wood for fuel, which is very vital to the majority of households in rural areas of the region. The size of the population affected is very important since all the countries in the region are relying mainly on agriculture. The degree of impact is different according to the area within the region or even within the country. In the northern Senegal valley, ecosystem loss greatly affects agriculture (animal husbandry). In other regions in Senegal, the energy sector is affected due to wood loss. The loss of natural ecosystems that attract tourists costs these countries dearly.

Wetlands and other aquatic as well as terrestrial resources are the sources of livelihoods for majority of people in the region, so any type of impact translates to the loss of livelihoods and suffering, even illness. Loss and degradation of habitats compromises water quality as wetlands generally act as sinks for pollutants from land-based activities. These impacts in turn escalate health problems.

Against this backdrop, the assessment recognised that a greater percentage of the population in the Canary Current South sub-system suffer from these impacts as compared to the North. Intestinal bilharzia in Senegal, for example, erupted after the construction of Antisel Dam at Diama, because the dam created favorable conditions for the mollusks that are the intermediate hosts for the organism. The infection can result in some hepatic complications for children and adults. The risks of complication are linked to the intensity of the infection; serious pathologies have tendency to be concentrated in communities where the prevalence of the organism is greatest. In certain villages along the Senegal River, infections can sometimes reach a rate of 75%, as is the case in Richard Toll, a village close to Lake Guiers (Tandia & Dieng 2001). Urinary bilharzias associated with complications of impotence among men and sterility among women is widespread particularly in Tambacounda region, where 385 982 inhabitants (with a prevalence rate of 80%) are affected (Tandia & Dieng 2001). Onchocercciasis is widespread southeast of Tambacounda, Kolda, in an area that includes 456 villages. The disease is caused by organisms whose larvae develop in running water. In Senegal, 200 000 people are exposed, 65 000 are infested and 2 800 are blind. In Guinea, out of 510 000 recorded cases, 9 000 are blind; in Guinea-Bissau, out of 3 300 cases recorded, 100 are blind; and in Mali, out of 196 000 cases recorded, 2 700 are blind (Tandia & Dieng 2001). Trypanosomes are re-emerging in certain countries where it had disappeared. Changes in the ecosystem have created a favorable environment for the tsetse fly. Currently the disease is widespread in Guinea-Bissau.

In the Canary Current South sub-system, the impacts are significant, because of the large numbers of affected people, and the sectors that are involved. These impacts include: migration (occasionally even transboundary migration), conflicts, and settling of nomads. In Mauritania for example, the number of nomads decreased from 60% to less than 5% in less than 15 years (Diop 2001).

Conclusions and future outlook

Some habitats and communities are already lost, so that the remaining are becoming more important for the region. A social awareness about marine resources is starting to develop, helping to stop their degradation. As regards continental habitats and ecosystems, conservation areas are being created and some restoration is taking place in the currently degraded areas. The majority of the countries in the region are altering their regulations and have already adhered to or are in the process of adhering to international conventions. For example, Morocco has already ratified the Convention on Biological Diversity and 50 others conventions related to the preservation of the environment such as the International Trade Convention on Endangered Species, Ramsar, and Framework Convention on Climatic Change to name just a few (see Table 7). The Task team that evaluated the environmental impacts of habitat and community modification knows as a result of this that an improvement over the next 20 years can be expected but the impacts of the current degradation will likely still be moderate.

The countries in the region have responded to the problems of habitat loss by placing natural areas under protection. However, the number and size of protected areas varies from country to country. At present there are 42 national terrestrial protected areas in the region, with a combined area of more than 5.5 million ha and 30 marine protected areas (World Bank 2001). Details of national and international protected areas are given in Table 13.

International efforts to conserve natural habitats have been very successful in these countries, mainly as a result of ratification of the Ramsar Convention, and the Convention on Biological Diversity. There are eight Biosphere Reserves in the region, four World Heritage Sites, and 18 Ramsar sites. Many more sites are proposed for protection (Hegazy et al. 2001). However, in spite of such efforts, the total area officially declared as protected in the region remains less than the international target of 10%, although some countries are aiming to increase their protected areas to more than 15% within the next three decades.

Unsustainable exploitation of fish and other living resources

IMPACT **Canary Current North** IMPACT **Canary Current South**

Fishing activities in the region have increased for the last three decades with the pressure from the industrial and traditional flotilla from European and Asian countries as well as from fleets originating in the respective countries themselves (Figure 9). The marine fisheries sector in the region is characterised by operations at industrial and artisanal levels which target pelagic and demersal stocks. These stocks constitute vital renewable natural resources that provide food and income for local populations, revenues for the national governments, foreign exchange earnings as well as employment opportunities.

Environmental impacts

Overexploitation

Overexploitation currently constitutes a major issue in the majority of the countries in the Canary Current region. Fish catches in many countries of the region have shown a systematic decline since 1974.

Table 13 National and international protected areas in the Canary Current region.

Country	National protected area				International protected area					
	Terrestrial			Marine	Biosphere Reserves		World Heritage Sites		Ramsar Sites	
	Number	Area (ha)	Land area (%)	Number	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Gambia	6	23 000	2	5	0	0	0	0	1	20 000
Guinea	3	164 000	0.7	1	2	133 000	1	13 000	6	225 000
Guinea Bissau	0	0	0	2	1	110 000	0	0	1	39 000
Mauritania	9	1 746 000	1.7	5	0	0	1	1 200 000	2	1 231 000
Morocco	12	317 000	0.7	10	2	ND	0	0	4	14 000
Senegal	12	2 181 000	11.1	7	3	1 094 000	2	929 000	4	100 000
Total	42	4 431 000	16	30	8	1 337 000	4	2 142 000	18	1 629 000

Note: ND = No Data. Data not available for Cape Verde. Some Biosphere Reserves are also World Heritage Sites or Ramsar sites.
(Source: Ramsar 2002, UNDP 2000, UNESCO 2002, World Bank 2001)

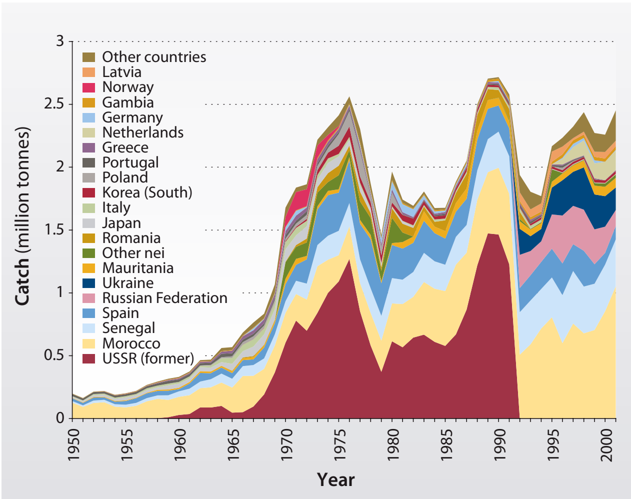

Figure 9 Fish catch in the Canary Current Large Marine Ecosystem.
(Source: LME2005)

Uncontrolled exploitation of the fisheries by foreign vessels is also leading to the depletion of some fish stocks. It has also been observed that the Gambian dermesal production over the past decade has been near and even above the 15 000-17 000 tonnes MSY set for dermesal fish (Tables 14 and 15).

Table 14 Maximum sustainable yield for fish stocks in Gambia, 1997.

Stocks	Maximum sustainable yield (tonnes)
Pelagics	65 000-75 000
Dermesals	15 000-17 000
Crustaceans & other shell fishes	1 000
Total	80 000-92 000

(Source: Gambia Fisheries Department 2002)

Table 15 Fish production in Gambia 1990-1999.

Year	Industrial production (tonnes)	Artisanal production (tonnes	Total (tonnes
1990	18 486	2 793	21 279
1991	19 564	2 087	21 651
1992	4 822	1 312	6 134
1993	6 843	2 519	9 362
1994	6 767	2 398	9 165
1995	6 049	85 170	11 219
1996	7 302	6 172	13 475
1997	6 131	6 673	12 803
1998	5 043	3 507	8 550

(Source: Gambia Fisheries Department 2002)

Table 16 Fishing potential and exploitation of the main stocks in Cape Verde.

Stock	Estimated total allowable catch (tonnes)	Expansion potential (tonnes)
Tuna species	25 000-30 000	17 500-22 500
Small pelagics	10 000-12 000	7 600-9 600
Dermesal	3 000-5 000	2 100-4 100
Lobster	50-70	Fully exploited
Total	38 000-47 000	27 200-36 200

(Source: INDP 1999 in Fonseca 2000)

Table 17 Fishing potential and exploitation status of fish stocks in waters off Senegal and Mauritania.

Fish stock	Senegal (tonnes)		Mauritania (tonnes)	
Large pelagics	15 000-20 000	Fully exploited	1 000	ND
Small pelagics	200 000-450 000	Moderately exploited	800 000	Moderately exploited
Dermesal	130 000	Slightly overexploited	12 800	Slightly overexploited
Total	545 000-700 000		813 800	

Note: ND = No Data.

(Source: FAO 1997 in Fonseca 2000)

Discussions between the European Community and a number of the countries in the region for the renewal of fishing agreements are under way. With the exception of Cape Verde (Table 16), the intensification of fishing activities in the region has had a drastic impact on the state of fisheries resources such as pelagic fish, which notably underwent a strong decline in productivity (Table 17). The infection of coastal waterways by floating weeds has also led to a decline in fisheries activities due to clogging of waterways, estuaries and lagoons.

Stocks in Senegal and Morocco have also experienced overexploitation. Figures 10 and 11 illustrate the fishing effort as well as the catch for the Pink shrimp (*Parapenaeus longirostis*). The recorded landings of Moroccan fisheries in the Atlantic increased by a factor of two from 1950 (139 700 tonnes) to 1974 (264 300 tonnes) and a factor of five from 1950 to 1998 (708 700 tonnes). This substantial increase was due to increase in the fishing effort for all fleets (small-scale, coastal and industrial) and to the addition of the Western Sahara catches in 1975. During the period 1985-1998 demersal species were dominants; their catch increased from 5 400 tonnes in 1985 to 23 700 tonnes in 1998. The octopus catch increased from 3 000 tonnes in 1993 to 15 000 tonnes in 1998. The catch of sparids (Seabreams) decreased from 13 124 tonnes in 1984 to 3 240 tonnes in 1998, suggesting that these species may be overfished. The total catch of small pelagic species in Morocco increased from 110 800 tonnes in 1995 to 485 500 tonnes in 1998 (Baddyr & Guénette 1998).

For more figures and data on overexploitation in the Canary Current region, please refer to the Causal chain and policy option sections.

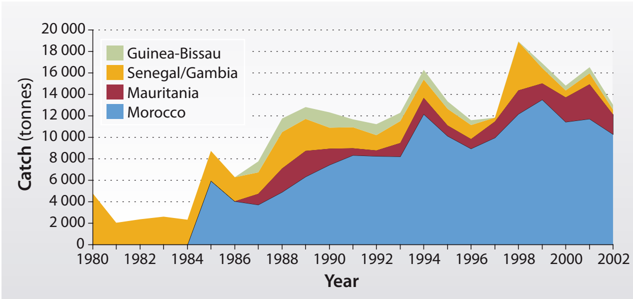

Figure 10 Catch of Pink shrimp (*Parapenaeus longirostis*) in the Canary Current region.
(Source: Diop 2001)

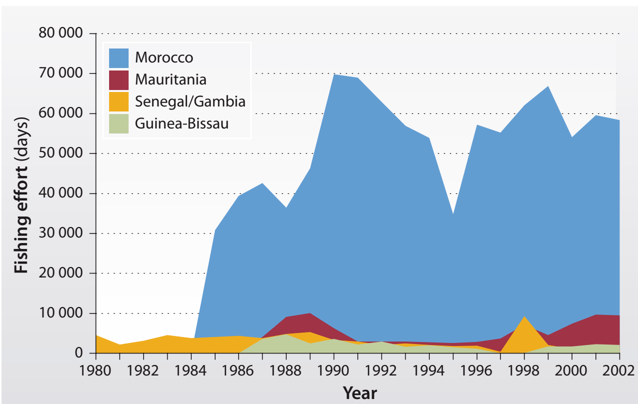

Figure 11 Fishing effort for Pink shrimp (*Parapenaeus longirostis*) in the Canary Current region.
(Source: Diop 2001)

Excessive by-catch and discards

By-catch and discards are mostly caused by the use of net types that capture fishes that are later considered to be undesirable, a problem that is especially common in traditional fishing. Table 18 shows the percentage of unreported landings and the discard rate by decade in the case of Morocco. In 1984, the unreported landing of the coastal fisheries was estimated at 23% of the total reported landings in the port of Tangier, Casablanca and Agadir (El Hannach 1986). In 1999, a study using direct observations and a fishers' survey described the illegal trading of fishery products (El Mamoun 1999) and showed that, except for Tangier, landings arrived from boats or transiting through ports are reported in a larger proportion (30-60%) than those being transported by trucks (12%). Underreporting seemed to be more important for cephalopods and crustaceans. The difference between the results obtained in 1984 and 1999 is large and most likely corresponds to a change in social and economic incentives in Morocco. Prior to the 1990s fish were not consumed much by the local population, thus the opportunity to sell fish locally and directly was scarce. In the 1990s demand for fish increased sharply at the same time as the human population increased, and refrigerated transport facilities increased.

Table 18 Unreported landings and discards in Morocco.

Fleet	Fishery	Unreported landing and discard		
		1970s	1980s	1990s
Unreported landings (% of total landing)				
Coastal	All	23 (Assumed)	23 (El Hannach , 1986)	47-60 (El Mamoun 1999, Durand 1995)
Industrial	All	ND	47 (Assumed)	47-60 (Durand 1995)
Discards (%of total catch)				
Coastal	Pelagic	ND	4 (Assumed)	4 (El Mamoun 1999)
	Dermesal	ND	ND	12 (El Mamoun 1999)
Industrial	Dermesal trawlers	66 (Balguerias 1997)	46 (Balguerias 1997)	30 (Haddad 1994)

Note: ND = No Data.
(Source: Baddyr & Guénette 1998)

Studies of discards in the Atlantic Coast of Morocco for the Spanish cephalopod commercial trawl fishery documented large rates of discards (Balgueiras 1997). The species composition of the discards was dominated by invertebrates other than cephalopods (16-28%), Sea breams (4-9%), Elasmobranchs (5%), Triglidae (Searobins, 10%) and various other dermesal species (Haddad 1994). In comparison, Mauritania cephalopod trawlers fishing in Mauritania and Senegal were found to discard 72% and 60-75% of their catch respectively, while the Senegalese mixed fleet (which was targeting finfish and shrimp in shallow waters) had a discard rate of 67% (Balguerias 1997). As an indication of the changes in the shrimp fisheries, Senegalese shrimp trawlers operating in Senegal and Guinea are thought to have discarded 38.5% of their catch in the mid-1980s (Baddyr & Guénette 1998).

Destructive fishing practices

The use of destructive fishing practices such as explosives and inappropriate nets have been reported in the region (Deme et al. 2001, Dahou & Deme 2001). In spite of a prohibition against their use, explosives are employed by some fishers in the region, causing serious damage to the resource and to the environment. The use of the dynamite destroys the rocky zones that provide an essential breeding place for many species. In the same way, although prohibited by regulations, nets manufactured from monofilaments and multi-monofilaments elements are still in use in the artisanal fishing in the region. These nets are non-biodegradable and quite often are left in the ocean. Finally, the use of non-selective gear and small mesh size and the lack of respect for minimum fish weights accentuates the overexploitation of fish resources in the region. Consequently, fish catches have decreased, prices for the producer have increased, local markets suffer disruptions in supplies, household food security is threatened, and the tensions between socio-professional categories for the access to the products has increased.

Socio-economic impacts

The economic difficulties caused by unsustainable exploitation of living resources are considerable given the fact that fisheries is an important sector in the economy of the region. Fisheries provide substantial momentum for the GDP of the various countries. Similarly, its contribution at the household level is significant in terms of employment, food and trade. Additionally, changes or losses in this sector can have severe repercussions for human health. Approximately two thirds of the population of the Canary Current region lives in the coastal zone, and particularly in cities located on the Atlantic coastline. This heavy concentration is dictated by the search for employment that is readily available in industry, particularly the marine fishing industry.

Unsustainable exploitation of living resources harms the fisheries sector and leads to unacceptable levels of environmental degradation. Considerable numbers of people are employed in this sector, such as fishermen, traders and processors, the majority of whom bear the burden of any environmental degradation. Degradation in the sector translates into significant negative impacts on employment. Loss of employment translates into impoverishment and suffering of people, mostly among vulnerable groups such as women, children and the elderly. Fish processing industries suffer when overexploitation takes place because it means that these industries operate below capacity. There are negative impacts on state income, losses in the fishing industry, reduction of food supply, the increase in costs for inshore maritime surveillance, the loss of biological diversity and loss of employment.

Overexploitation of living resources results in a reduction of protein sources, since the majority of fish are exploited for export, leaving a bare minimum for the local market. This in turn contributes to the accentuation of protein deficits, particularly for small children, through nutritional diseases such as kwashiorkor (protein-caloric malnutrition disease), which is a widespread problem in the Canary Current South sub-system. This malnutrition is accentuated mostly in rural areas where livestock (sources of protein) are under severe threat from droughts brought about by the vagaries of climate change. In the Canary Current North sub-system, few people are affected by this concern.

Unsustainable exploitation of fish leads to a decrease in the commercial viability of fishing activities, and results in unemployment, particularly for younger people, who may find themselves without any job opportunities. This condition results in increased cases of delinquency and poverty. Loss of employment in the fishery sector in Senegal may be as high as 80%. Unsustainable exploitation of fish also leads to bitter competition among different user groups (Deme et al. 2001).

Conclusion and future outlook

The major issue in the Canary Current region is presently overexploitation. Most if not all the coastal countries are already taking steps in terms of regulating the use of the fish stocks at the national and international level as demonstrated by discussions with the European Community regarding the renewal of fishing agreements with the different countries in the region. All these countries have determined that there is overexploitation of their fish stocks and have therefore determined that the ecosystem needs a rest. In addition, government fisheries institutions that used to be departments in the Ministry of Agriculture have been elevated to the status of their own Ministry of Fisheries. In addition, there is a growing concern and awareness of the need for conserving fisheries and improving management and control. In the region, fisheries authorities have instituted certain policy measures to control industrial fishing pressure by reducing the fishing effort. Since the beginning of the 1990s, governments have been implementing a policy of gradually reducing the number of licenses issued annually to fishing vessels. Table 19 shows an example from The Gambia.

Table 19 Licensed vessels in Gambia 1993-1997.

Type of vessel	Number of vessels				
	1993	1994	1995	1996	1997
Tuna purse seiner	23	18	15	1	0
Tuna long liner	31	8	5	7	1
Shrimp trawler	30	16	15	17	9
Stern trawler	18	8	5	5	6
Pair trawler	0	0	2	6	3
Total	101	50	42	36	19

(Source: Gambia Fisheries Department 1998)

In addition, there has been a regional effort among countries to coordinate their different fisheries regulations under the framework of a committee called CSRP (Commission Sous Régionale des Pêches/ Under-Regional Fisheries Sub Committee). This committee includes Mauritania, Senegal, The Gambia, Guinea, Cape Verde and Guinea-Bissau.

