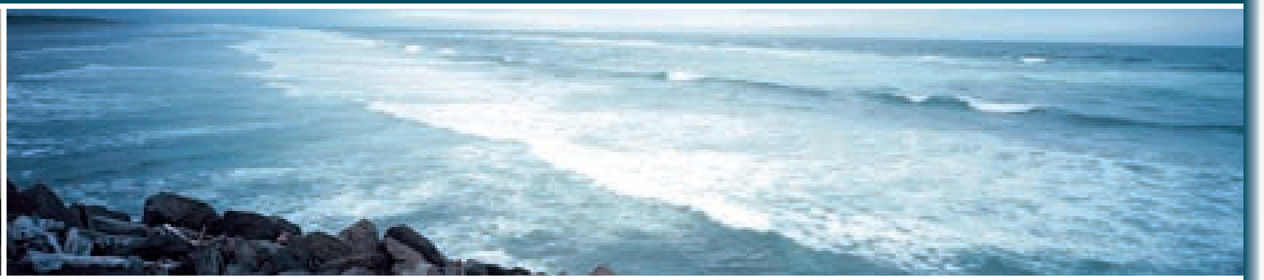
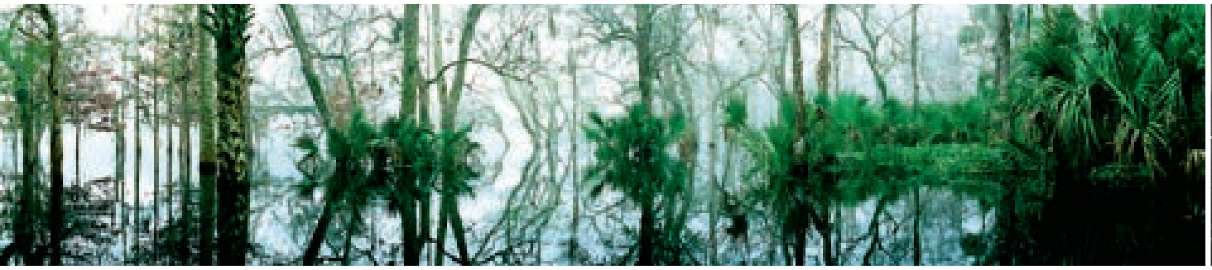
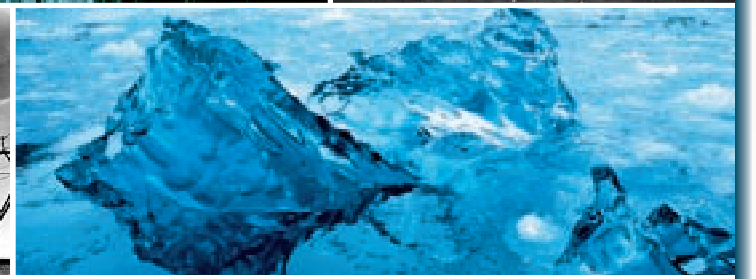
GLOBAL INTERNATIONAL
WATERS ASSESSMENT