Global change

Canary Current North **Canary Current South**

Environmental impacts

Changes in hydrological cycle and ocean circulation

Although global model simulations project little significant change to rainfall amount and its seasonal distribution in the region in the next two decades, models of run-off show slight reductions over the whole area, especially around the Mediterranean, leading to reduced water availability. Temperature increases will also increase water stress on crops across much of the region. Despite the fact that clear scientific evidence has yet to be provided, some analysists argue that drought frequency and severity have already increased in conjunction with climate change in the region, with dramatic impacts on water availability.

Predicted changes in rainfall amounts and distribution are much less reliable (Morton & Saer 2001). However, available information tends to indicate that in recent decades, some parts of the region have become wetter while other parts are now drier than they used to be. In Morocco, the rainfall pattern has varied with a rate of -7% to +0% in the northern region and about -7.5 to +2.8% in the southern part of the country.

Sea level change

A recent review of the scientific basis for climate change in the region (Morton & Saer 2001) suggests that small increases in temperatures across the region have occurred in recent decades, although lower than the global average median forecast of 0.35°C per decade, or 0.7°C by 2020 for the region as a whole (Alibou 2002). In Morocco, the use of several simulation models predicts temperature increases on the order of 0.7 to 1°C by 2020 (Alibou 2002). As a result, sea level would rise between 2.6 and 15.6 cm during the period 1990-2020. In the Canary Current South sub-system, there is also some evidence of sea level change, but without major harm to populations or organisms (Alibou 2002). However, the GIWA Task team pointed out that advanced erosion on small islands and flooding at Saint Louis (Senegal) obliged the authorities to build a protection dam. The same problem has been experienced by a community of fishers in the zone of the Arguin Bench in Mauritania.

Socio-economic impacts

The economic sectors mainly affected by drought are agriculture and fisheries and to a lesser extent industry and tourism. The impact on the agricultural sector is significant since both crop and animal production rely heavily on rainfall and changes in climate result in high variability and associated variability in yields. The agriculture sector contributes on average about 20% of the GDP for the entire region (19% for Morocco, 20% for Senegal, and 26% for Mauritania). Based on these statistics, it is clear that the single most serious economic impact of global change is on agriculture. Fisheries are also affected, as are tourism and wildlife. The public sectors affected include health, education and infrastructure (in the cases of flooding). Income from traditional agriculture, which relies on rainfall, has decreased by 10 to 15% in the last decades. Other costs include: construction of dams and inter-basin transfer schemes to supply water, the costs of alternative sources of water (especially by desalination), the costs of deepening wells and pumping. The different countries in the region have had to expend a great deal of effort and money to alleviate the impact of the drought and the desertification in order to limit migration, both within or out of the country.

Drought results in habitat and community modification (see section above), which in turn affects human health by promoting increased rates of urinary Bilharzias (with prevalences more than 80% in certain villages in the Senegal River valley and in Tabcounda region) (Tandia & Dieng 2001). This is equally true for other regions in Mali.

These impacts are felt by a large number of people: some migrate (occasionally even transboundary), there are conflicts, and nomads may be forced to abandon their lifestyle and settle down. In Mauritania, for example, the number of nomads decreased from 60% to less than 5% in less than 15 years.

Conclusions and future outlook

The impact of global change has a direct effect on freshwater. Freshwater shortage is therefore the main problem in most countries of the region. As predicted by the Intergovernmental Panel for Climate Change model simulations (IPCC 2001), water scarcity may be severely problematic as a result of changing climatic patterns in the region, with dramatic effects on the availability of drinking water. Global change would have a pervasive influence on future demand for, and supply and quality of freshwater in the region, and would add to the pressure on water and environment resources, as well as coastal systems currently under stress. The region's irrigation systems are also under stress. In nearly all countries of the region, irrigated agriculture is adversely affected by salinity and waterlogged soils. It is estimated that in some countries of the region, up to 50% of irrigated land suffers from some degree of salinity. Another issue is the overexploitation of groundwater. Indeed, global change would also affect the fauna and flora of habitats in the region and result in a great loss of biodiversity.

All sectors of the economy, environment and society may be vulnerable to one degree or another, where steps to increase the capacity to adapt to greater climatic and hydrological variability, including more frequent flood and drought extremes are required.

Priority concerns for further analysis

Based upon this assessment, the main concerns and issues are freshwater shortage (stream flow modification, pollution of existing supplies and change in water table) and the unsustainable exploitation of fish. The concerns were ranked in descending order of severity for the two sub-systems as follows:

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

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

The ranking was based on overall scoring. The Canary Current South sub-system has been suffering from water shortage problems (modification of stream flow) for the last three decades and will most likely suffer in the next 20 years from water shortage. The annual discharge of the Senegal River shows a period of significant deficit after 1970. The percentage of reduction between the mean annual discharge over the years before 1970 and the deficient periods is more than 40%. The same tendency has been also reported for other major river basins in the region.

In the Canary Current North sub-system, the declining groundwater base flow is a major issue that is linked to the long dry periods (more than 30 years) that the region as a whole is experiencing. Data show that in the last two decades, the average aquifer draw down in the Souss-Massa River Basin varied from 0.5 to 1.5 m per year (CSEC 2001).

The environmental impacts of stream flow modification, water regime change and a dropping water table lead to very serious socio-economic impacts that often have significant transboundary implications. These socio-economic impacts include the loss of agricultural income and potential, the high costs associated with the construction of dams and inter-basin transfer schemes to supply water, the costs of alternative sources of water, and the cost of deepening wells and pumping, increases in water-borne diseases, and conflicts about water.

Unsustainable exploitation of living resources is also considered as a main concern in the Canary Current region. Most of the countries in the region bordering the Atlantic Ocean have important marine fish stocks. Fishing activities have increased for the last three decades with pressure of fleets from both the bordering countries as well as from the traditional and inustrial fleets from European and Asian countries. The efforts of the state of the region to develop and use these fish stocks in a sustainable manner are limited by the lack of adequate manpower and financial and material resources.

Causal chain analysis

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

Stream flow modification – Senegal River Basin

The Senegal River Basin is located in West Africa and occupies an area of roughly 475 000 km^2 (Figure 3 in the Regional definition). The entire Basin, including the upstream catchments, is drained by the 1 800 km-long Senegal River and its tributaries. The area of the River Basin accounts for about 1.6% of the African continent and lies within the territory of four different countries: Guinea, Mali, Mauritania and Senegal (Table 20).

The Basin is divided into three distinct regions; the upper basin lies in the mountains of Mali; the middle valley forms the 500 km long border between Senegal and Mauritania; and the delta in the lower valley is where the Senegal River discharges into the Atlantic Ocean. The delta is about 80 km long and consists of numerous estuaries that form a complex canal system.

The management and the development of water resources in the Basin are carried out within the framework of the Organisation for the Development of the Senegal River Basin (OMVS), which represents Mali, Mauritania and Senegal. During the last 30 years, important

Table 20 Countries in the Senegal River Basin.

Country	Country area (km^2)	Country area within the Basin		% of the total area of the country
		(km^2)	%	
Guinea	245 857	30 610	6.4	12.5
Mali	1 240 190	48 940	31.2	12.0
Mauritania	1 025 520	219 710	45.9	21.4
Senegal	196 720	78 680	16.5	40.0
Senegal River Basin		477 940	100	

(Source: Finger & Teodoru 2003, EROS Data Center 2003, ESRI 2002)

actions have been conducted, particularly the implementation of the hydroagricultural and the hydroelectric infrastructures as well as the extension of urban areas. The consequences of these actions have been a reduction of freshwater resources linked to the modifications of the observed regime of the River as well as deterioration of water quality and the lowering of the groundwater table.

Table 21 Rainfall in the Senegal River Basin.

Country	Average annual rainfall in the Basin (mm)		
	Min	Max	Mean
Guinea	1 120	2 100	1 475
Mali	455	1 410	855
Mauritania	55	600	270
Senegal	270	1 340	520

(Source: Finger & Teodoru 2003)

System description

The Senegal River is the second largest river in West Africa. It is formed by the confluence of two smaller rivers, the Bafing and the Bakoye, which occurs near Bafoulabé in Mali, about 1 083 km from the Atlantic Ocean. Downstream of Bafoulabé the River flows northwest, crossing the arid lands of western Mali. About 200 km further downstream, the Falémé River gushes into the Senegal River. From this point on the Senegal River forms a natural border between Mauritania and Senegal flowing westwards towards the Atlantic Ocean. All three main tributaries of the Senegal River (the Bafing, Bakoye and Falémé) have their sources in the Fouta Djallon Mountains of Guinea and in the southwestern part of Mali. Several other small tributaries, originating in Mauritania, also discharge into the Senegal River. One of them, the Karakoro River, enters the Senegal River at more or less the same point as the Falémé River. About 200 km further downstream, the Gorgol River enters the Senegal River. Downstream from Bakel, the River does not have any more important tributaries. The slope of the streambed decreases gradually until the River is essentially flat in the valley and the delta. This area is characterised by a broad flood plain and many depressions supplied by the river flow: Lake Guiers, Lake R'kiz, Three Backwaters and Djoudj. The Senegal River discharges in the Atlantic Ocean downstream from St Louis City.

The Senegal River Basin presents many geological, topographic, climatic and hydrological contrasts due to its extension between latitudes 11° N and 18° N. The eastern and the southeastern parts of the Basin consist of geologic formation from the Precambrian era (Fouta Djallon Mountains), characterised by impermeable rocks such as schists and granites, and clay soils. The topography is undulating and the elevation can exceed 1 000 m. To the west, elevations are relatively low and can be below sea level.

The climatic regime in the Basin can be divided into three seasons: a rainy season from June to September, a cold and dry season from October to February, and a hot and dry season from March to June. Rainfall in the Basin can be as high as about 2 000 mm per year. In the valley and the delta, it is generally low and exceeds rarely more than 500 mm per year (Table 21) (Finger & Teodoru 2003). Flooding can occur during the high flow period between June and October. During this high water period, the River overflows its banks and floods the broad alluvial plain of the middle valley. This has enabled farmers to grow crops during the dry season, after the waters have receded and the low-water period has started. In areas of low rainfall, the River's annual flood is a necessity to life.

The flow rate of the River depends mainly upon events in the upper basin in Guinea, which is, hydrologically speaking, the most active part of the Basin. The total annual discharge leaving Guinea is estimated at about 8 km^3, with an increase as a result of the inflow of the different tributaries of up to 20 km^3 by the time the River reaches the meeting point at the juncture of Mali, Mauritania and Senegal (SGPRE 1994). The mean annual discharge and volume of the main tributaries are shown in Table 22.

Table 22 Hydrological characteristics of the main tributaries of the Senegal River.

River	Outlet/control station	Mean annual discharge (m^3/s)	Mean volume (km^3)
Bafing	Bafing Makana	271.0	8.55
Bakoye	Toukoto	58.4	1.84
Baoulé	Siramakana	44.9	1.42
Falémé	Kidira	148.0	4.67
Senegal Basin	Bakel	648.0	20.40

(Source: SGPRE 1994)

The Senegal river flow is controlled by two dams, the Diama and the Manantali. The Diama Dam is located 30 km upstream of the city of St Louis. It was built in 1986 in order to stop the dry season intrusion of seawater along the river bed. In fact during dry years, saltwater could penetrate as far as 100 km inland, which makes the whole delta unsuitable for agriculture use (Gac 1986a & 1986b). The construction of the Diama was supplemented by the damming of the upper left and right bank located between Rosso and Diama. The second dam,

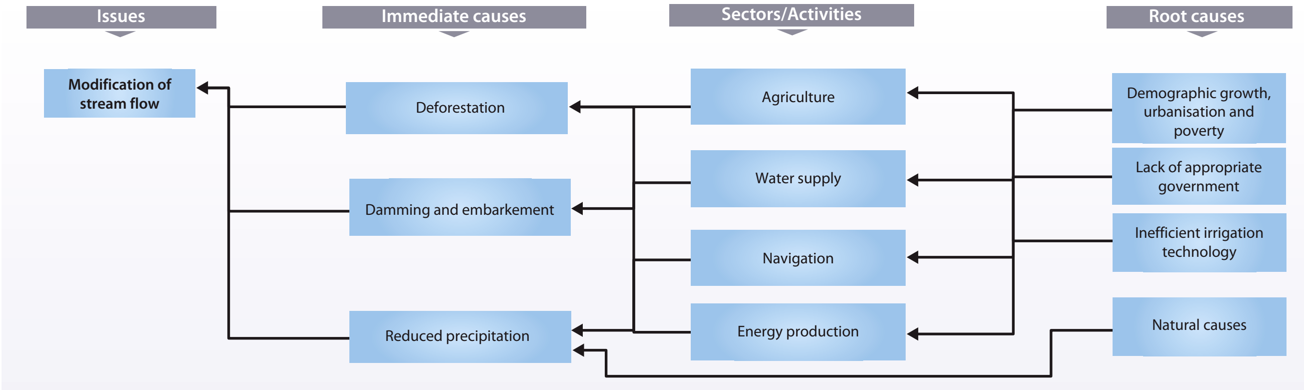

Figure 12 Causal chain diagram illustrating the causal links for stream flow modification in the Senegal River Basin.

the Manantali, was completed in 1988 and is located in Mali 1 200 km upstream from the Senegal River outlet. Its storage capacity is 12.8 km^3. It was built on the Bafing River, which supplies approximately 60% of the annual flow of the Senegal River in a reservoir (Gac 1986a,b).

The major development objectives assigned to the two dams are (SGPRE 1994, OMVS/SOGED 2003):

- Regulate the River's discharge at a rate of 2 500 m^3/s during the rainy season to allow the traditional flood-recession farming;
- Regularisation of river flows to 300 m^3/s at Bakel;
- Irrigate 375 000 ha of former floodplain for two crops per year, especially for rice production;
- Produce hydropower (800 GWh per year);
- Provide a 1 500 km transport line network to assure energy delivery to inter-connected networks in the three member states;
- Make the River navigable all year round between Saint Louis at the river mouth and Ambibédi in Mali (about 900 km).

In 1988, the population of the Basin was 1.55 million inhabitants, including 767 000 Senegalese, 696 000 Mauritanians and 80 000 Malians (OMVS/SOGED 2003). With a growth rate of 2.2%, the population in 2000 was a little bit over 2 million inhabitants. The population is concentrated mainly in rural areas; however recent demographic trends show a tendency for an increase in the urban population. A large ethnic diversity characterises the Basin's population, with Peuls, Toucouleurs, Soninkes, Malinkes, Bambaras, Wolofs and Moors. However, there is an internal migratory flow (periodic transhumance towards the pastures) and an external migratory flow towards to the cities or even outside the countries, particularly towards Europe (OMVS/SOGED 2003).

Causal chain analysis

During the period 1966 to 1970, a marked shift in the climate was observed. This gave rise to a prolonged drought characterised by a reduction in the annual rainfall and in the length of the rainy season (DaCosta 1993, Diouf 1996, Malou et al. 1998). The consequence was a reduction in river discharges as well as an invasion of seawater in all the estuaries. The mean annual discharge of Senegal River decreased from 25.9 billion m^3 for the period 1903-1967 to 13.8 billion m^3 for the period 1968-1999, indicating a trend in the reduction of stream flows since about 1967 (SGPRE/PNUE/DHI/TROPIS 2002).

The main issues addressed in the analysis of the freshwater shortage in the Senegal River Basin concern stream flow modification. In reality there are two types of modification: (i) the reduction of river discharges due to the drought, leading to an intrusion of the river by seawater; and (ii) a reduction/exclusion of seawater intrusion in the river due to damming. The first type of modification is natural, while the second one is artificial. This reduction of seawater has been superimposed on the reductions in river flow due to the drought, with the combination now characteristic of the Senegal River Delta. Therefore, the focus of the causal chain analysis will be on the damming of the River, with the drought considered as an immediate cause. Figure 12 illustrates the causal links for stream flow modification in the Senegal River Basin.

Environmental and socio-economic impacts

Reduced wetland areas (Ndiael, Djoudj) and the risk of losses in biological diversity

The persistence of the drought, the road and hydraulic infrastructure installations have resulted in a reduction in wet areas. This is accompanied by important biodiversity losses (SGPRE/PNUE/DHI/TROPIS 2002). The Ndiael reserve, classified as a Ramsar site, has been drying out, with the socio-economic and environmental consequences being vegetation degradation, wind erosion, tannes formation, reduction in biodiversity (particularly in icthyofauna and avifauna) and a loss of breeding grounds for migratory birds.

Water quality changes due to the accumulation of salt and pollutants

The deterioration of water quality becomes a problem of primary importance for the delta because of drainage from irrigated areas or water stagnation, inappropriate domestic use, the mismanagement of solid waste, the discharge of industrial waste water from Senegalese Sugar Company factory into Lake Guiers as well as the proliferation of aquatic plants. The lack of an appropriate discharge outlet in low Ferlo and a high evaporation rate has resulted in a salt accumulation in Lake Guiers. Data indicate that salt concentration in the Lake can reach as much as 40 000 tonnes per year in the Lake Guiers/low Ferlo system (SGPRE 1999). The aquatic plant proliferation has caused excessive evapotranspiration losses, which are estimated to be 3 billion m^3 per year (OMVS/SOGED 2003). Aquatic plants also constitute a tight curtain that prevents access to water uses by the population.

Reproduction areas not accessible to fish

The absence of a fish ladder in the Diama Dam and the presence of gates and embankments prevent fish from migrating to spawning areas. This contributes to the reduction of the fish population of the River. The abrupt changes of water salinity related to the discharge of the Diama Dam are often the cause of fish mortality.

Erosion and sedimentation

During the last several years, strong erosion of the banks in the Gandiolais area has been observed. There is also an accumulation of coarse sand sediments at the outlet of the River. Bank erosion is also widespread in the high river valley. Water and wind erosion are greatly accentuated in the Basin and involve the progressive degradation of the land and the loss of vegetation cover. Soil erosion and vegetation degradation in the River Basin result in run-off and the transport of sediments, and the appearance of laterite. Sediments deposited in the river outlet is one of the most frequent causes of flooding in St Louis City (SGPRE/PNUE/DHI/TROPIS 2002).

Loss of mangrove forest

Downstream from Diama, marine dynamics prevails from December to July. This increases the salinity and stresses the mangrove swamps. With the loss of mangroves, the formerly flooded mud holes gradually turn into tannes (salted soils).

Flooding of St Louis City

With the reduction in the cross-section of the river mouth due to sediments, floods have become more frequent in St Louis, most recently in 1999 and 2003. During the most recent flood in 2003, the authorities were obliged to open a channel to dump excess water into the ocean. During flood periods in St Louis there is a rise in the groundwater level mainly due to soil saturation and the stagnation of run-off. In Lake Guiers, this rise in water levels is at the origin of the destruction of the embankment and flooding of tracks, houses and irrigated perimeters.

Groundwater level rise and soil salinisation

An increase in soil salinity has been observed in some badly drained cultivated perimeters and certain wastewater discharge basins. In irrigated areas, water losses generated by less efficient irrigation practices contribute to the rise in groundwater levels. In low Ferlo, salinity can exceed 5 g/l because of industrial wastewater from the sugar factory, evaporation and lack of water circulation; this salinity makes the water quasi unusable.

Water-borne diseases

The permanent presence of standing water in the valley and the suppression of the periodic salt concentration increase favours the aquatic plants and pathogenic germs development. As a consequence, the incidence of water-borne diseases already found in the area have increased. The diseases are malaria, urinary schistosomiasis, diarrhoea, and intestinal parasitic diseases (Verhoef 1996). The delta has become a hotbed of bilharzia and prevalence rates of 80% were observed in certain villages (SGPRE 1999).