UNEP GEF HÖGSKOLAN KALMAR UNIVERSITY FORMIN.FINLAND.FI MINISTRY FOR FOREIGN AFFAIRS OF FINLAND





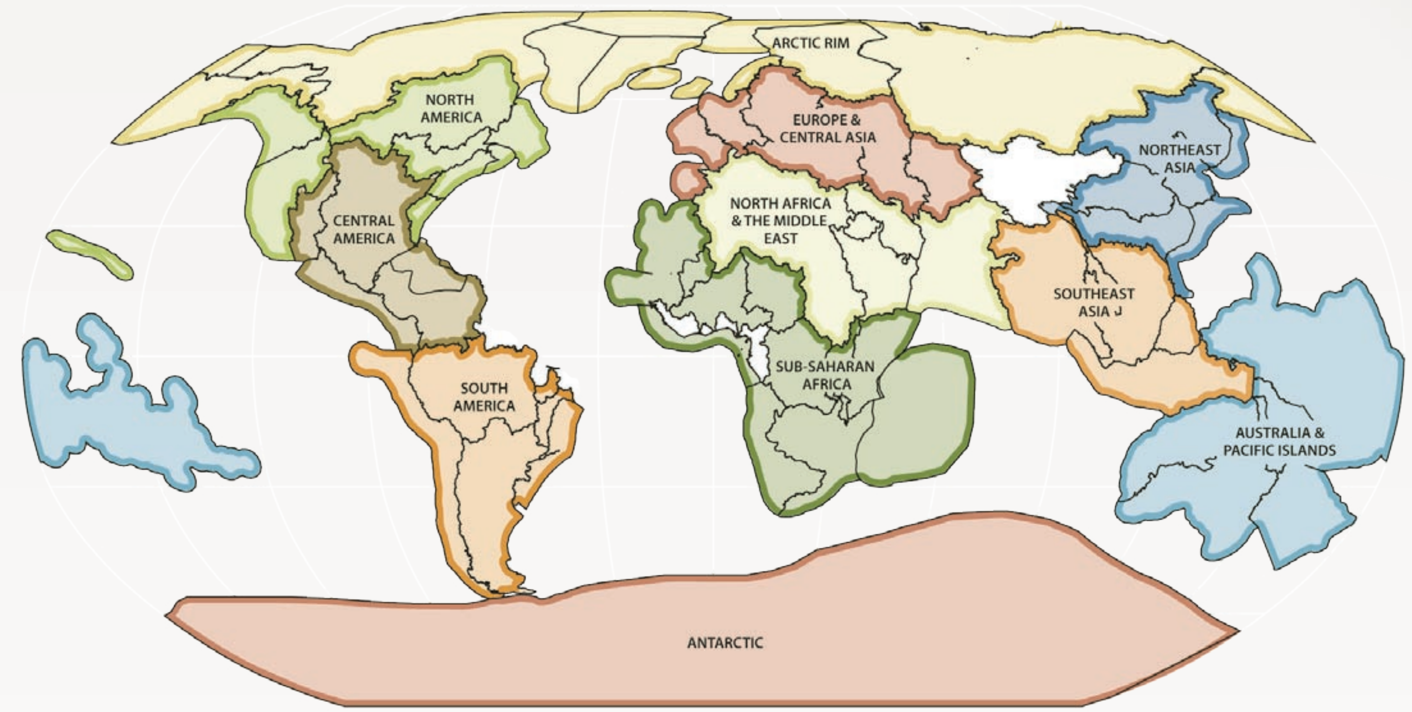
Challenges to International Waters

Regional Assessments in a Global Perspective

THE GIWA FINAL REPORT

MAP: GIWA REGIONS AND SUB-SYSTEMS

GIWA MEGA REGIONS



AREA SHADING BY MEGA REGION

Arctic Rim
1a Russian Arctic*
1b Arctic Greenland*
1c Arctic European/Atlantic
1d Arctic North American
11 Barents Sea*
12 Norwegian Sea
13 Faroe Plateau*
14 Iceland Shelf
15 East Greenland Shelf*
16 West Greenland Shelf*
28a Bering Sea (West Bering Sea)*
28b Bering Sea (East Bering Sea)*

Europe & Central Asia
17 Baltic Sea*
18 North Sea
19 Celtic-Biscay Shelf
20 Iberian Coastal Sea
22 Black Sea*
23 Caspian Sea*
24 Aral Sea*

North America
5 Southeast Shelf
6 Northeast Shelf
7 Scotian Shelf
8 Gulf of St Lawrence
9 Newfoundland Shelf
10 Baffin Bay, Labrador Sea, Canadian Archipelago
25 Gulf of Alaska
26 California Current
37 Hawaiian Archipelago

Central America
2a Gulf of Mexico (Mississippi River)*
2b Gulf of Mexico (Rio Grande/Rio Bravo)*
2c Gulf of Mexico (Usumacinta/Grijalva)*
2d Gulf of Mexico (Rio Hondo/Chetumal Bay)*
3a Caribbean Sea (Small Islands)*
3b Caribbean Sea (Orinoco/Magdalena/Catatumbo)*
3c Caribbean Sea (Central America/Mexico)*
4 Caribbean Islands*
27 Gulf of California*
65a Eastern Equatorial Pacific (Southwest Mexico)*
65b Eastern Equatorial Pacific (Central Equatorial Pacific)*
65c Eastern Equatorial Pacific (Pacific Colombian)*