Migration due to the loss of arable land

The cultivated area experienced a notable reduction because of abandonment of certain private areas where the irrigation infrastructure was rudimentary. The deterioration of the irrigation infrastructure, soil salinisation due to the lack of drainage, and the competition from imported agricultural products (such as rice) are the causes of the abandonment of these perimeters and the associated migration of farmers to other sectors or other places (Tandia & Dieng 2001).

Reduced access for transhumant cattle farmers

There is a severe reduction in natural pasture areas due to the increase of the irrigated perimeters. In addition, access to the River became very difficult for cattle. This situation generates frequent conflicts between stockbreeders and farmers.

Reduced freshwater fishing potential

With the permanent standing freshwater, aquatic plants developed to excess and now prevent access to the water. The Cattail (*Typha australis*) constitutes a refuge and a spawning area for fish. However, the abundance of vegetation also constitutes an obstacle for fishing. In addition, infrastructure installations represent obstacles for fish migration to spawning areas.

Reduced water access

In spite of the water availability in the Basin, natural reservoirs and lakes as well as irrigated perimeters are poorly supplied because of the following factors:

- Wind erosion and sediment deposits are abundant in the delta. They limit the transport capacity of the main waterways through the formation of dikes.
- Aquatic plants form an obstacle to stream flow.
- The majority of the gates are obsolete and date back to 1940 or 1950. They were designed before the existence of the dams.
- The water intake pipe is sometimes above the actual water level.

The results are that, during high flows, certain areas are flooded and others are subjected to a severe water deficit in spite of their proximity to the River. In the estuary, marine sediment deposits represent a constraint for navigation.

Immediate causes

Reduced precipitation

The Senegal River Basin presents important climatic contrasts because of its extension between the tropical wet areas in the south and the arid areas in the north, located at the limit of the Sahara. The climate of the Basin is marked by the rhythmical movements of the Inter-Tropical Front (ITF), which separates the monsoon from the harmattan. The monsoon conveys humid air masses coming from the southwest from the anticyclone of St Helene. These humid air masses are dominants in the winter (May-June to October-November).

The season is affected when the ITF moves up north. The rainfall is very variable in the Basin, with a marked decrease towards the north (SGPRE 1994, Rochette 1975). Rainfall in the upper part of the Basin (the Guinean and Sahelian climatic domain) ranges from 1 300 to 2 000 mm per year. In the valley and the delta, which belong to the Sahelian climatic domain, annual rainfall varies from 200 to 800 mm. In dry season (November-April), the Basin is subjected to the harmattan wind, which blows from the northeast and brings hot and dry air masses. On the coast, maritime trade winds blowing from the Azores anticyclone are dominant during the winter. The reinforcement of the trade winds at the beginning of the winter induces a delay of the rainy seasons, especially in the delta. The annual rainfall is highly variable, especially in the northern part of the Basin. The coefficient of variation reaches 0.41 in Dagana, 0.19 in Kédougou and 0.25 at the center of Senegal in Bakel. The inter-annual average rainfall is 1 250 mm at Kédougou, 489 mm at Bakel and 282 mm at Dagana.

Since 1968, there is a decrease in rainfall. Figure 13 shows that the average rainfall decreased from 370 mm (1892-1967) to 238 mm (1967-2000) in St Louis (SPRE/PNUE/DHI/TROPIS 2002). The same tendency has been observed at other stations such as Dagana and Kédougou. It should be mentioned, however, that recent years have been characterised by a resumption of rainfall. For example, rainfall in St Louis exceeded 400 mm in 2000 and 1 500 mm in Kédougou in 2003.

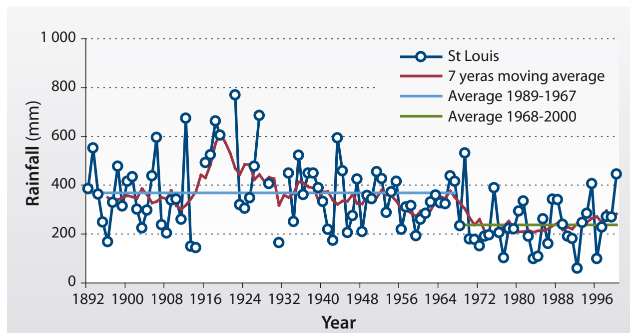

Figure 13 Annual rainfall at St Louis 1892-2000.
(Source: SGPRE/ PNUE/DHI/TROPIS 2002)

Damming and embankments

Since 1988, the Senegal River has been regulated by the Diama Dam, with its embankments, and the Manantali Dam. The Diama Dam serves to block seawater intrusion and thereby protects water and irrigation wells, and raises the level of the upstream water body, creating reserves that enable irrigation and double cropping. The Manatali Dam is supposed to attenuate extreme floods, generate electric power and store water in the wet season to augment dry-season flow for the benefit of irrigation and navigation. The water management objectives for these dams have been defined by the Standing Water Committee (Commission Permanente des Eaux, CPE). The instructions for water use are defined as satisfying the needs for various water uses while taking into account dams and population safety measures. In the rainy season, the objectives are to: (i) fill up the Manantali Dam; (ii) augment dry-season flow for the benefit of irrigation and navigation; (iii) attenuate extreme floods; and (iv) produce electrical energy. In the dry season the goal is to: (i) support and sustain low flows to allow seasonal and industrial cropping; (ii) supply drinking water for urban centres; and (iii) permit navigation from the outlet of the River to Kayes.

The blockage of salt intrusion has allowed the proliferation of aquatic plants and water-borne diseases. Recent studies undertaken by the Diama Dam Company (SOGED) show that invasive plants currently occupy 150 000 ha in the delta (OMVS/SOGED 2003). These species are mainly Cattail (*Typha australis)* and the Water salads.

Deforestation

In the Senegal River Basin, deforestation and soil degradation are major problems that tend to be widespread across the Basin. In the upper part, the valley and the delta, there is a decrease in the vegetation cover and a loss of soil fertility, often due to anthropogenic causes. The results are an increase in stream flow and sediment transport. This creates flooding problems in the villages located near river tributaries and the destruction of roads. The deforestation phenomenon is worsened by wind action, rainfall deficits, increases in salinity and the lack of drainage in the irrigated perimeters.

Sector activities

The construction of the Diama and Manantali dams on the Senegal River was designed to solve two main problems closely linked to the drought and its impacts: the availability of arable lands and water supply. The other two objectives assigned to these dams were the navigability between St Louis and Kayes and the production of hydroelectricity. Agriculture is the major sector activity of concern, followed by water supply, fluvial transport and energy production.

Agriculture

Agriculture is the main economic sector in Senegal and was for many decades characterised by a quasi monopoly for peanut production. Impacts of the drought combined with inadequate agricultural practices resulted in a general degradation of the soils, particularly in the "peanut basin" (Thiès, Diourbel, Kaolack and Fatick regions). The persistence of the drought weakened peanut production, which is solely dependent on rainfall. In the river valley, agriculture practiced mainly in flood prone areas ("waalo"), was compromised as a result of the decrease in the river discharge (Olivry 1983, Handschumacher et al. 1992). In the Senegal River Basin, it is estimated that 400 000 ha of soils were affected by salinisation (Sadio 1991). Consequently, it was decided to build the Diama and Manantali dams.

One of the objectives of the Senegal River damming was to allow the development of irrigated crops, particularly rice. In 1987 (before the damming of the river) irrigated areas covered almost 40 000 ha, located mainly in the delta and the low valley, with another 2 700 ha in the area of Lake R'kiz (OMVS 2000). Recession flood farming areas in the River Basin are shown in Table 23.

Table 23 Recession flood farming area in the Senegal Basin in 1987 before the damming of the River.

Areas	**Flooded area** (ha)	**Cultivated area** (ha)	**Collected area** (ha)
Left bank	31 000	20 150	18 780
Right bank	27 000	19 170	17 200
Upper part	4 500	1 125	810
Senegal River Basin	62 500	40 445	36 790

(Source: OMVS 2000)

It well recognised that the damming increased the availability of water in the Basin. However, agriculture in the valley is currently faced with many problems, and the benefits from the dam are below expectation. This situation resulted mainly from the limited financial capacity of poorer residents, for whom the equipment investment is too costly. Rice production decreased from 130 600 tonnes in 1994 to 85 300 tonnes in 1996. According to Devey (1997), this is due essentially to the fact that the rice produced locally is less competitive with imported rice. Other difficulties are:

- The rate of irrigation infrastructure installation is low and does not reach 2 000 ha per year.
- Crops produced (rice and onions) does not adequately meet food needs and must be supplemented with imports.
- The lack of professionalism and the low quality of the irrigation infrastructure.

The development of the irrigated area since 1975 in the Senegal River Basin is illustrated in Figure 14. Long-term projections are: 98 000 ha for Senegal in year 2010, 73 377 ha for Mauritania in year 2017 and 14 500 ha for Mali in year 2025 (OMVS 2000).

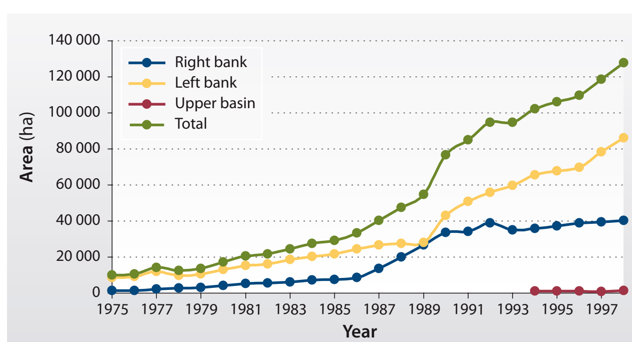

Figure 14 Irrigated area in the Senegal River Basin 1975-1998.
(Source: OMVS 2000)

Water supply

The second main objective of the Diama Dam was to ensure a water supply, especially for Dakar. Lake Guiers, with the Ngnith station pumps, provides a drinking water volume of 64 000 m^3 per day for the city of Dakar. The construction of a new water treatment plant at Keur Momar Sarr in the southern Lake Guiers is planned within the framework of the Long Term Water Project. The treatment plant is expected to provide an additional volume of 65 000 m^3/day during the first phase of the project (2003-2007) and 135 000 m^3 per day in the second phase (after 2008).

This increase in water supply volume will make it possible to stop the overexploitation of groundwater resources of Dakar and Thiès. It is also expected that 85% of water supply for the city of Nouakchott in Mauritania will be provided by the Senegal River, with the remaining 15% provided by the Trarza aquifer.

On the right bank of the River, the annual water supply production for Rosso in 1999 was 584 000 m^3, with a monthly average volume of 48 600 m^3. In the same year on the left bank of the River, the private Water Supply Company (Sénégalaise des Eaux, SDE) supplied a total of more than 27.5 million m^3 of drinking water for St Louis, Richard Toll, Dagana, Podor, Matam and Bakel. In the Malian part of the upper Senegal River Basin, the drinking water supply volume was close to 2.7 million m^3 in 1999.

In 1999, the total drinking water supply for the population in the River Basin was 2.63 m^3/s and it is expected to triple (7.03 m^3/s) in year 2025 (OMVS 2000) (Table 24). The industrial water supply demand for the Senegal River Basin is about 6 888 km^3 per year (Table 25). The main industrial companies are: the Senegalese Sugar Company (CSS), the Senegalese Canned Food company (SOCAS) located on the left bank, and the gold mining Company of Sadiola (SEMOS) in Mali.

Navigation

Another objective of the dams was to ensure the navigability of the River between its mouth and Kayes (940 km upstream in Mali). The continuous decrease in the river discharge has considerably reduced the use of the Senegal River for transport and trade since 1972. The establishment of a stable river discharge (227 m^3/s) in Bakel allows the resurgence of this activity. Actually, the Organisation for the Development of the Senegal River Basin (OMVS) is in charge of the navigability between St. Louis and Kayes while Senegalese council of shippers (COSEC) will consider the building of a new harbour in St Louis as well an access from the sea. A feasibility study was begun in 2001 (Niang-Diop et al. 2002).

Table 24 Drinking water needs in the Senegal River Basin.

Area	1999		2010		2025	
	m^3/s	m^3/day	m^3/s	m^3/day	m^3/s	m^3/day
Dakar	0.76	64 000	2.38	199 000	2.35	199 000
Nouakchott	ND	ND	0.99	84 150	1.91	161 500
Urban centres	1.18	99 491	1.31	110 999	1.52	128 866
Other areas	0.69	58 649	0.87	73 971	1.25	105 725
Total	2.63	222 140	5.55	468 120	7.03	59 091

ND = No Data.

(Source: OMVS 2000)

Table 25 Industrial water needs in Senegal River Basin.

Company	Water needs (km^3)
Senegalese Sugar Company (CSS)	549
Gold mining Company of Sadiola in Mali (SEMOS)	5 790
Senegalese canning food Company (SOCAS)	549
Total	6 888

(Source: OMVS 2000)

Energy production

Forest product ; either firewood, 1.5 million tonnes, or charcoal, 330 000 tonnes per year, provide 61% of the energy used in Senegal, followed by imported petroleum (37%). As early as 1981, new strategies have been developed to try to change this energy consumption pattern (Devey 1997). The construction of the Manantali Dam is a part of this strategy. It allows the production of 800 GWh per year of hydroelectricity. This production is not totally consumed. Since 2001, the difference is restored to the downstream of the dam to be used for other needs.

Root causes

Demographic growth, urbanisation and poverty

The population in the Senegal River Basin was 1.55 million inhabitants in 1988 and approximately 2 million inhabitants in 2000 (OMVS/SOGED 2003). This population exerts a pressure either directly on water resources of the Basin or indirectly in terms of the search for income. Another problem linked to demographic growth is poverty that aggravates the negative impacts of the population pressure.

The population growth resulted in a high water demand for different uses and an increase in water pollution. In addition, there is an uncontrolled expansion of urban areas, which are generally established in the riverbed, which results in a reduction of the River's cross-section and more frequent flooding. The urbanisation rate increased from

23% in 1960 to 39% in 1988 and 41.2% in 1996. In Dakar, for example, population density increased considerably, from 930 inhabitans/km^2 in 1960 to 2 730 in 1988 and 4 081 in 1999. This rapid growth of Dakar and other major cities is due to a high natural fertility rate and the important migratory fluxes that have been exacerbated by the drought.

Poverty is a critical problem for the populations and communities of the Basin. This is represented by of the root causes of poor quality water resources infrastructure installations, inappropriate or even the lack of drainage control design in the irrigated perimeters, and the lack of adequate drinking water systems. The population of the Basin is primarily rural with a relatively low income that does not allow for investments that would result in a better life.

Lack of appropriate governance

The lack of appropriate governance is manifested by the lack of enforcement of regulations, the absence of an adequate institutional setting and the absence of democracy, which means that stakeholders cannot participate in decision-making and are not held accountable for their actions. In many cases, powerless and unwilling partners endure decisions that are often dictated by powerful economic operators. Problems related to the lack of appropriate governance and the institutional setting are well identified and are well known, particularly the insufficiency or the absence of the organisation and location of activities that are the source of many conflicts concerning the water resources use and the deterioration of living conditions.

The institutional setting is less efficient because of the rapid changes in institutions, stakeholders and the division of power. Projects and decisions are often taken without taking into account the opinion of the others. Lack of appropriate governance is also illustrated by the numerous problems related to information; the absence of any circulation of information, the deficiency at times in the quality of information, the insufficiency of the sensitisation to environmental degradation and the lack of environmental education (SGPRE/PNUE/DHI/TROPIS 2002).

Illiteracy and the lack of appropriate environmental education are also causes of water pollution. This is reflected by poor agricultural practices; for example, in certain irrigated perimeters, polluted drained water is discharged directly into freshwater. The Senegalese Sugar Company and the neighbouring irrigated perimeters are discharging polluted water into Lake Guiers, the Ndiael, and the Senegal River. Data indicates that the Senegalese Sugar Company is discharging the equivalent of 40 000 tonnes of salt per year in Lake Guiers (SGPRE 1999). The population in the neighbouring localities is not always aware of the dangers represented by the pollution, the mismanagement of solid waste and the direct use of untreated raw water for domestic and purposes.

Inefficient irrigation technology

Irrigation water use efficiency is very low. In some irrigated perimeters in the river valley, water use efficiency is quite often lower than 50%, particularly in those areas cultivated in rice and market gardening crops, where furrow irrigation is practiced. This is linked to the lack of farmer education or insufficient financial resources for install appropriate irrigation systems. The main water supply pipes are not well maintained. In many cases, drainage systems are not taken into account. Consequently, several pollution problems are observed in the region such as the pollution of Lake Guiers and the drainage of the SAED perimeter in the Ndiael.

Natural causes

The stream flow in the Senegal River is strongly related to rainfall. For the period 1904-1999, the mean annual flow volume was 22.1 billion m^3 at Bakel (SGPRE 1999). The maximum and the minimum volume observed were 42 billion m^3 (1924) and 6.5 billion m^3 (1984) respectively. The average stream flow volume at Bakel decreased from 25.9 billion m^3 (1904-1967) to 13.78 billion m^3 (1967-1999) (SGPRE 1999).

Lowering of the water table – Souss-Massa River Basin

In Morocco, the consequences of increased industrialisation and a rapidly growing population have accentuated the growth in demands for water resources and have promoted their intensive use. For the last three decades the emphasis was on maximising the capture of Morocco's surface water resources for irrigated agriculture, potable water supplies, industrialisation and energy generation. Important infrastructure to capture and use about two-thirds of surface water is already in place, and a number infrastructure projects are in advanced stages of planning and construction to capture most of the remaining potential.

Despite remarkable achievements, Morocco faces growing challenges in the water sector. One of the major issues is the decline in water resources. The mean annual rainfall is 150 billion m^3 but the renewable water resources do not exceed 29 billion m^3. Taking into account potential storage sites and groundwater development possibilities, only 20 billion m^3 are divertible. A number of river basins are already experiencing water shortages, which will impose costly interbasin transfers. Some of the more intensively used aquifers are now considered to be under stress with serious drawdowns and saltwater intrusion in the coastal ones. This is the case of the Souss aquifer in the Souss-Massa Basin (Ait Kadi 2002).

The focus of the causal chain analysis is to determine the source, the underlying constraints and the root causes of the shortage of freshwater in this region. The reasoning behind the choice of focusing the causal chain analysis on freshwater shortages can be argued in view of the observed trends in water table depletion in the whole region and the need to address the issue of water shortage to prevent further environmental deterioration. The underlying characteristics and assumptions of the water table depletion problem are summarised below:

- Recent problematic trends in the water balance of the Souss aquifer;
- Increased agricultural water demand;
- Increased non-agricultural water demand;
- Unsustainable water table drawdown.

System description

The Souss River Basin covers approximately 27 000 km^2. It is located at the southern end of the Atlas Mountains. It is bounded on the north by the High Atlas Mountains and on the south by the Anti Atlas Mountains (Figure 5 in Regional definition). The two mountains ranges joint at Mount Siroua (3 304 m above sea level) to form the drainage divide between the Souss-Massa Basin to the west and the Draa Basin to the east. The River Basin encompasses the Souss River, the Massa River and the coastal river basins of Tamri and Tamraght, all of which discharge into the Atlantic Ocean. In 1994, the population in the Basin was 1 541 000 inhabitants.

The land use in general is dominated by forest (48%), pasture land (33%) and arable land (19%) (Baroud 2002). The potential irrigated area is 250 000 ha, with 134 295 ha currently under irrigation. Citrus and vegetables represent 44% of crops grown in the irrigated area (Table 26). With a year-round growing season, irrigation from reservoirs and groundwater enables the region to produce more than 60% of Morocco's agricultural exports (mostly citrus and tomatoes), but the overdrawn aquifer is falling by more than 1.5 m per year in some areas (Rhodes 1999).

Table 26 Irrigated crops in Souss-Massa River Basin.

Crop	Irrigated area* (%)
Citrus	27
Vegetables	17
Cereals	17
Olive tree	17
Fodders	10
Banana	2
Others	10
Total	100

*Note: * During a normal year.*
(Source: Baroud 2002)

The region is arid to semi-arid, and receives 270 mm of rain in an average year. The Souss and Massa rivers are the primary sources of surface water in the area. The normally available surface water each year ranges from 341 to 635 million m^3, but it can drop as low as 35 million m^3 in dry years, as it did in 1960-1961, and as high as 2 160 million m^3 (1962-1963). Surface water is collected and stored in seven reservoirs with a total storage capacity of more than 750 million m^3 (CSEC 2001) (Table 27). Groundwater is obtained from two major aquifers (DGH 1999):

- The Souss aquifer, limited to the north by the High Atlas Mountains and to the south by the Anti-Atlas Mountains and to the west by

Table 27 Dams in Souss River Basin.

Dam	Storage capacity (million m³)	Use
Youssef Ben Tachefine	303	Irrigation and drinking water
Abdelmoumen	214	Irrigation and drinking water
Aoulouz	110	Groundwater recharge
Med Mokhtar Soussi	50	Irrigation
Imin El Kheng	12	Irrigation and groundwater recharge
Moulay Abdellah	110	No data
Total	799	

(Source: CSEC 2001)

the Atlantic Ocean and covers 4 150 km². Its capacity is estimated to be 30 billion m³ with a depth ranging form 150 m to 500 m;

- The Chtoukas aquifer, which is located south west of the Souss valley and covers an area of 940 km². Its estimated capacity is 1 billion m³ with a depth ranging from 50 to 300 m.

Even though the Souss-Massa Basin is located entirely in Morocco, there are several tranboundary issues that are relevant for this report: (i) a significant portion of the available water resources of the Souss-Massa Basin can be lost to the Atlantic Ocean when a strong flash flood occurs; (ii) a large proportion (roughly 60%) of the national production of fresh fruits and vegetables that are exported from Morocco to international markets originates in the Basin; (iii) a correspondingly large amount of 'virtual water' is exported annually through the export of commercial high-cash crop commodities; and (iv) an equally important amount of irrigation water is currently pumped from the transboundary aquifer, around two-thirds of the total water used for irrigation purposes.

Despite the water scarcity in the region, the international character of the Souss-Massa Basin is reflected in the level of export of what is known as 'virtual water'. This refers to the volume of water contained in commodities that are exported, both food and non-food. For example, as 1 tonnes of tomato production is approximately between 80 and 90% of water by weight, the export of 195 000 tonnes of Moroccan tomatoes to Europe in 2001 would correspond to the export of 165 750 tonnes of water, of which 60% were produced in the Souss-Massa Basin. The figure is even higher when considering the total export of fruits and vegetables from this region, totaling about 380 000 tonnes or an export equivalent of 323 000 tonnes of virtual water during the same year (MCE 2001). Over the last decade, total export of fruits and vegetables from the region to the international market varied between 257 570 tonnes in 1996 to 456 723 tonnes in 1999, demonstrating a large inter-annual variability (Figure 15).

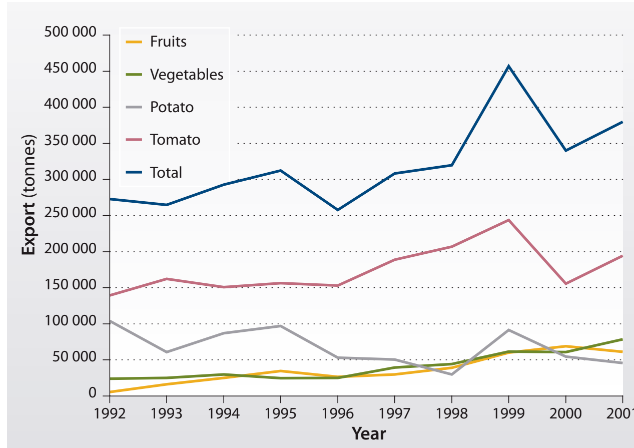

Figure 15 Export of fruits and vegetables in the Souss-Massa River Basin.
(Source: MCE 2001)

The region is one of the most water-poor regions in the world and significant efforts are being made to improve the management of water resources. Although there is still room for further progress, particularly regarding irrigation efficiency, the region appears to be structurally unable to feed its increasing population and will probably need to rely more and more on virtual water, such as food imports, mainly in the form of grain cereals.

Causal chain analysis

In recent years, agriculture has developed in the central plain of Souss-Massa River Basin, in spite of the natural dryness of the soil. Nevertheless, agriculture is not a new economic activity in the area. Traditionally, water for irrigation was obtained by digging almost horizontal galleries to the groundwater table, and then letting the water flow by gravity down the gallery. At present, water is pumped from the subsurface. For the last three or four decades pumping has depleted the water table. In some places, the aquifer drawdown can be as high as 2 m per year and has ranged between 10 to 65 m since 1970 (CSEC 2001). Along with increasing pumping costs to a considerable degree, the lowering of the water table means that the system will reach a point where the availability of water will not meet the demand. In addition, the high evaporation and infiltration rates in the central plain means that rivers in the Basin tend to dry up before reaching the main stream. In general, run-off occurs only after consecutive rainy days and, mostly, the horizontal movement of water takes place in the deep groundwater system.

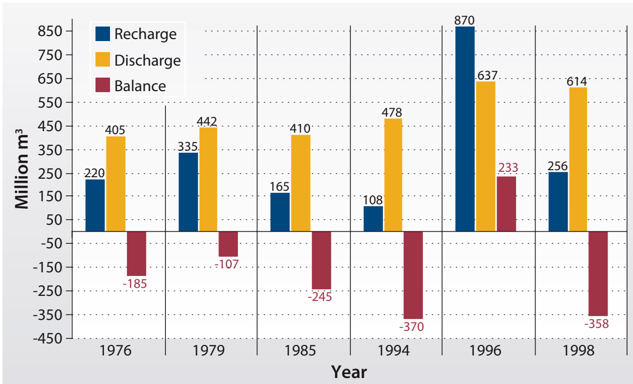

Figure 16 Groundwater balance in the Souss River Basin.
(Source: DGH 1999)

Intensive irrigation development, urban and industrial growth, and the expansion of the tourist industry are making increasingly heavy demands on the area's water resources. The situation is worsened by the Basin's arid ecological conditions. The region is therefore experiencing chronic water deficits.

Evidence based on existing meteorological and hydrological records clearly indicates that the impacts of freshwater shortages are becoming more and more acute in the Souss-Massa region. Figure 16 provides a good illustration of recent trends in the water balance deterioration.

The impacts are most severe during the dry season, which lasts for at least six months each year, and the situation is further complicated by the frequent occurrence of drought episodes in Morocco as a whole and in the region in particular. While the freshwater shortage creates periodic water scarcity, which in time will become more acute due to the increases in water demand (population growth, tourism, industrial activities), the additional water shortages created by droughts will be more frequent and more widespread as the region's water utilisation rate increases.

Therefore, management of the freshwater shortage in the Souss aquifer is not only a major environmental concern; but it is also a crucial problem for the local community's well being. Furthermore, it is indeed a severe constraint for future development of commercial agriculture and tourism industry, the two most important sources of revenue in the region.

The main issues addressed in the analysis of the freshwater shortage in the Souss-Massa Basin concerned the lowering of water table level and the rapid depletion of underground water resources and the modification of stream flow in the River (Figure 17). The changes in water table may be considered as part of a global change that is occurring in the whole region, as described under the Global change concern. However, the lowering of water table is considered to be more critical in the context of the Souss-Massa Basin than the modification of stream flow. Therefore, the focus of the causal chain analysis has been placed on the underground water table depletion issue (DGH 1999).

Immediate causes

The immediate causes underlying the stream flow modification problem are associated with decreased input, drop in annual rainfall patterns and decreased inflow. These may be considered a part of the global change described earlier.

Excessive pumping

The drop in the water table has mainly resulted from excessive pumping for agricultural irrigation purposes and from reduced recharge. The evidence for excessive underground water pumping is reflected in the fact that out of 918 million m^3 of water that is used

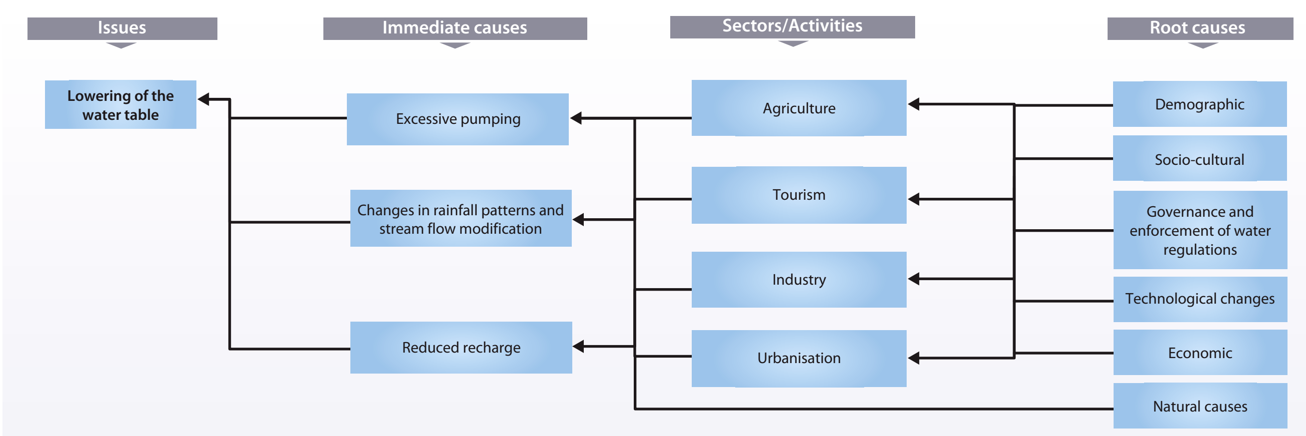

Figure 17 Causal chain diagram illustrating the causal links for lowering of the water table in the Souss-Massa River Basin.

annually, 618 million m³, or 67% of the total volume, is withdrawn from the groundwater (CSEC 2001). Groundwater, which is the major water source for the region, is obtained primarily from the alluvium in the Souss-Massa valley. In 2002, more than 13 000 wells were used to withdraw groundwater for domestic, industrial, and agricultural uses. The number of wells has rapidly increased with the more frequent drought episodes experienced in the region over the past two decades. Generally, the water quality in the alluvium is good, with most wells producing fairly good quality water. Some wells, however, show deteriorated water quality.

Changes in rainfall patterns and stream flow modification

The excessive pumping is exacerbated by low and variable rainfall and surface water. Rainfall in the Basin is highly variable and averages 280 mm per year in the northeast Souss Valley and 265 mm per year in the southwest area of the valley. The Souss River, the main river in the basin, is characterised by an irregular flow and frequently dries up for as many as 310 days per year. During the last 80 years, Morocco in general and the Souss-Massa River Basin in particular experienced 27 years of drought recurring at a three-year interval (Swearingen & Bencherifa 1996). Prior to the construction of major dams, groundwater was the only source of water for irrigation during the dry periods.

Reduced recharge

The reduced recharge of the Souss aquifer is illustrated in Figure 16 above. The evidence for this problem is also reflected in the inter-annual variation of the depth of water table over the period 1969-1999, as shown in Figure 18. The data indicate that the deficit ranges from -185 million m³ in 1976 to -358 million m³ in 1996 and that the water table level dropped from -15 m in 1969 to -35 m in 1999 with an

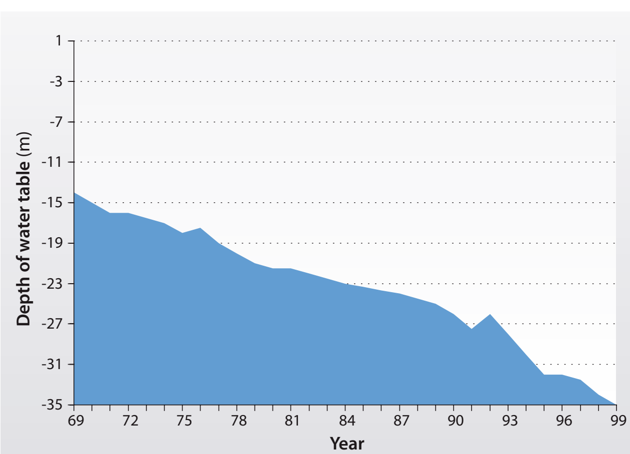

Figure 18 Inter-annual variation in the water table depth in the Souss aquifer.
(Source: DGH 1999)

average drawdown of 0.8 m/year and a maximum of 1.5 m/year for 1990 and 1997. The low rate of renewable groundwater (0.29 billion m³) exacerbates the reduced recharge problem, which is further aggravated by run-off losses (DGH 1999).

Sector activities

The main sector activities that generate freshwater shortages in the Souss-Massa Basin are associated with the allocation of water resources for: irrigated agriculture, tourism and industrial activities, and urbanisation.

Table 28 Water demand by sector in the Souss Massa Basin.

Sector		Water demand (million m³)		
		1993	2000	2020*
Agricultural sector	Total	915	1 005	1 075
	Surface water	300	315	315
	Groundwater	615	690	760
Non-agricultural sector		ND	50.8	88.6

*Note: ND = No Data. * Projected demand.*
(Source: CSEC 2001)

The water demand by sector is summarised in Table 28. The data indicate that through the sustained effort of water mobilisation in the Souss-Massa Basin, about 1 056 million m³ were regulated in 2000 and about 690 million m³ were extracted from aquifers, making roughly 1 005 million m³ available for irrigation, and the remaining 51 million m³ for tourism, industrial and domestic water (CSEC 2001). It is worth noting the steady increase in water demand by sector and the corresponding projected figures for 2020, which predicts the levels will reach 1 075 million m³ for agriculture and 88.6 million m³ for the non-agricultural sector. The resulting consequences of the increasing water demand in both agricultural and non-agricultural sector activities have led to a major deterioration of the groundwater balance to meet the growing needs.

Irrigated agriculture

In terms of water use, irrigated agriculture is the main user of the available water in the region, as is the case for the whole of Morocco. In 2000, only 51 million m³ were allocated to industrial activities and domestic water, making the agricultural water sector consumption at around 95% of the total available water in the region (CSEC 2001).
The increased agricultural water demand in the Souss-Massa region resulted from a steady increase in irrigated acreages over the past three decades. The recent figures indicate that total irrigated area increased from 134 295 ha in 1993 to 140 455 ha in 2000; the projected increase by 2020 is 150 000 ha (CSEC 2001). Changes in the cropping

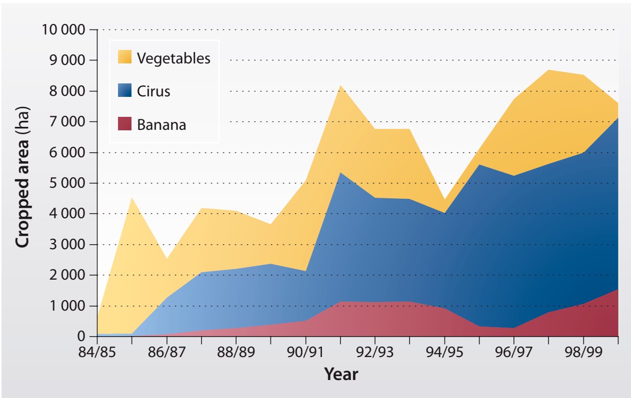

Figure 19 Cropped area for irrigated cash crops in the Souss-Massa River Basin.
(Source: CSEC 2001)

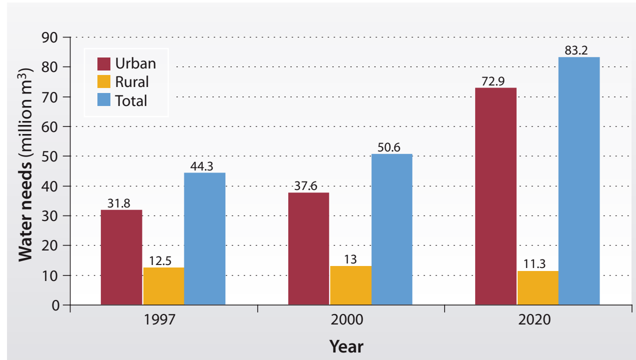

Figure 20 Present and projected domestic water needs in the Souss-Massa River Basin.
(Source: CSESC 2001)

patterns for the last three decades have also contributed through the introduction of new high-water-demand cash crops such as bananas, along with the development of the vegetable crop for export (Figure 19).

The water losses through evaporation associated with the use of traditional open irrigation canals, and the limited maintenance of the water transport system through the canals also explain the increased agricultural water demand observed in the region. However, the predominance of inefficient traditional irrigation systems, comprised of 50% flood irrigation and 28% sprinkler irrigation, represents the main reason for the 40 to 50% water use efficiency index observed in the region (Kent & Ouattar 2002).

Tourism, industry and urbanisation

In parallel with the steady increase in the agricultural water demand, the non-agricultural water demand is also rapidly increasing as a result of demographic pressure, an improving standard of living, urbanisation and the development of tourism and other industrial activities. Presently, it is estimated that almost 60% of the potable water supply in the Agadir area comes from groundwater wells and 40% from surface water reservoirs (Kent & Ouattar 2002). Figure 20 documents such development and indicates an alarming projected water demand by 2020 on the order of 83 million m^3. Fully 86% of this demand would be allocated to meet urbanisation needs.

Root causes

Demographic

In 1971, the population of the Souss-Massa River Basin was 938 000 inhabitants (about 6.1% of the total population of Morocco). In 1994, the population had grown to 1 541 000 inhabitants and is expected almost to double by the year 2020 (CSEC 2001) (Figure 21). The region's population is equally divided between rural and urban settlements. Urban populations have grown enormously in the past decade, as drought has pushed people out of subsistence farming, and economic opportunities have pulled people into towns where there is at least seasonal work in export agriculture, tourism, fishing, and transportation.

The estimated water demand for domestic use, which is currently about 75 liters per capita per day, is expected to increase to 120-160 liters per capita per day by the year 2020 (Reiss & Ouattar 2002). A comparatively much higher water demand is expected to apply to the tourism industry, as in 2002 it already ranged from 450 to 1 600 liters per capita per day in some hotels in Agadir. The corresponding total water demand would total 83.2 million m^3.