South America
38a Patagonian Shelf (La Plata River Basin)*
38b Patagonian Shelf (South Atlantic Drainage System)*
39a Brazil Current (South/Southeast Atlantic Basins)*
39b Brazil Current (East Atlantic Basins)*
39c Brazil Current (São Francisco River Basin)*
40a Northeast Brazil Shelf*
40b Amazon*
64 Humboldt Current*

Sub-Saharan Africa
41a Canary Current (North)*
41b Canary Current (South)*
42a Guinea Current (Comoe Basin)*
42b Guinea Current (Volta Basin)*
42c Guinea Current (Niger Basin)*
42d Guinea Current (Congo Basin)*
42e Guinea Current LME*
43 Lake Chad*
44 Benguela Current*
45a Agulhas Current
45b Indian Ocean Islands*
46a Somali Coastal Current (Juba/Shebelle)*
46b Somali Coastal Current (Tana/Athi/Sabaki)*
46c Somali Coastal Current (Wami/Ruvu/Pangani)*
46d Somali Coastal Current (Rufiji/Ruvuma)*
46e Somali Coastal Current (Lake Jipe/Chala)*
47a East African Rift Valley Lakes (Lake Turkana)*
47b East African Rift Valley Lakes (Lake Victoria)*
47c East African Rift Valley Lakes (Lake Tanganyika)*
47d East African Rift Valley Lakes (Lake Malawi)*

North Africa & Middle East
21 North Africa and Nile River Basin
49 Red Sea and Gulf of Aden
50 Euphrates and Tigris River Basin
51 Jordan*
52 Arabian Sea

Northeast Asia
30 Sea of Okhotsk*
31 Oyashio Current*
32 Kuroshio Current
33 Sea of Japan*
34a Yellow Sea (Yellow Sea)*
34b Yellow Sea (Bohai Sea)*
36 East China Sea*

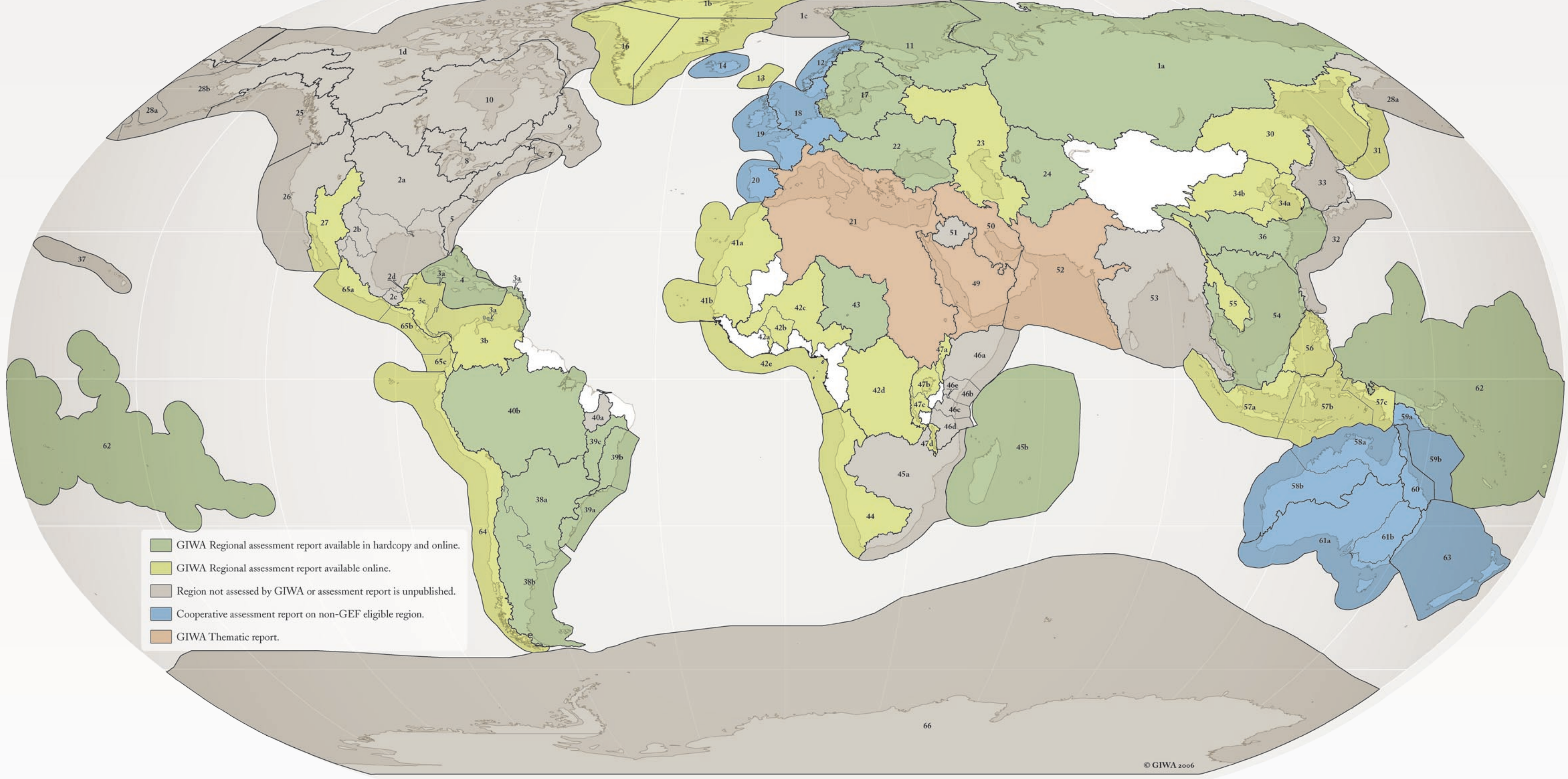
Southeast Asia
53 Bay of Bengal*
54 South China Sea*
55 Mekong River*
56 Sulu-Celebes Sea*
57a Indonesian Seas (Sunda)*
57b Indonesian Seas (Wallacea)*
57c Indonesian Seas (Sahul)*