Socio-cultural

In Morocco, water is traditionally considered a free public resource. This inevitably influences the enforcement of regulations. The Moroccan government effectively has total rights to all of the country's water and in 1995 passed a law authorising the management of the country's

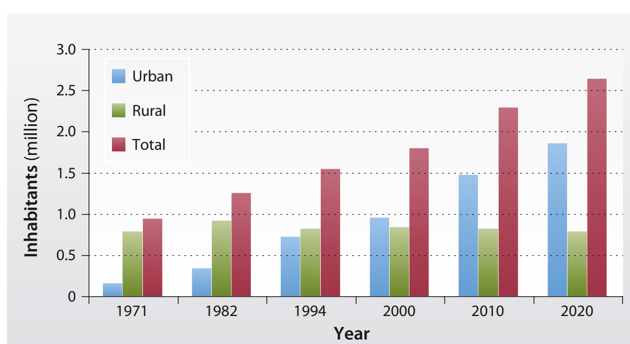

Figure 21 Population in Souss -Massa River Basin.
(Source: CSEC 2001)

water at the basin level. This law, when fully implemented, will result in a more decentralised and participatory process for water management. The newly established Souss-Massa River Basin Agency must work with five major public existing organisations currently operating in the water sector: irrigation, potable water, environment and health, in addition to water user associations (see Root cause: Governance and enforcement of water regulations below).

Historically, water rights and water management issues have been handled by local communities that are located in traditional irrigation zones. The modern legislation applies to large, commercial irrigation areas, which have developed during the past 30 years. The Moroccan legal system includes a mixture of community, Islamic and newly developed water rights and rules from the 1995 Water Law, which now constitutes the main legal context for water management, rights and use. The law recognises that all water resources are a public good and that water should be managed at a river basin level.

Governance and enforcement of water regulations

In Morocco, several active institutional bodies intervene to one extent or another in water management at the local, regional and national levels. These include:

- The High Council for Water and Climate (Conseil Supèrieur de l'Eau et du Climat, CSEC) is a national consultative body that approves national and regional water resource master plans.
- The Irrigation Agency (Office Regional de Mise en Valeur Agricole de Souss Massa, ORVASM), responsible for irrigation perimeters, planning and construction of irrigation canals and transporting water from reservoirs to farmers. It has also drilled numerous irrigation wells used for irrigation. In the absence of a Water User Association, it collects money directly from farmers for operation and maintenance of the irrigation system, but capital costs are not recovered.
- The Souss-Massa River Basin Agency (Agence Régionale de Bassin, RBA) was created recently and is responsible for reservoirs and hydraulic infrastructure maintenance and for upgrading regional master plans and planning for the use of water resources in the basin, including groundwater. In addition it coordinates water management committees at the basin level.
- The Drinking Water Agency (Office National de l'Eau Potable, ONEP)provides wholesale water to the Agadir Municipal Authority and directly to other small towns and villages in the area.
- The Agadir Municipal Authority (Régie Autonome Multi Service d'Agadir, RAMSA) is an autonomous state-controlled water utility company that distributes and sells drinking water to Agadir.
- Water User Associations (Association des Usagers d 'Eau Agricole, AUEA) have been created to take over operation and maintenance responsibilities, and charge each farmer for water that is used to maintain the distribution systems. If user groups have not been formed, the Regional Agricultural Development Authority (Offices Régionaux de Mise en Valeur Agricole, ORMVA) collects money directly from the farmers for operation and maintenance of the distribution system.

The revision of the Moroccan Water Law in 1995 introduced many new considerations about the management of water at the national and local level. One of the important aspects is the official recognition of planning by the state of water mobilisation and allocation as the main instrument for decision-making about public infrastructure, water allocation and water transfer. The Water Basin Plan is to be prepared by the Regional Basin Agency (RBA) and to be submitted to the High Council for Water and Climate (CSEC) in order to adopt it formally. Once adopted, the master plan, which is comprised of an integrated management of water resource at the hydrological basin level, is the main document for the support of intersectoral water allocation, extraction agreements and concessions. It also includes goals in terms of quality (CSEC 2001).

A number of new tools have been implemented to enforce the new water management rules. These include:

- The introduction of the Regional Basin Agency, as the main entity in charge of water issues at the water basin level.
- The introduction of new taxes, (River Basin recovering tax) based on extraction and pollution levels.
- The formal introduction of the National Hydrological Plan as the main tool for solving allocation conflicts.
- The introduction of new instruments to deal with pollution and drought; specifically fees for polluters, subsidies for investments to reduce pollution and new powers so that the administration can deal with drought.

However, more time is needed for the 1995 Water Law prescriptions to come into force, and presently the decision-making process is highly concentrated, which results in poor enforcement of regulations. The fact that a ministerial department (the Secretary of State for Water) is entirely devoted to water issues may help speed up the implementation of the Water Law principles in practice, and yield a more comprehensive package for water management, including enforcement of regulations.

Technological changes

Inefficient irrigation systems

In spite of the fact that the Souss-Massa region is technologically more advanced than the rest of Morocco, most of the land is still under flood irrigation. Flood irrigation still covers almost 50% of irrigated land, sprinkler irrigation is used on another 28%, and drip and irrigation covers only 25% of all irrigated agricultural land in the Souss River Basin (Kent & Ouattar 2002). Thus, water-saving technologies have been slow to reach farmers. The region invested heavily in mobilising and managing the water supply at macro-scale level, and little attention was devoted to saving water and improving water demand management. Water-savings data indicates that global water losses at the farm level as well as in the irrigation systems range from 45% to 95% with an average of 69% for the period 1987-1999 (Tayaa 2002) (Figure 22).

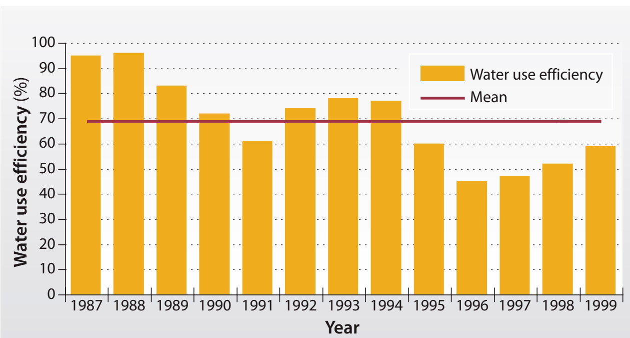

Figure 22 Irrigation water use efficiency in the Souss Massa River Basin.
(Source:Tayaa 2002)

Inappropriate well technologies

The lowering of the groundwater table is further complicated by the use of inappropriate well digging technologies, which are similar to that used by commercial oil prospecting companies. The policies thus far implemented have failed to provide local farming communities the necessary incentives to participate in responsible water management decisions. This is true both from the perspective of technology use and water pricing.

Economic

The economic root causes elaborated in this section include water pricing policies, water market failures and distortions due to subsidies, and users' behaviors and attitudes. There is a great paradox regarding the economics of the freshwater shortage issues in the Souss-Massa Basin and in Morocco as a whole. On the one hand, low-priced water provides little incentive for farmers to invest in water-saving technologies such as drip irrigation. Instead, it encourages farmers to overuse water, thereby exacerbating the problems of decreases in the groundwater table, with associated waterlogging and salinity problems. On the other hand, sustainability of the irrigation systems is at stake: at present, water for irrigation is practically free, mainly because a large number of farmers cannot afford to pay water charges, even to cover the operating and maintenance costs. There are also social and cultural obstacles to charging a fee for water for irrigation and even for other uses.

This is why the policies initially implemented overemphasised irrigation subsidies. The effective rate of subsidies for investment was as high as 95% for small farms, which represent the majority of the farming community. Although the subsidy rate was revised to 40% in 1984, most exemptions were maintained and only 10% of the investment cost was included in water rate charges. In 1996, following the 1995 Water Law, all exemptions have been cancelled and the 40% subsidy is to be recovered independently of water rate charges (BenAberrazik 2002).

The average urban charge for water in Agadir is 0.24 USD per m^3 for users consuming less than 24 m^3 per month and 0.76 USD per m^3 for those consuming more than 60 m^3 per month (Kent & Ouattar 2002). The average charge for irrigation water is approximately 0.052 USD per m^3. Because neither urban nor irrigation rates include the capital cost of construction of dams, urban charges frequently cover only 50% of the full cost of water and irrigation charges less than 10% of the full cost of water. Private well owners do not currently pay for water. When the 1995 Water Law becomes fully implemented, it will allow the Souss-Massa Basin Agency to charge approximately 0.002 USD per m^3 for groundwater pumped from private wells. Therefore, water pricing is still not sufficiently compelling to stimulate water savings. In fact water distributed to farmers within the irrigated Massa perimeter is priced at half its real distribution cost (0.052 USD per m^3 paid by farmers, as compared to 0.123 USD per m^3 for the estimated operation and maintenance cost). If we include the investment cost, the difference between the price paid and the real cost is even higher. Investment costs are still supported by government budgets. Pricing reform, implemented during the last years, which aims at increasing gradually water irrigation prices, has been slow to achieve its goals. Improving water allocation efficiency, via water pricing, is still considered an important strategic objective.

Natural causes

Rainfall in the Souss-Massa Basin is highly variable and the Souss River is characterised by an irregular flow and frequently dries up. During the last 80 years, the River Basin has experienced 27 years of drought, recurring at a three-years interval (Swearingen & Bencherifa 1996).

Overexploitation of fish – Canary Current

At least seven of the countries in Canary Current region, Morocco, Mauritania, Senegal, Cape Verde, The Gambia, Guinea, and Guinea-Bissau, as well as the Canary Islands, are coastal states bordering the Atlantic Ocean and have important marine fisheries stocks. Generally, the marine fisheries of the region consist of two sub-sectors, industrial and artisanal, which target pelagic and demersal stocks. These stocks constitute, for the states, vital renewable natural resources that provide food and income for local populations, foreign exchange earnings, revenue for the national governments (balance of payments) and employment opportunities. Throughout the region, local populations are engage in artisanal fishing, whereas exploitation at the industrial level is dominated by fleets of vessels, equipped with ultra efficient state-of-the-art fish detection and capture equipment.

The fisheries sector, which is vital for social stability and the survival of local populations, is threatened by destructive, unsustainable fishing methods and practices, ever-increasing fishing effort without due consideration of the ability of the resources to support the exploitation. This results in overexploitation, excessive by-catches of non-target organisms, including endangered and protected species, and discards.

The efforts of the states of the region to develop and to use these fish stocks in a sustainable manner are limited by the lack of adequate skilled manpower and financial and material resources. Furthermore, the poor and precarious state of their national economies compel these countries to grant fishing access rights to vessels, the majority of them foreign-owned, at a level that exceeds sustainable harvesting. This has resulted in the overexploitation of several stocks such as shrimps, cephalopods, demersal and pelagic fishes, and other aquatic organisms. Another constraint is that the existing fisheries resources management regime grants little power to local communities in decision-making regarding allocation of fishing access rights.

System description

Marine fisheries of the region

Generally, the marine fisheries sector in the region is characterised by operations at industrial and artisanal levels, with the industrial sub-sector being distinguished by large-scale investment in export oriented production. Investment in the artisanal sub-sector is relatively small, with fisherfolk operating from many dispersed, and often isolated, landing sites. Most of the industrial vessels are large, off-shore and foreign-owned while the artisanal vessels are locally built wooden canoes. Senegalese artisanal fishermen dominate fishing in the region because of their recognised fishing skills and willingness to migrate along the entire marine coastline from Mauritania in the north to Guinea in the south.

Fisheries resources potentials

The marine zone of the region is characterised by a high biological diversity and significant fisheries resources. Generally, the fish stocks that are exploited in the region can be divided into two main groups; pelagics and demersals species.

In Senegal, the resources are further characterised by two major groups; offshore and coastal pelagic resources, and deep sea and coastal demersal resources. The Republic of Cape Verde, off the coast of Senegal, has a vast fishing zone of some 734 000 km^2 with abundant stocks of tuna, spiny lobsters and pelagics. The Gambia groups its fisheries resources into three main classes; pelagics, demersals and crustaceans (including shellfish).

Mauritania, like Senegal, classifies its resources into two large groups; demersal resources and pelagic resources. The resources have an exploitable potential of about 1 500 000 tonnes per year, of which 65% are pelagic fish, 20% are clams and 15% are demersal fish, tuna and crustaceans (UNEP/CNROP 2002). Regarding pelagic resource, a dozen species out of 50 are exploitable stocks; for example Sardine, Horse mackerel, Mackerel, Anchovy and Mullet. These stock evaluations indicate that tuna, horse mackerel, sardines, and mackerel have the potential to supply 1 million tonnes per year in the EEZ of Mauritania alone.

Status of resources

The various global results available regarding on the coastal demersal resources indicate a serious overexploitation. The signs of overfishing of coastal demersal resources are manifestly evident, declining production of industrial fishing units, exacerbation of the conflicts between artisanal and industrial fishing and even within the artisanal fishery, adoption of new fishing strategies, a significant reduction in mean individual sizes of landed species, and stagnation or reduction in landings per type of fishing in spite of the increasing level of fishing effort. For example, the most recent resource evaluations by Senegal's oceanographic research centre, CRODT, confirm this overexploitation (Barry et al. 2002).

The change in indices of abundance of the species captured by bottom trawls during the CRODT trawl campaigns shows, in all species combined, a significant reduction between the 1970s-1980s and the 1990s. Nearly all fish species are affected by the decrease. The total catches, all species included, declined from about 1 000 kg/hour in 1986 to only 500 kg/hour in 1991 for the entire Senegalese continental shelf, corresponding to a 50% reduction (PNUD/ENDA 2001). The Serranidae group declined from mean abundance level of about 30 kg/hour for all species, already relatively low, to less than 10 kg/hour within the same period (UNEP/ETP 2002). The same phenomenon is observed for the Sparidae group, particularly with regard to the Sparus species, whose relative abundance declined from more than 40 kg/hour to less than 10 kg/hour, and that of guitar-fishes, which changed from 60 kg/hour to 5 kg/hour respectively.

In Mauritania, the level of knowledge on the state of the resources is uneven. The evaluation results for pelagic and cephalopod species, notably the octopus, are considered to be more reliable than those for other stocks, such as the crustaceans and demersal fish. Details of the quality of the results are given in Table 29. The table shows that most of the demersal resources are fully exploited to overexploited. The octopus and the White grouper are overexploited. The hakes and shrimps are fully exploited, as is true for the majority of the big demersal species.

Table 29 Summary of the evaluation of pelagic stocks in Mauritania.

Resources	Current catches (tonnes)	Natural variability [1]	Exploitation	Maximum Sustainable Yield [2] (tonnes)	Excessive effort [3]	Management recommendation
Cephalopods						
Octopus	20 000	Productivity dependent on up-welling and not on exploitation level	Overexploitation, declining indices of abundance.	35 000 (26 000-43 000 according to up-welling)	25-40 %	Reduce fishing effort. Maintain closed season
Cuttlefish [4]	6000	Stable	Probably fully to overexploited	10 000	Unknown	Precautionary approach and encourage selective gears
Squids [4]	4000	Average	Unknown	6 000	Unknown	-
Demersal continental shelf	Emerging statistics: Estimated 40 000-50 000	Average (stock dependent)	Target species fully exploited. Others probably under- to fully exploited	Unknown, probably near current catch.	Probably weak	Freeze effort due to lack of stock evaluation
Black hake	13 000	Unknown	Probably under-exploited. High indices of abundance	12 000	0	Maintain effort at current levels
Mullets [4]	17 000		Big increase in effort	Unknown	Unknown	Freeze effort
Crustaceans						
Deep sea shrimps [4] (*Parapenaeus longirostris, Aristeus varidens*)	3 300/400	High	Probably fully exploited	Unknown	Most likely 0 or weak	Freeze effort (high amount of by-catches)
Coastal shrimps [4] (*Penaeus notialis, P. kerathurus*)	1 900	High	Probably fully exploited	Unknown	Weak	Freeze effort.
Crabs [5] (Gerion)	160	High	Probably fully exploited	400	0	Freeze effort
Red lobsters [5]	200	High	-	800	Unknown	-
Green lobsters [5]	100	High	Northern stock probably recovering	220	Weak	Delay any increase in effort
Clams [5]						
Venus rosalina	0	High	Not exploited	< 300 000	0	-
Venus verrucos	0	High	Not exploited	500-1 000	0	-
Coastal pelagics						
Sardinella	480 000	-	Fully exploited (excepting *S. eba* in Mauritania	500 000	0	Freeze global in the regional-
Horse mackerel	192 000	-	Moderately exploited	400 000	Weak to 0	Maintain effort
Green horse mackerel	21 000	-	No evaluation	Unknown	Weak to 0	-
Mackerel	159 000	-	Moderately exploited	Unknown	Weak to 0	-
Scabbard fish	-	-	-	Unknown	-	-
Sardine	-	-	-	Unknown	-	-
Anchovy	-	-	-	Unknown	-	-
Albacore	135 000 (East Atlantic)	-	Fully exploited	Atlantic stock 144 000	0	Freeze effort and minimum size
Listao	112 000 (East Atlantic)	-	Exploited to fully exploited	Unknown	Weak	None
Patudo	99 000 (East Atlantic)	-	Fully exploited	Atlantic stock 94 000	0	Freeze effort

Note: [1] Natural stock variability independent of exploitation (recruitment variability). [2] Maximum Sustainable Yield (MSY) (This potential cannot be reached without setting the effort to the corresponding level (fMSY), which implies in some cases effort reduction). [3] Current excessive fishing effort to reach the MSY. [4] No evaluation 2002, values and recommendations are from 1998. [5] No evaluation since 1993, 1993 or 1988 values and recommendations.

(Source: IMROP 2002)

Production

Regardless of the species, the total capture production of the countries in the region is well over 1 million tonnes per year. There is a disparity in the individual production by country. According to FAO (2002) statistics the capture production in 2002 was 45 800 tonnes in The Gambia and 895 000 tonnes in Morocco. Senegalese and Mauritanian produced about 79 000 and 376 000 respectively. Cape Verde on the other hand, had a production of 8 000 tonnes.

Contribution to the economy

Due to the particularly productive environment, the sector makes an important contribution to food security, employment and national treasuries of the region. Fish is largely the only source of cheap animal protein. In Senegal and The Gambia, 40% of animal protein is from fish. In spite of the significant quantities exported from the region, the average per capita consumption (about 20 kg per year) of fish is much more than the African average of 8.2 kg per year. The average consumption of fish in the European Union is estimated at 22.1 kg per year and household. The fisheries sector provides direct and indirect employment for some 300 000 people, meaning that about 4% of the active population of the region works in the fisheries sector, engaged in fish harvest, processing and marketing. About 400 local and 300 foreign industrial vessels operate in the region.

The marine fisheries sector is also an important source of revenue for national economies and national treasury revenues, which are often used for servicing local and foreign debts. The contribution of the sector to national economies varies from country to country. Fishing is of vital importance for the Mauritanian economy. It accounted for more than 54% of foreign-exchange inflows and more than 27% of the State budget in 1998 (UNEP/CNROP 2002). The sector's share of GNP is considerable and varied between 5% and 6% between 1984 and 1995 and reached 7% in 1996. The number of jobs created by the various branches in the fisheries sector was probably about 27 000 in 2000, 21 000 of them in non-industrial fishing and about 6 000 in industrial fishing.

In Senegal, earnings from the export of fishery products usually exceeds 160 billion FCFA (approximately 280 million USD), about 20% of earnings from exports (Diouf et al. 2002). With annual fish landings of over 400 000 tonnes (80% caught by artisanal fishermen), the Senegalese marine fisheries provide over 600 000 employment opportunities. In Cape Verde most of the fisheries production is exported to the European Union (EU). The fisheries sector also contributes to national earnings through various bilateral agreements and fishing licence fees. The financial compensation paid to six countries within the region by the EU within the framework of bilateral fishing agreements amounted to 50 million USD between 1992 and 1995 (Saine 1999).

Causal chain analysis

Figure 23 illustrate the causal links for overexploitation of fish in the Canary Current region.

Immediate causes

There has been an increase in both the artisanal and industrial fishing effort in the Canary Current and capacity targeting an apparently

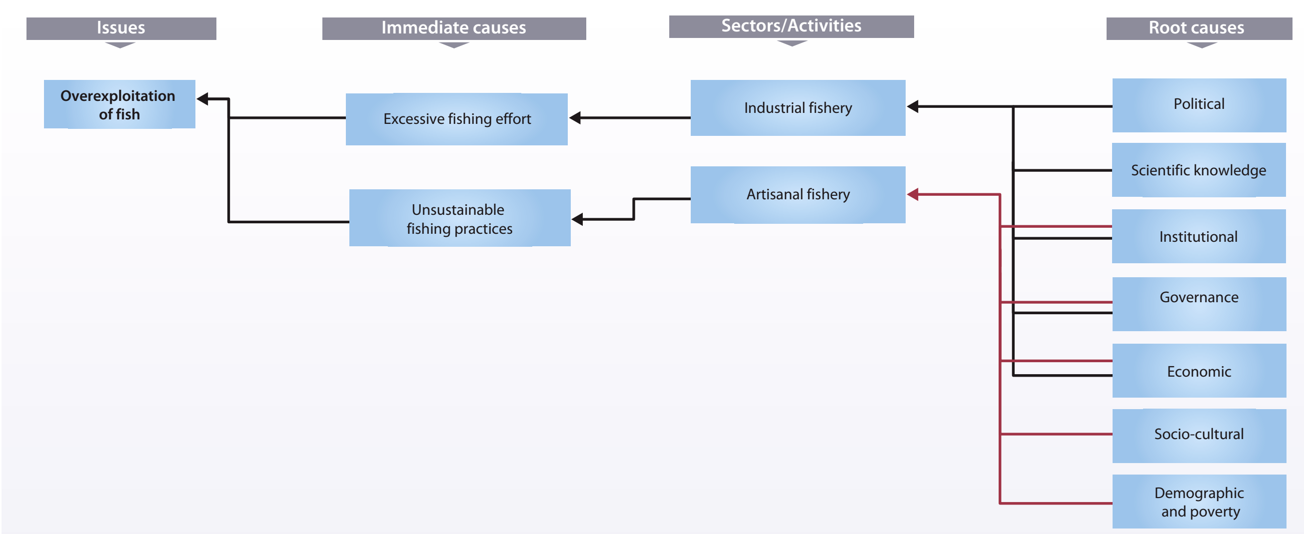

Figure 23 Causal chain diagram illustrating the causal links for overexploitation in the Canary Current region.

declining resource base. An increasing demand for fish and fish products has motivated the use of all means to land more fish by increasing effort and by using destructive and unsustainable fishing methods. The immediate causes of the overexploitation of fish throughout the region are excessive fishing effort and unsutainable fishing practices.

Excessive fishing effort

The sector activities that encourage the increasing excessive fishing effort for coastal demersal resources are essentially the industrial demersal fisheries (various shrimp trawls, red mullet, fish and cephalopods) and the artisanal canoe fisheries (hand lines, hook and line, cages, set nets, etc.).

Industrial fishing effort

As the demand for fish and fish products increases and fish stocks in several parts of the world are depleted, operators have shifted fishing operations to the West African region. This has translated into an increasing number of licensed industrial vessels fishing in these waters, an increase that is not appropriate given the state of the fish stocks. The growth of national industrial fleets was marked by the arrival of more and more powerful and bigger vessels with more powerful engines and medium to high Gross Registered Tonnage (GRT).

In 1994, the Gambian government started implementing its policy of a systematic reduction in the number of licensed industrial vessels. Until 1999, the number of licensed shrimp trawlers remained low (below 40 were licensed yearly) (Figure 24). This was followed by a dramatic and steady increase in 2000. An analysis of catch data from the industrial fisheries in The Gambia also indicates declining annual shrimp (coastal) production and export during the past decade (Figure 25).

Furthermore, due to the acute need for funds for socio-economic development, governments were compelled to grant more fishing licenses to satisfy the demands of countries in the north in exchange for financial and development assistance (Table 30). In Mauritania, the industrial fleet was 69 vessels in 1990 but by 2000, the fleet had grown to about 400 vessels and then about 500 in 2001 (Table 31). These vessels are comprised of Mauritanian vessels as well as vessels from Eastern European countries.

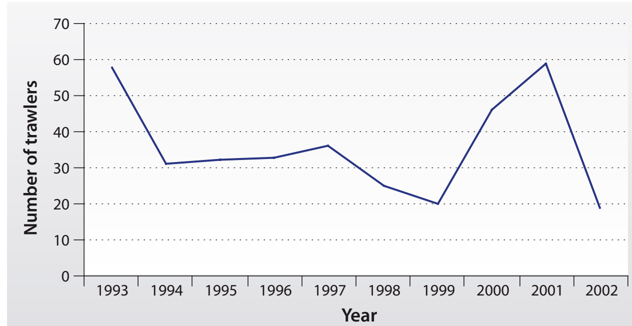

Figure 24 Number of shrimp trawlers fishing in the Gambian waters 1993-2002.
(Source: Gambia Fisheries Department 2002)

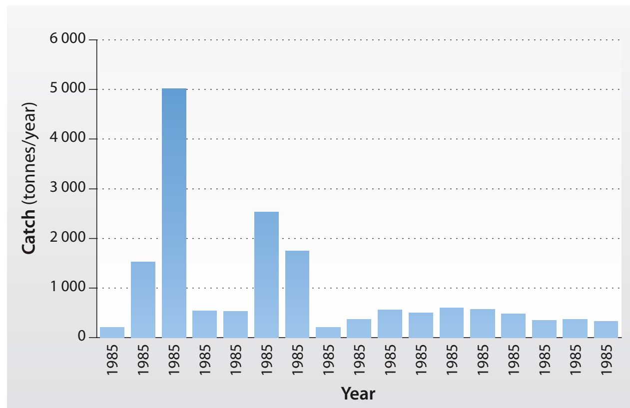

Figure 25 Annual shrimp production in The Gambia.
(Source: Gambia Fisheries Department 2002)

Table 30 Number of licensed industrial vessels operating in The Gambia from 1993-2002.

Vessel	1993		1994		1995		1996		1997		1998		1999		2000		2001		2002
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Stern trawlers	14	22	15	13	5	10	15	10	18	16	15	17	21	42	22	24	14	16	12
Shrimp trawlers	25	33	19	12	13	19	13	20	18	18	9	16	7	13	15	31	22	37	19
Tuna Long-Liners	20	0	12	4	5	15	8	0	5	1	1	4	3	0	2	1	1	0	2
Pair trawlers	0	0	0	0	1	1	2	2	0	0	0	0	0	0	0	0	0	0	0
Tuna Purse Seniors	0	24	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long Liners	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gill Netters	0	0	0	0	0	0	0	0	3	3	0	7	0	0	0	0	0	0	0
Multiple Purpose /Processing Vessels	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0
Total	61	79	46	46	24	45	38	32	39	40	25	44	31	55	39	56	37	54	33

(Source: Gambia Fisheries Department 2002)

Table 31 Number of vessels authorised to fish in Mauritania 1990-2000.

Type of vessel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cephalopod vessels	0	113	116	120	134	172	224	239	206	159	160	200
Shrimp vessels	32	25	21	18	22	33	32	41	41	47	42	68
Hake vessels	37	42	37	70	67	71	0	0	0	40	43	40
Demersal vessels	0	0	0	0	0	0	0	0	0	0	0	45
Pelagic vessels	0	59	102	83	53	72	84	61	0	80	83	82
Tuna vessels	0	0	31	34	35	38	34	35	37	65	73	65
Total	69	239	307	325	311	386	374	376	284	391	401	500

(Source: IMROP 2002)

Table 32 Coastal artisanal canoes in The Gambia.

Year	Total number of canoes	Motorised canoes (%)
1980	290	89
1981	490	66
1983	397	66
1986	346	65
1990	472	60
1992	492	76
1994	503	83
1997	494	87
1999	467	95
2000	580	97

(Source: Gambia Fisheries Department 2002)

Artisanal fishing effort

An increase in fishing effort has been observed in the artisanal sector during the past three decades. An increasing number of people have been entering the sector due to declining agricultural production. A 1996 socio-economic survey of The Gambia's artisanal fisheries sector estimated the growth rate of the sector (fishermen and related industries) at about 5% per year (Mendy 1996). Table 32 clearly shows the increasing trend in the number and percentage of motorised canoes operating along the Atlantic coast of The Gambia.

The scenario is similar in other countries of the region. The Senegalese fleet of artisanal canoes is by far the largest in the region. In 2002, the number of the operational fishing units counted along the marine coastline between Djifère and Saint-Louis was about 9 000, compared to only about 100 at the beginning of the 1960s. Some significant modifications have been made to the types of fishing practised by the artisanal demersal fleet. These were mainly the introduction and development of hook and line fishing in 1987 and a considerable increase in the number of canoes with ice holds onboard as well as those fishing with hand line and/or cuttlefish cages. The increase in the use of multiple kinds of fishing gear also became important. In Mauritania, the artisanal fleet consists of 3 000 canoes and 12 000 artisanal fishermen, representing more than three times the number of individuals aboard industrial vessels (IMROP 2002).

Unsustainable fishing practices

Some fishing methods or practices employed by operators in both the industrial and artisanal sub-sectors accentuate overexploitation of the fish stocks. The following non-selective fishing gear and harmful fishing practices/methods are considered destructive and contribute to overfishing:

Beach seining

The beach seine, used by artisanal small-scale fishermen, is destructive fishing gear due to its mesh size, which is smaller than the regulation size. This gear catches juveniles and small-sized fish as well as breeding or spawning adults that are found inshore or along the coast. The adults and other medium-size fishes are retained while the tiny fishes are often discarded or abandoned on the beach. This fishing gear was banned by an act of the Gambian Parliament in 1989, but is used in all countries of the region.

Trawling

This fishing method destroys marine habitats of demersal and benthic organisms as well as the ecosystem. The majority of the licensed industrial fishing vessels in the region are foreign-owned and an increasing number of them are trawlers. Considering the huge number of trawlers fishing in the marine waters of the region under various international agreements, it is easy to see that substantial and often irreparable damage is being done to the nursery, sheltering and feeding grounds, as well as critical habitats of aquatic organisms and the entire ecosystem. Furthermore, the catches of these trawls invariably include a high amount of by-catches comprised of non-target species, juvenile fish, sharks, green turtles and dolphins.

Some studies have found that about two-thirds of shrimp trawler catches are discarded at sea. Out of about 47 321 tonnes landed by Senegalese trawlers in 1998, 2 056 tonnes were discarded at sea (Baddyr & Guenette 1998).

Stow nets (artisanal shrimp fishing)

The negative impacts of this gear, used in the shrimp fishery, are that the mesh sizes do not normally comply with regulations. Smaller mesh sizes are often used, resulting in the catch of small juvenile shrimps and fish. Small shrimp are retained and sold at lower prices while juvenile or small fish are discarded. This constitutes a serious waste of resources and a destructive and unsustainable way of fishing. As there are no closed seasons or restrictions on the fishing zones for shrimps and also no rigorous enforcement of the mesh size regulations, estuarine shrimp fishing by artisanal small-scale fishermen has become a destructive fishing activity.

Shark fishing

The development of a distinctive artisanal shark fishery started towards the end of the 1960s, pioneered by an immigrant Ghanaian fishing community that had developed specialised skills in the catching, processing and exporting of dried, salted shark meat from their base in The Gambia (Saine 2000). These Ghanaian shark fishermen now operate in coastal countries throughout the region from Mauritania to Guinea. In the early 1970s a lucrative shark fin market emerged in Southeast Asia. Prior to these dates, there was no direct intense targeting of sharks by the artisanal fishery. By-catches were simply processed, marketed and consumed.

The shark fishing industry has become a lucrative business because of the attractive prices being paid for shark fins in Southeast Asia. In a bid to land more shark fins, artisanal fishermen have cut off the fins of the animals and the living animals are thrown back into the water. A new twist in the shark fishing techniques is the use of dolphin meat as bait (Anane 2001).

Scientists at Ghana's Centre for Industrial and Scientific Research have concluded that shark fishing contributes to the reduction of dolphin populations in Ghanaian waters due to the use of dolphin meat as bait for catching sharks. This practice by Ghanaian fishermen, leaders of the shark fishery throughout the West African region, is a danger to dolphins, which are already protected as threatened species in several West African states.

Poaching

Fisheries regulations in all countries of the region have reserved the inshore and offshore parts of their fisheries waters for artisanal small-scale fisheries operators. Licensed industrial fishing vessels are compelled to fish outside and beyond this reserved zone. However, industrial fishing trawlers often fish in this area, thereby destroying the nursery and feeding grounds of juvenile fish, damaging the fishing nets and other gear of artisanal fishermen and causing conflict. Table 33 shows records of the activity of unlicensed/delinquent vessels in The Gambia in 2000 and 2001.

Table 33 Unlicensed/delinquent vessels in The Gambia.

Year	Number of vessels spotted	Number of violating regulations	Violating regulations (%)	Number of arrested
2000	816	85	10	7
2001	103	8	8	5

(Source: Jones pers. comm.)

With increasing effort and declining fish resources, artisanal fishermen are also motivated to go further out to sea in search of fish, thus going beyond the area reserved for them and entering the industrial fishing zone where they come into conflict with industrial fishing trawlers. Despite the regulations delimiting fishing zones and all the effort being made to monitor and control industrial fishing, several vessels annually are caught poaching (fishing without license) or fishing in the wrong zone or using unauthorised/illegal fishing gear. The Sub-Regional Marine Fishing Surveillance Project (AFR/013) of the Sub-Regional Fisheries Commission (SRFC) based in Banjul reported that between 2000 and 2001, only 12 out of a total of 93 vessels were arrested after being spotted by the Project's aerial surveillance aircraft while violating fisheries regulations (Lux-Development/FAO/SRFC 1999).

Use of explosives

With diminishing fish stocks, artisanal fishermen in some countries in the region such as Senegal and Mauritania, have resorted to using explosives in fishing. It has been unanimously acknowledged that the use of dynamite destroys the rocky zones that are essential breeding grounds for several important species.

Root causes

The root causes of overexploitation of fish have been analysed for industrial and artisanal fisheries. Root causes are categorised under these two themes as described below.

Excessive fishing efforts - Industrial fisheries

Economic

Beginning in the 1970s most governments in the region implemented policies aimed at development of the industrial sub-sector by providing assistance for the construction of fishing vessels. These policies provided industrial gear and semi-industrial vessels to the artisanal fisheries and resulted in the introduction of new types of coastal demersal fishing. All these interventions invariably resulted in overcapitalisation.

In the early 1980s, government support was oriented toward facilitating the development of fisheries products for exports. This support included the provision of duty-free concessions and incentives such as exemptions from various duties (subsidy on export, 25% for value-added industrial products) and taxes (Deme 1999). The Lome Convention facility, which granted a duty and tax exemption for fisheries products entering Europe from ACP countries, along with fishing agreements contributed to the increasing link of the sector to external markets for countries in the region.

The objective of all this fiscal support was to facilitate the establishment of fish-processing enterprises to take advantage of the growth in world demand for fisheries products, notably in developed countries. This was expected to reduce the balance of trade deficit through the acquisition of foreign exchange. The activities of these numerous enterprises have exacerbated the demand for exportable products, resulting in the intensification of the fishing effort and seriously threatening demersal stocks.

Institutional

Countries of the region have signed fishing access agreements with foreign countries and interest groups, by far most the important of which are those with the European Union that target already highly threatened species. Presently, all the countries in the region bordering the Atlantic Ocean, excepting The Gambia, have an ongoing fishing agreement with the European Union. These agreements were entered into primarily because the stocks were believed to be abundant enough to satisfy the requirements of citizens of the countries in the region and also because the countries did not have the capacity to exploit their fish stocks.

The fishing agreements are viewed by several experts as one of the main causes of overexploitation of the marine resources in African countries. By lowering the production costs of fishing units, the agreements encourage them to fish beyond the economic optimum compatible with sustainable use of the resources. Furthermore, since the agreements involve specific, allocated industrial fishing, the vessels would not hesitate to reject non-target species or small individuals, in order to maximise the value of their catches. On the other hand, this fishing activity by foreign fishing fleets is not being properly monitored due to the lack of adequate surveillance resources.

Now that the national fleets are able to exploit these stocks, and do so fully, there is no reserve left over that could justifiably be sold to any foreign fleet. The real reason for these agreements could be assigned to the huge financial compensation offered by the European Community to the signatory coastal countries.

Scientific knowledge

The management of the stocks is largely based on scientific knowledge related to biological, economic, sociological and technological factors. The limited scientific knowledge concerning some of the stocks constrains the participants from using optimal strategies and tactics and establishing plans for responsible use necessary for the sustainable development of the fisheries sector.

Governance

Management of the fisheries sector in virtually all countries of the region is characterised by an inefficient system of the monitoring, control and surveillance. The inadequacies in the monitoring, control, and surveillance systems are blamed for the frequent incursions by industrial vessels into the coastal zone reserved for artisanal fishing (spawning grounds), the use of unauthorised fishing gear, destruction of the resources and the marine environment, frequent illegal fishing (poaching) by unlicensed industrial vessels and the fraudulent shipment of catches at sea to the detriment of local markets and industries.

The regulations are, in some cases, inappropriate and difficult to implement. Both fisheries regulations and legislation are characterised by a command and control approach, which is further limited by a lack of education, information and communication. National and local advisory bodies do not have sufficient power to make decisions. All these practices constitute a serious threat to the sustainability of the fisheries and to the maintenance of biodiversity. They encourage the overexploitation of resources, particularly coastal demersals.

Political

For strategic and empowerment purposes, and to enhance their negotiating capabilities, operators in the industrial fisheries sub-sectors have formed different Socio-Professional Organisations (SPO) such as the Association of Vessel Owners and Industrial Marine Fisheries (GAIPES), the Union of Fishermen and Export Traders in Senegal (UPAMES) and the Association of Industrial Fishing Companies in the Gambia. These SPOs, at the political level, are powerful lobbies that protect the interests of their profession members. These interests are not always in the best interests of sustainable development and use of the fisheries resources.

Excessive fishing effort - Artisanal canoe fisheries

Demographic

At the current growth rate of around 2%, the population of the region, will increase by two-fold practically every 25 years. This population explosion is linked to a high urbanisation rate essentially due to rural migration. The urban population could soon exceed 60%. There will be a net increase in the demand for fisheries products by the local market as well as for export. If the 22 kg consumption per capita estimated for the urban area is maintained, the demand for fisheries products would be 1 million tonnes in 2012. To maintain the same level of export, the production of about 2.1 million tonnes would be necessary.

Poverty and lack of awareness

The poverty rate in the coastal zones of the region is particularly high and there is a great dependence on coastal resources, particularly fish, for income generation and food security. Generally, resource users, the coastal communities and other stakeholders lack awareness about the state of the resources and the effects of overexploitation on its sustainability.

Although it is evident that some of the resource users are aware of the problems with regard to the general state of the resources, poverty and the absence of alternative sources of livelihoods compel them to persist in these unsustainable resource use practices. Most of the resource users and other stakeholders have known nothing aside from fishing and fishing-related activities for their livelihoods. The changing trends in society and cultural values have little positive effects on how they view these resources, along with ownership and access. Generally, these resources are considered common property and open-access resources.