Australia & Pacific Islands
58a North Australian Shelf (Wet Tropics)*
58b North Australian Shelf (Dry Tropics)*
59a Coral Sea Basin (South PNG and Papua)*
59b Coral Sea Basin (Coral Sea)*
60 Great Barrier Reef*
61a Great Australian Bight*
61b Great Australian Bight (Muray Darling Basin)*
62 Pacific Islands*
63 Tasman Sea*

Antarctic
66 Antarctic

* Assessed by GIWA.

GIWA REGIONS AND SUB-SYSTEMS



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Global International Waters Assessment
Challenges to International Waters – Regional Assessments in a Global Perspective

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To obtain copies of this publication or further information, please contact:

Division of Early Warning and Assessment
United Nations Environment Programme
PO Box 30552
Nairobi 00100, Kenya
Tel: +254 20 762-4299
Fax: +254 20 762-4269
Email: dewainfo@unep.org

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Contents

Preface

Clean water and the many products and services of aquatic ecosystems are necessities for human welfare. Water connects human societies and ecological systems by providing food and energy. The hydrological cycle maintains the health and stimulates the productivity and diversity of all ecosystems.

Wherever rivers, lakes and aquifers, as well as coastal current systems and marine fish stocks, are shared by two or more nations, these transboundary resources are interlinked by a complex web of environmental, political, economic and security interdependencies. Throughout history, while water has generally been shared peacefully, competition for scarce water resources can invoke conflict between nations sharing international waters. Today, global trade, migration and tourism, as well as global climate change, have created worldwide dimensions to many water related issues.

Over the past 20 years, the international community has increasingly recognised and asserted the urgent need for concerted actions to reverse the negative societal trends that adversely affect the world's aquatic systems and to achieve sustainability in the use of water resources.

Short-term commercial interests are often prioritised over long-term sustainable development. This is due to the false assumption that environmental protection and sustainability can only be achieved at the expense of economic development and social well-being. On the contrary, by investing in environmental improvements significant economic returns can be achieved through, for example, increased ecosystem and resource productivity, improvements in public health and poverty alleviation. Sustainable development is only possible by enhancing environmental management.

Achieving sustainability in international waters requires the development and implementation of practical policies within an ecosystem-based management framework, including the following components:

- Political and societal commitments to tackle water-related challenges in a concerted and cooperative manner;
- Sound scientific assessments of the current state of all freshwater and coastal marine resources and their aquatic ecosystems;
- Informed dialogue between governments, stakeholders and experts, based on the assessments;
- Technological support and capacity enhancement; and
- Adequate financing for projects and programmes related to water resources and aquatic ecosystems.