Economic

Initially, the state intervened in favour of production by the artisanal sector, and in this connection motorisation of canoes was facilitated. Outboard engines became the trend in the artisanal fisheries sub-sector. Motorisation was accompanied by several supporting provisions, such as duty waivers, fuel subsidies, and the creation of financial institutions to fund the sector. The objective was to reduce production (exploitation) costs of the artisanal fishing units to enable them supply the local market with prices commensurate with the incomes of the local population.

The fuel subsidy for artisanal canoes was a determining factor in the modernisation of fishing equipment. It enabled fishermen to use more powerful outboard engines and bigger canoes, and to stay longer at sea, which allowed access to new fishing grounds. There is no doubt that the fuel subsidy had an important impact on the increase in the time spent at sea by hand-line canoes equipped with iceboxes. This contributed to the intensification of fishing effort for demersal fisheries. Maintaining the subsidy under current conditions, where the profitability of fishing units targeting the export market has improved, is no longer justifiable.

These efforts by the countries involved have enabled the sub-sector to be modernised and integrated into the world market. Far from confining itself to simply supplying the local market, new types of artisanal fishing have been developed for export markets (cage fishing, for example). This redeployment of artisanal fishing effort to supply the international market, stimulated by the present administrative set-up, contributed largely to the current state of demersal resources overexploitation. Because the artisanal sub-sector provides raw material (more than 60% in Senegal) for factories, these indirect subsidies also benefit the export operators to the same if not greater extent than local populations.

Overexploitation of demersal resources is likely to worsen, especially since the possibility of reconverting artisanal fishers is limited.

Institutional

There are no fees or requirements that govern entry into artisanal fishing or access to the resource. This free and open access to the resource partly explains the industry's spectacular growth. For example, in Senegal, the artisanal canoe fleet grew from a few hundred units in the 1960s to close to 15 000 canoes today. This sub-sector accounts for more than two-thirds of fisheries production, yet operates without any control on its fishing effort. The free and open access to the fisheries resource has enabled industrial fishers without fishing licenses to have access to the resource by collaborating with or sponsoring artisanal units. Close to 95% of the Senegalese canoe fleet targets coastal demersal species.

Socio-cultural

Generally, the artisanal fishing profession is handed down from father to son. With the particularly high demographic growth rate in fisheries communities, the opportunities for reconversion are very limited and with the economic crisis affecting most countries in the region, the number of artisanal fisheries operators is bound to increase exponentially. As resources are not unlimited, there is the possibility of a biological disruption of several demersal species if the present tendencies are not reversed.

Governance

The artisanal fisheries in the region operate with several different types of gear and target different species at the same time. They operate on a long coastline (Mauritania 745 km and Senegal 531 km) and land on countless fish landing sites (more than 200 in Senegal, about 50 in The Gambia). Confronted with scarce resources in waters under Senegalese jurisdiction, the artisanal fishermen are now found in several coastal countries of the region (The Gambia, Mauritania, Guinea-Bissau). Additionally, as a way to fish all year round, artisanal fishermen have adopted the use of a combination of several types of gear. Because it is a very complex sub-sector, artisanal fishing is faces acute governance problems in its management. The situation is made more difficult by very limited logistical and human resources for the administration of the fisheries.

Political

In all of the countries in the region, recognised Socio-Professional Organisations (SPO) bring together actors in the artisanal fisheries sub-sector. Actors in all areas of activity are involved; fishing, marketing, and artisanal processing of fish products. In Senegal, these organisations have created a federation to better defend their interests. This big lobby of artisanal fishermen through their influential SPO is blocking the institution of an artisanal fishing license system.

Unsustainable fishing practices - Industrial fishing

Economic

A factor accelerating the reduction in species abundance is the discards at sea by industrial freezer trawlers, which retain individuals of acceptable size while rejecting small juvenile fish caught by their nets. These discards, which constitute a waste of precious diminishing resources, pose socio-economic risks as they affect the catch of other fisheries that target these rejected species. Discards also have a significant impact on the equilibrium that exists among the different exploited stocks.

Institutional

Unsustainable fishing practices by the industrial fisheries sector can be attributed to a lack of compliance with fisheries regulations. The presence of observers aboard licensed industrial fishing vessels operating within the framework of fishing agreements ensures compliance with the regulations governing their activities. This is not the case with all Senegalese registered vessels. National vessels commit the majority of recorded infringements, or incursions into reserved zones, mesh-size violations, and the use of unauthorised gear by licensed vessels.

Unsustainable fishing practices - Artisanal fishing

Economic

By offering attractive prices for certain desirable species, hotels encourage the fishing of immature species (small White groupers, young Pink sea breams, lobsters and small-sized locust lobsters). An increase in these activities has been reported as related to tourism in the region. In Senegal, the large demand from fish feed meal factories in Dakar and traders from countries in the Gulf of Guinea also encourage the landing of juvenile fish.

Socio-cultural

Beach seines with nets more than 1 000 m in length represent the gear used by a great percentage of the canoe fleet. Ownership profiles show that these units are in general village-based. Although beach seines play a vital role in production and socio-economic development, they mostly capture juvenile fish and thus seriously threaten the sustainability of the fishery.

Institutional

A lack of enforcement of regulations has enabled certain artisanal operators to resort to illegal fishing techniques (fishing with explosives in Senegal and Mauritania) and gear (mono-filament, nylon nets in almost all states of the region). Such practices are largely responsible for the destruction of marine fauna and flora. It has been unanimously acknowledged that the use of dynamite destroys the rocky zones that are essential breeding grounds for several important species. These nylon nets are non-biodegradable and therefore remain in the sea. A lack of enforcement of the mesh size regulations and the allowed minimal sizes and weights for fish to be landed also exacerbates overexploitation of the resource.

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.

Stream flow modification – Senegal River Basin

Definition of the problem

Stream flow modifications were observed in Senegal River Basin at levels equivalent to what can be seen in other basins of the region. The main consequence is the problem of water resources availability, in terms of quantity or quality.

The major causes of stream flow modification in the Senegal River relate primarily to climatic change, population growth and its implications, problems in implementation of appropriate management, and insufficiencies in technology and financial resources. These causes are summarised as follows:

- Since 1968, the climate of the region has been characterised by decreased and irregular rainfall and thus a reduction in river flow.
- Demographic growth has resulted in pressing demands from water infrastructure installations in order to supply the needs of new development, to assure food security, to create jobs and to guarantee a good livelihood for the populations of the Basin, particularly in urban zones that are subjected to a strong demographic pressure.
- Technologies used are limited or are inappropriate. It is the reason why water resources control and use in the Basin have not been mastered and installations are generally poorly designed. This is due essentially to the insufficiency of financial resources and to the lack of education.
- Constraints related to water resources management are the insufficiency of knowledge and tools for monitoring, the absence of an appropriate institutional setting, the absence of water and environment regulations or their lack of enforcement, and the lack of stakeholder accountability.

Policy options

Different actions can be carried out to face these problems and to ameliorate the impacts of the reduction of freshwater resources in the Senegal River Basin. For each major cause, specific measures and recommendations that have been identified from the previous analysis are described below.

Reduced precipitation

This phenomenon is very complex and its scale exceeds the framework of the Basin, since it has a regional or even a worldwide extent and implications. Its temporal evolution in the region is not well known, as even time series show an alternation of dry and wet periods. However, a predominance of dry years has been observed after 1968, but it would be difficult to conclude with certainty about future climatic trends based on these records. Nevertheless, the persistence of this tendency is worrisome in view of the history of the Sahara Desert, which was once wet and populated. Some Senegal River tributaries such as the Ferlo are not active anymore because of climatic change, which is also the reason behind a general decrease in groundwater recharge.

Taking into account the space and time scale variation of this phenomenon, the actions to be carried out should be implemented within the framework of regional programmes aiming at limiting the negative effects of climate change; soil and water conservation (protecting the existing vegetation cover and reforestation), preventing the use of inappropriate agricultural practices, preventing bush fires, controlling atmospheric pollution, and coming up with a system for environmental impact assessments for all new projects. These programmes should also be accompanied by monitoring of environmental indicators, with scientific research and by environmental education and sensitisation activities.

Demographic aspects

The Senegal River Basin is far from being overpopulated. Certain parts of the Basin such as the Falémé and Ferlo basins are even under-populated. What is needed however, is an appropriate land use planning strategy that would:

- Avoid the population concentration in the irrigated perimeters;
- Avoid the pollution of water resources;
- Better distribute the resource between areas with a surplus of water and others with water deficits;
- Facilitate the access to water in order to avoid the conflicts between users;
- Limit the risks of floods;
- Optimise existing infrastructures.

Feasibility studies and environment impact assessment studies should be realised in a systematic way for all projects in order to identify and to evaluate the risks early on and to carry out the necessary accompanying measures (preventive or curative). The insufficiency of financial resources of the populations and the institutions involved is also one of the major constraints that is linked to demographic aspects. To this end, a better organisation of the trade relationships for agricultural products and a better distribution of wealth (loans, investments in infrastructures) are also essential to fight against poverty in the Basin, to improve the financial resources of populations in order to enable them to get better water-saving technologies.

Water sector technology

The weakness in technology is due primarily to insufficient financial means for intervention. It is also due to the lack of professionalism and the lack of enforcement of regulations. The means for intervention and financial resources could be reinforced by better organisation of trade relationships and a better distribution of wealth. Educating and sensitising the population would make it possible to improve professionalism of different breeders (farmers, fishermen, and technicians) in terms of water-saving technologies, pollution control and the appropriate design of installations. To this end, it is also essential to create a system for feasibility studies as well as environmental impact assessment studies for each planned project.

Agriculture practices such as cultivation after slash-burning and deforestation, bush fires, inefficient irrigation systems and poorly designed drainage systems, and misuse of fertilisers and pesticides should all be banished. Taking into account the increase in water demand, the re-use of treated water is one possible way to increase water resource availability. The Senegal National Sanitation Board (ONAS) produces nearly 10 000 m^3 per day of treated wastewater, which can be made profitable for farm gardening, reforestation and arboriculture. In urban areas, it is essential to improve purification systems to reduce groundwater pollution by nitrates. In the Thiaroye area in Dakar, the nitrate concentration in the aquifer can reach 200 mg/l, which compromises its use as drinking water.

Water governance

Many problems related to the management and the mobilisation of water resources in the Senegal River Basin are in reality due to the lack of good governance. Some examples of this problem are:

- The inefficiency of the actual institutional setting which in general encompasses non-functional structures;
- The absence of democracy or the lack of inclusion of all stakeholders in the design of the projects or in the decision-making process;

- The lack of information dissemination;
- The failure to enforce existing regulations (water and environment laws) or the insufficiency of these regulations;
- The insufficiency of the coordination of existing regulations;
- The insufficiency or the absence of monitoring indicators;
- The insufficiency of education and sensitising policies concerning good agricultural and forest practices, and appropriate water management technologies.

Identified policy options

Addressing these problems will require major changes. Attention should also be paid to the transboundary issues, since water resources in the Basin are shared and the problems are quickly transported elsewhere, whether the proliferation of invasive plants, or the transport of pollutants and water-borne diseases, or other, similar problems that know no boundaries. This demonstrates how essential it is to maintain permanent appropriate institutional organisations such as the Organisation for the Development of the Senegal River Basin (OMVS) and the irrigated domain network of the Management and Exploitation Society for Senegal Delta River (SAED) and to promote and implement the different existing regulations related to water and environmental law in the countries concerned.

Conclusions and recommendations

Senegal River Basin is a good example of how joint programmes can be implemented in the context of a regional institution such as OMVS. The consolidation of OMVS assets is one of the major and immediate options to be pursued, particularly a concerted follow-up and monitoring of the water resources at the basin scale. Institutional instruments such as the Environment Observatory are one possible way to ensure the monitoring and the management of the River Basin. The Standing Committee of Water (Commission Permanente des Eaux, CPE) constitutes a framework for dialogue concerning the technical aspects of water resources management; the committee can formulate and present recommendations for the Ministers' Council. The role of these two bodies (the Environment Observatory and CPE) should be reinforced.

Capacity building in the institutions in charge of water resources management will have to accompany all governance measures, in particular the implementation at the local, national and regional level of the various laws, agreements and regulations (Water Code, Environment Code, Forest Code, Cleansing and Hygiene Code, Charter of the Irrigated Field, OMVS Charter of Water) and the different planning tools at the community level (Local Plan of Development, Plan of Installation and Land Occupation).

Finally, the following concerns must also be addressed:

- Monitoring of different indicators and the inclusion and informing of all stakeholders through dialogue and management committees;
- The creation of a system for feasibility and environmental impacts studies for all projects;
- The reinforcement of financial capacities in both institutions and residents by establishing agricultural credit and equitable sharing of national resources.

Lowering of the water table – Souss-Massa River Basin

Definition of the problem

In many cases, the great expansion of irrigated lands using groundwater has caused the overdraft of aquifer reserves largely beyond their recharge capacity. This process may lead to depletion in the mid-term. Five main root causes for lowering of the water table in the Souss-Massa River Basin were identified:

- Demographic growth and population changes;
- Socio - cultural constraints;
- Governance and enforcement of water regulation;
- Technological changes;
- Economic causes.

The approach aims to create a management system of the aquifer as well as to explore appropriate techniques for its appropriate exploitation. The following analysis considers both supply and demand management, including socio-economic and environmental perspectives. Therefore the process must involve the majority of economic and social agents affected.

The development of management tools, which can harmonise resource exploitation while ensuring sufficient reserve sustainability, must therefore be an objective of any potential policy. The purpose of the policy options are:

- Basin level:
  - Increase agricultural and non-agricultural production.
  - Improve efficiency of water use.
- Local level:
  - Satisfy domestic and industrial needs for water;
  - Provide agriculture with enough irrigation water;
  - Alleviate transaction costs linked to regulation enforcement;
  - Generate a technological change;
  - Shift farmers' behaviour toward more rational water use.

The situation in the Souss-Massa Basin is paradoxal: Water supply decreases and demand for water increases while production intended to increase. Proper socio-economic management can be achieved only if it is founded on a decision making process which takes into consideration the different possible options.

Policy options

Three options for water resource exploitation are presented and ranked from the least feasible to the most workable.

Governmental control

Government agencies collect water and distribute it to users without any charges and the cost are fully supported by the government. The consequences of such a policy are:

- Free water results in poor efficiency in water use;
- A burden on the government budget.

This option is not workable because of scarce financial resources. This policy prevailed in Morocco up until the 1980s within the framework of a planned economy governed by the objective of "food self-sufficiency" mainly for strategic crops, primarily sugarcane and sugar beets, vegetable oil, soft wheat, milk, and meat.

Free market distribution

The free market would be the most efficient way to allocate water resources among users. But water is actually not a good that can be freely traded; instead its trade is ruled by customs and Islamic inheritance practices (i.e. the Moroccan Ulama Malekite school interpretation) and the fact that the rights to most water resources in Morocco belongs to the government. Therefore this setting can be made workable only if the following two-stage scheme is considered:

- Basin level: Government financing; government agencies will take care of environmental issues (erosion, reforestation, pollution prevention)
- Local level: Supply and demand basis: concession approach; a cost and benefits analysis will have to be employed in decision-making.

Holistic approach

The general framework of this scenario assumes a clear understanding of an integrated system (technical, institutional, political and economical settings) and full stakeholder participation through consultation and education (Figure 26). It is only through this participation that benefits from future actions can effectively be transferred from the level at which policies are made down to the people affected by them.

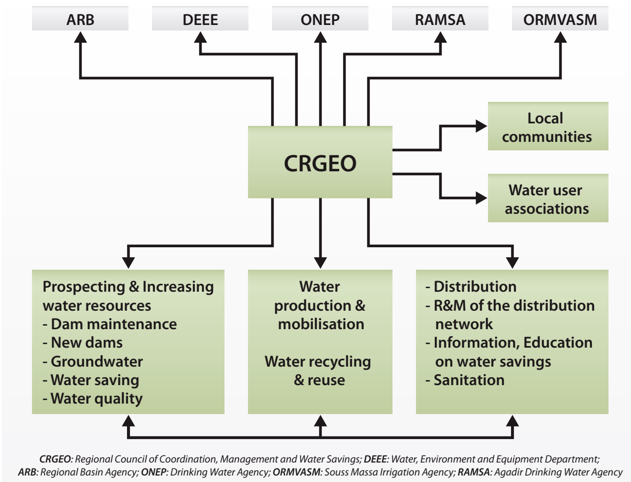

Figure 26 Local water management system in the Souss-Massa River Basin.

The policy option most suitable for the Souss-Massa case is based on:
- The existing water law (1995);
- Existing regulations ("Code des Investissments Agricoles");
- Traditional water rights and local rules.

Given the previous facts, this option is intended to be effective, efficient, equitable and politically feasible.

Economic instruments: Pricing policy

Prior to the 1980s, Morocco employed different pricing policies, ranging from a land betterment levy, volumetric charges, and pumping charges. From 1983, agricultural sector adjustment reforms have been introduced and one of the main concerns is about the impending water shortage and the need for conserving water and managing demand.

The proposed water price for Souss-Massa case should include: (i) private cost (cost of pumping); and (ii) social cost, to partially compensate for the damage caused by overexploiting the aquifer. To make irrigation water use more rational, and to take in to account the root and immediate causes, any pricing policy should embody a component of financial cost (fully or partially) and the social cost (environmental variable). Moreover, the irrigation water charge should be one that is affordable, even by small producers.

Based on the principles listed above and using various techniques to lower transaction costs, this should result in finding "the right price". A volumetric charge and the acreage involved might be two criteria that would give farmers incentives to conserve water.

The GIWA Task team expects this policy to result in:
- Some technological change (more progressive irrigation systems)
- Changes in cropping patterns (the introduction of more value-added crops)

Institutional instruments

Any pricing policy will not work without institutional change. In fact, the institutions, rules and property rights needed for reform already exist, but they are not operating effectively. Moreover, there is no alternative for existing institutions because at this stage, the market cannot allocate water resources based on supply and demand.

Regulation and governance could be the responsibility of para-state agencies that are already established in the region. Their mission would be guided by:
- Governance will be achieved by para-state agencies with autonomous financing status
- Para-state agencies will also have responsibility for education, information and creating awareness about water use and the need for environmental protection.

Identified policy options

The expected results of the recommended policy are as follows:

Effectiveness

An adequate pricing policy will: (i) have an effective impact on non-agricultural water use (rational, not wasteful, water use); (ii) improve water governance and lower transaction costs; and (iii) encourage technological changes (water-saving techniques).

Efficiency

No additional cost is required to implement and enforce the proposed policy and more advantages are associated with this policy (rational water use).

Equity

Price scaling according to acreages and volumetric charges are fundamental techniques for ensuring equity in cost distribution.

Political feasibility

Agreements between stakeholders (users, government agencies, NGO's) could be reached via the existing High Council for Water and Climate at the national level and the Water User Associations at the local level.

Conclusions and recommendations

In the Souss-Massa Basin, even under the best planning conditions, the current rate of water usage is unsustainable if no drastic water policy changes are made. The overpumping of the aquifer has resulted in significant water level declines and by the year 2010, groundwater levels will be sufficiently low in some locations that it may be uneconomical to pump. Some land now under cultivation may have to be abandoned, with an associated loss of agricultural employment.

The lowering of the groundwater table is further complicated by the use of inappropriate well digging technology that is similar to that used by commercial oil prospecting companies. The policies thus far used have failed to give local farming communities the necessary incentives to participate in responsible water management decisions, both from the perspectives of technology use and water pricing.

Furthermore, with the current irrigation systems and practices, there is a little opportunity for change without implementing new policies and mechanisms that encourage adoption of innovative water-saving technologies. The efficient use of water is therefore not adequately addressed in the region, despite the fact that water is a scarce factor in agricultural production and that the groundwater resource is being overused.

The most critical water management issue in the region will be the ability of the River Basin Management Authority to reverse or slow the declining water levels in the aquifer to prevent the cost of pumping water from becoming too excessive for economical crop production. Unless policies are implemented to conserve water, the export economy of the Souss-Massa Basin may decline with severe economic impacts to the region.

For the Souss-Massa region and for Morocco as a whole, ongoing global climate change will have a pervasive influence on the future demand, supply and quality of freshwater resources, and will add pressure to water and environment resources, and coastal systems currently under stress. All sectors of the economy, environment and society may be vulnerable to one degree or another, and measures to increase the capacity to adapt to greater climatic and hydrological variability, including more frequent flood and drought extremes will be required.

Overexploitation of fish – Canary Current

Definition of the problem

Excessive fishing effort

The artisanal fisheries, which account for a large proportion of the fisheries production throughout the region, have always operated outside of the system that controls fishing effort. Free access to the fisheries resources is not without undesirable effects on fishermen, who are faced with problems of overproduction and low prices during periods of glut.

Unsustainable fishing practices

The use of unsustainable fishing methods and gear has significantly exacerbated the overexploitation of resources in most coastal countries of the West African region. The consequences are inter-connected; decreased catches, increased production costs, disruption in supplies to local markets and threats to household food security.

Policy options

Artisanal fishing license system

The current thinking in the region is to explore the possibility of instituting a licensing system for the artisanal fishing units as a way to manage access to the resource. This approach will consist of controlling fishing effort through various components, such as restricting the number of fishing units and their actual fishing capacity and the issuance of restrictive licenses. These licenses would confer fishing rights to license holders only. The benefits of issuing artisanal fishing licenses would be that it would be possible to control fishing capacity and the catches by these fishing units and it would also systematically eliminate excessive fishing capacity.

However, an artisanal fishing license system invariably poses the problem of equity or fairness related to the allocation of the licenses both in the choice of the first beneficiaries (fishermens, canoe owners) and the conditions of issuance (the modalities and duration of licenses, payment of fees etc.). The solution of this problem is critical as artisanal fishing is currently handed from fathers to sons, and it is unlikely that those denied licences will convert to other ways of making a living. Other sectors of the national economy are already being undermined by successive crises, for example, the drought, which affects agriculture, or unfavourable terms of trade affecting other products. Furthermore, fishing remains the only sector open to those who have lost opportunities in the other sectors of the economy.

The feasibility of an artisanal license system poses a number of problems also linked to the availability of certain basic information to determine the optimal number of licenses for canoes, gears and tonnage. A license system also requires people and mechanisms for control and regulation of the system like administrative staff, material and financial resources. The artisanal fisheries sector operates along a several hundred kilometres-long coastline with more than 1 000 landing sites and countless related ancillary service providers. Confronted with declining resources, artisanal fishers have adopted several strategies so they can fish year-round: migration along the coast and a combination of different kinds of fishing gear.

Regulation of access to resources

This method of regulation aims to set the mesh sizes of fishing nets and trawl nets used in the fishery, the minimum authorised sizes and minimum weights of species that could be landed and the prohibition of certain types of fishing such as explosives, drift nets, beach seines and mono-filament (nylon) nets.

Immediate application of this management method could pose a problem of equity. In view of the high investments made by the fishers to equip themselves with monofilament nets, it would be necessary to grant them a grace period to allow them to time to change gear before the strict application of all these regulations.

As far as efficiency is concerned, the proposed regulation would protect juveniles, reduce discards at sea and encourage the catching of bigger individuals of commercial value. Thus, by modifying the selectivity of fishing gear, one modifies the size of fish caught, and thereby the average age at first capture. The individuals protected as a result of this change could then contribute to the recruitment of future stocks. These measures must be accompanied with measures aimed at exercising direct control of fishing, such as a ban on the landing and marketing of species with sizes or weights below certain set limits.

This regulation is already being applied in the Senegalese fisheries and is addressed by a provision in the Fishing Code. The main problem is its efficient application. In Senegal, as in most coastal countries of the region, a lack of enforcement of the fisheries regulations and the control and surveillance of unsustainable fishing methods and practices can be attributed to the lack of adequate human, financial and logistical resources.

Banning use of the beach seine

The ban on the use of the beach seine, enacted by the Gambian Parliament in 1989, could be an example to be emulated in the region. But this measure needs to be carefully assessed before it can be applied in other states such as Senegal, where banning use of the beach seine could have far reaching socio-economic and political implications.

Joint negotiation of fishing agreements

The Sub-Regional Fisheries Commission (SRFC), comprised of seven countries in the West African region, has as its objectives the strengthening of cooperation and coordination of member states by coordinating policies on preservation, conservation and exploitation of marine resources in the region. It also works to develop regional cooperation in the area of fisheries surveillance and to develop the capacity of states to conduct fisheries research at the regional level.

The motivation for the establishment of the SRFC is the fact that several fish stocks are either shared by one or two states or are highly migratory or both. Successful management and sustainable exploitation of such stocks requires regional cooperation by the nations that share these stocks.

The most significant singular initiative of the Sub-Regional Fisheries Commission (SRFC) is the establishment of a mechanism that would enable member states to conduct joint negotiation of fishing agreement with third parties seeking access to fisheries resources of member states. This initiative has not made much progress because of insufficient commitment and political will on the part of member states to see it through.

Figure 27 Tuna fishing boat at sea off the coast of Mauritania.
(Photo: Corbis)

Conclusions and recommendations

A primary initiative is to create a programme to promote the restoration of sensitive and degraded marine habitats by the immersion of artificial reefs. The objective of restoring degraded habitats is the reconstitution of ecosystems to make them favourable for the return and maintenance of species. Stabilisation of the ecosystems will contribute to keeping artisanal fishermen to the areas reserved for them. The promotion of skills and reduction of conflicts between the different fisheries justifies this policy.

In recent years, national and local organisations and institutions in West Africa have been working to promote coastal planning. Several Marine Protected Areas (MPAs) have been established along the coastline by West African states, chiefly by state members of the Subregional Fisheries Commission (CSRP). These areas make it possible to preserve some of the coast's key hot spots which are of crucial importance for the replenishment of fish stocks and biodiversity as a whole.

Coalition of environment and fisheries ministers from West African nations have agreed to establish a network of national and transboundary Marine Protected Areas in the region and restore fisheries to sustainable levels, among other goals. The Regional Strategy for Marine Protected Areas in West Africa aims to allow the harmonisation of protection efforts within five years, based on a shared vision of sustainable development and poverty reduction. It will involve the governments of Cape Verde, The Gambia, Guinea, Guinea-Bissau, Mauritania and Senegal, which signed the Policy Statement in 2003.

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Annexes

Annex I
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Lead author and coordinator			
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Notes: [1] Mhammed Tayaa coordinated all the work and prepared the Scaling and Scoping part as well as the Causal chain and Policy options for the Souss Massa River. With contribution from Tayeb Ameziane and Abdelaziz Sbai in the preparation of the Causal chain and Policy options for the Souss Massa River.

[2] Prepared the Causal chain and Policy options analyses for the marine fisheries. With contributions from Moustapha DEME and Mika Samba DIOP.

[3] Gora Ndiaye prepared the Causal Chain analysis and Policy options of the Streamflow modification of the Senegal River.

Annex II
Detailed scoring tables: Canary Current North

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	1	30	Freshwater shortage	1.5
2. Pollution of existing supplies	1	40		
3. Changes in the water table	2	40		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	30
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	30
Weight average score for Economic impacts		**2.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	1	40
Degree of severity	Minimum – Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	0	20
Weight average score for Health impacts		**0.8**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	1	40
Degree of severity	Minimum – Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	20
Weight average score for Other social and community impacts		**1.0**	

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	0	10	Pollution	1.0
5. Eutrophication	1	40		
6. Chemical	1	20		
7. Suspended solids	2	10		
8. Solid wastes	1	10		
9. Thermal	0	0		
10. Radionuclides	0	0		
11. Spills	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)	1	40
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	20
Weight average score for Economic impacts		**1.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	1	40
Degree of severity	Minimum – Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	20
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	1	40
Degree of severity	Minimum – Severe (0 1 2 3)	1	20
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	40
Weight average score for Other social and community impacts		**1.0**	

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	3	50	Habitat and community modification	2.0
13. Modification of ecosystems or ecotones, including community structure and/or species composition	1	50		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	2
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	1	3
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	3
Weight average score for Economic impacts		**1.6**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	0	40
Degree of severity	Minimum – Severe (0 1 2 3)	0	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	0	20
Weight average score for Health impacts		**0**	
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	40
Degree of severity	Minimum – Severe (0 1 2 3)	0	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	0	20
Weight average score for Other social and community impacts		**0**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	30	Unsustainable exploitation of fish	2.3
15. Excessive by-catch and discards	2	25		
16. Destructive fishing practices	2	20		
17. Decreased viability of stock through pollution and disease	0	0		
18. Impact on biological and genetic diversity	2	25		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	30
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	2	50
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	20
Weight average score for Economic impacts		**2.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	0	30
Degree of severity	Minimum – Severe (0 1 2 3)	0	50
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	0	20
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	2	40
Degree of severity	Minimum – Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	20
Weight average score for Other social and community impacts		**1.6**	

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	70	Global change	0.8
20. Sea level change	1	10		
21. Increased UV-B radiation as a result of ozone depletion	0	10		
22. Changes in ocean CO_2 source/sink function	0	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	40
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Economic impacts		**1.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	40
Degree of severity	Minimum – Severe 0 1 2 3	0	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	20
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Other social and community impacts		**1.0**	

Comparative environmental and socio-economic impacts of each GIWA concern

	Types of impacts									
Concern	**Environmental score**		**Economic score**		**Human health score**		**Social and community score**		**Overall score**	**Rank**
	Present (a)	**Future (b)**	**Present (a)**	**Future (b)**	**Present (a)**	**Future (b)**	**Present (a)**	**Future (b)**		
Freshwater shortage	1.5	3.0	2.0	3.0	0.8	2.0	1.0	2.0	1.9	1
Pollution	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	3
Habitat and community modification	2.0	1.0	1.6	1.0	0	0.0	0	0.0	0.7	5
Unsustainable exploitation of fish and other living resources	2.3	1.0	2.0	1.0	0	2.0	1.6	1.0	1.4	2
Global change	0.8	2.0	1.0	2.0	0	1.0	1.0	1.0	1.1	4

Detailed scoring tables: Canary Current South

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	2	30	Freshwater shortage	1.8
2. Pollution of existing supplies	2	40		
3. Changes in the water table	1	40		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small … Very large (0 1 2 3)	2	30
Degree of impact (cost, output changes etc.)	Minimum … Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short … Continuous (0 1 2 3)	2	30
Weight average score for Economic impacts		**2.0**	
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	40
Frequency/Duration	Occasion/Short … Continuous (0 1 2 3)	3	20
Weight average score for Health impacts		**2.2**	
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)	2	40
Degree of severity	Minimum … Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short … Continuous (0 1 2 3)	1	20
Weight average score for Other social and community impacts		**1.4**	

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	1	10	Pollution	1.8
5. Eutrophication	2	40		
6. Chemical	2	20		
7. Suspended solids	2	10		
8. Solid wastes	2	10		
9. Thermal	0	0		
10. Radionuclides	0	0		
11. Spills	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)	1	40
Degree of impact (cost, output changes etc.)	Minimum … Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short … Continuous (0 1 2 3)	1	20
Weight average score for Economic impacts		**1.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small … Very large (0 1 2 3)	1	40
Degree of severity	Minimum … Severe (0 1 2 3)	1	40
Frequency/Duration	Occasion/Short … Continuous (0 1 2 3)	1	20
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small … Very large (0 1 2 3)	2	40
Degree of severity	Minimum … Severe (0 1 2 3)	1	20
Frequency/Duration	Occasion/Short … Continuous (0 1 2 3)	2	40
Weight average score for Other social and community impacts		**1.8**	

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	3	50	Habitat and community modification	3.0
13. Modification of ecosystems or ecotones, including community structure and/or species composition	3	50		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	40
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	3	40
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	20
Weight average score for Economic impacts		**2.6**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	2	40
Degree of severity	Minimum 0 1 2 3 Severe	2	40
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	20
Weight average score for Health impacts		**1.8**	
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	40
Degree of severity	Minimum 0 1 2 3 Severe	1	40
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	20
Weight average score for Other social and community impacts		**1.0**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	30	Unsustainable exploitation of fish	2.5
15. Excessive by-catch and discards	2	25		
16. Destructive fishing practices	3	20		
17. Decreased viability of stock through pollution and disease	0	0		
18. Impact on biological and genetic diversity	2	25		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	30
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	3	50
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	20
Weight average score for Economic impacts		**2.5**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	1	30
Degree of severity	Minimum 0 1 2 3 Severe	1	50
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	20
Weight average score for Health impacts		**1.2**	
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	3	40
Degree of severity	Minimum 0 1 2 3 Severe	2	40
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	20
Weight average score for Other social and community impacts		**2.4**	

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	70	Global change	0.8
20. Sea level change	1	10		
21. Increased UV-B radiation as a result of ozone depletion	0	10		
22. Changes in ocean CO_2 source/sink function	0	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	40
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Economic impacts		**1.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight average score for Other social and community impacts		**1.0**	

Comparative environmental and socio-economic impacts of each GIWA concern

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	1.8	3.0	2.0	3.0	2.2	3.0	1.0	2.0	2.3	1
Pollution	1.8	3.0	1.0	2.0	1.0	2.0	1.8	3.0	2.0	4
Habitat and community modification	3.0	2.0	2.6	2.0	1.8	1.0	1.0	1.0	1.8	3
Unsustainable exploitation of fish and other living resources	2.5	1.0	2.5	2.0	1.2	1.0	2.4	2.0	1.8	2
Global change	0.8	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.5	5

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Canary 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.

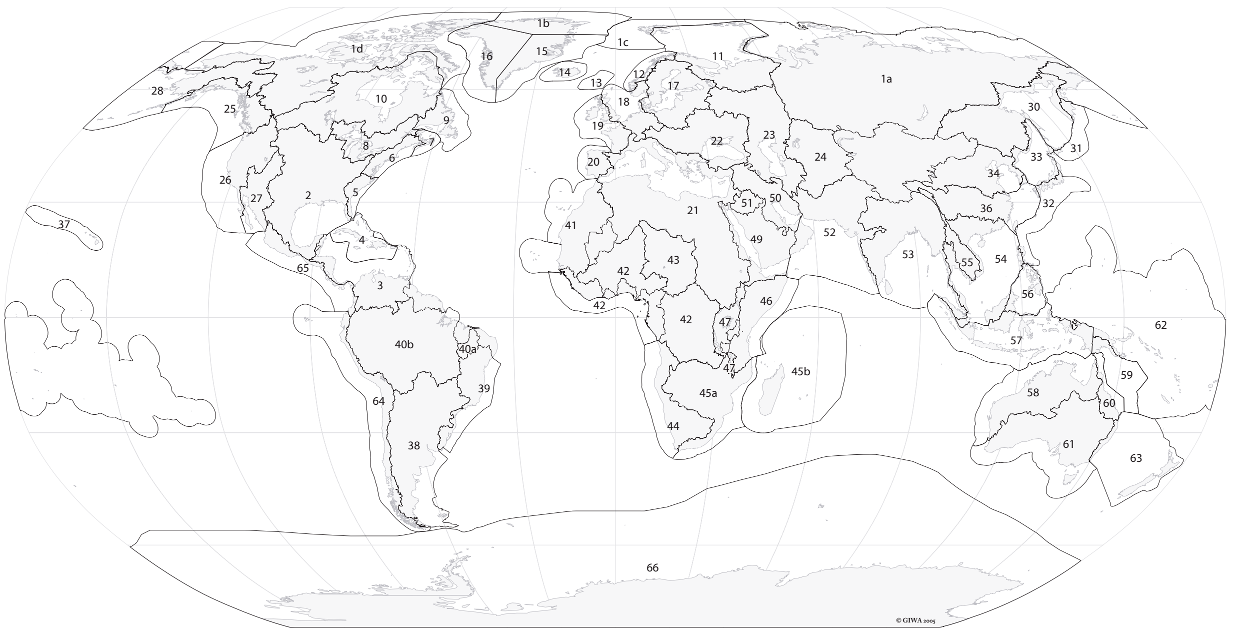
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and 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)



1a Russian Arctic (4 LMEs)
1b Arctic Greenland (LME)
1c Arctic European/Atlantic
1d Arctic North American
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands (LME)
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 Sea (LME)
21 North Africa and Nile River Basin (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 Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan (LME)
34 Yellow Sea (LME)
36 East China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Northeast Brazil Shelf (2 LMEs)
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
49 Red Sea and Gulf of Aden (LME)
50 Euphrates and Tigris River Basin
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal
54 South China Sea (2 LMEs)
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 Pacific Islands
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific (LME)
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).

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.

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.

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

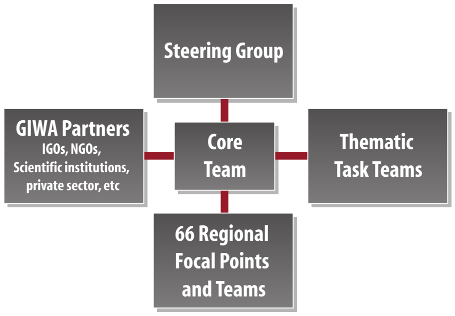


Figure 2 The organisation of the GIWA project.

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.

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**

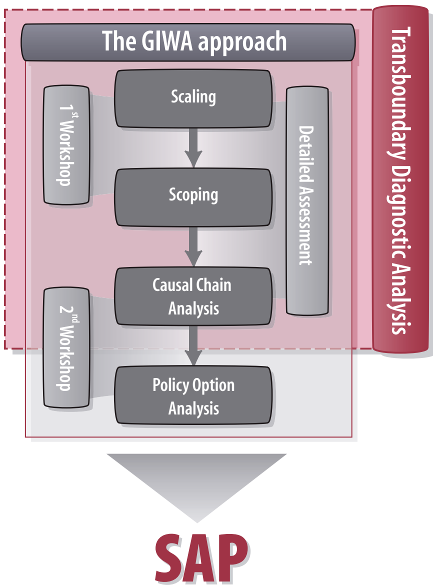

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

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.

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 Canary Current region, which covers the Canary Current Large Marine Ecosystem and the river systems draining into it. The region has several drainage systems of both national and international significance and are exploited for crop and livestock development, rural as well as urban domestic water needs and industrial development. The environmental impacts of stream flow modification and changes in the water table have led to serious socio-economic impacts that often have significant transboundary implications. Overexploitation of living resources in the marine waters is another major issue in the region and most of the coastal countries in the region have already taken steps in terms of regulating fisheries at national and international level. The root causes of freshwater shortage in the Senegal River and Souss-Massa River basins as well as for the overexploitation issues in the marine part of the region are identified and potential remedial policy options are presented.

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