In recognition of these needs, UNEP has implemented the Global International Waters Assessment (GIWA) project, funded by the Global Environment Facility (GEF) and by national donors, in particular Nordic countries. GIWA is a holistic and globally comparable assessment of the world's transboundary waters, based on the recognition that inextricable links exist between the freshwater and coastal marine environment. GIWA integrates environmental and socio-economic information to determine the impacts of a broad range of influences on the world's aquatic environment. A global perspective of the world's transboundary waters was achieved by conducting regional assessments in many of the major international drainage basins and marine shelf ecosystems. The project focused on developing regions, regions with economies in transition and small island states eligible for funding by the GEF. GIWA identifies the priority concerns of each region, determines their societal root causes and, in most regions, considers options to resolve or mitigate these causes.

In addition to GIWA regional assessment reports, the project developed a new assessment methodology and adopted a bottom-up approach involving multidisciplinary regional teams. About 1 500 experts from around the world conducted the assessments in collaboration with the GIWA Core team, hosted by the University of Kalmar, Sweden. The GIWA approach can serve as a platform for further assessments and for the surveillance of aquatic systems.

This GIWA Final Report provides a global synthesis of the GIWA regional assessments. The multitude of aquatic transboundary environmental problems are discussed under the concerns of freshwater shortage, pollution, overfishing and habitat modification. The report summarises the current and predicts the future state of transboundary water resources and associated aquatic ecosystems, the societal root causes and driving forces that engender adverse environmental pressures, and the causal relationships that underpin the deterioration of aquatic environments and their resources. The report identifies gaps in knowledge and presents conclusions relevant to the sustainable management of transboundary waters. This final report of the GIWA project, includes annexes describing the GIWA methodology and its theoretical background. It also acknowledges the regional teams, focal points and core team who have contributed considerable effort towards this global assessment.

Policy makers at all levels of government, global and regional non-governmental organisations, and other stakeholders involved in the use, development and management of transboundary water basins and their aquatic resources will find the results of this global synthesis invaluable.

It is my hope that "Challenges to International Waters – Regional Assessments in a Global Perspective" will assist in the development of a roadmap to environmental sustainability and will inspire actions necessary to overcome the global challenges to aquatic resources and ecosystems.

Klaus Toepfer
United Nations Under-Secretary General and
Executive Director, United Nations Environment Programme

Executive summary

The Global International Waters Assessment (GIWA) project is a holistic and globally comparable assessment of transboundary aquatic resources in the majority of the world's international river basins and their adjacent seas, particularly in developing regions. A bottom-up and multidisciplinary approach was adopted that involved nearly 1 500 natural and social scientists from around the world. The GIWA project provides strategic guidance to the Global Environment Facility (GEF) by identifying priorities for remedial and mitigatory actions in international waters.

The present Final Report presents the major results and findings of the GIWA regional assessments.

On a global scale, GIWA has confirmed that pressures from human activities have weakened the ability of aquatic ecosystems to perform essential functions, which is compromising human well-being and sustainable development. The complex interactions between mankind and aquatic resources were studied within four specific major concerns: freshwater shortage, pollution, overfishing and habitat modification. Global change is considered as a fifth concern which overarches the other four. It is clear that the five GIWA transboundary concerns are serious worldwide problems that are expected to increase in severity by 2020.

Pollution

Transboundary pollution has a moderate or severe impact in more GIWA regions than any other concern, and also has by far the gravest impact on human health. Pollution is mainly concentrated in inland and nearshore systems. The most critical transboundary pollution issue is suspended solids, causing the greatest impact in Latin America, Southeast Asia and Sub-Saharan Africa. Large-scale land-use changes, including infrastructure development, deforestation and agriculture, have increased the sediment load of international waters.

Eutrophication has its most severe transboundary impacts in Europe & Central Asia and Northeast Asia. Agricultural run-off was identified as the primary cause, but the tremendous growth of aquaculture in several East Asian regions has also become a factor. Oxygen-depleted zones, an extreme result of eutrophication, are now present not only in enclosed seas, such as the Baltic Sea and the Black Sea, but also in large coastal areas which have internationally important fisheries. Globally, harmful algal blooms are considerably more widespread and frequent than they were a decade ago, a situation that is expected to further deteriorate by 2020 due to the increased application of agricultural fertilizers, especially in Asia and Africa.

TABLE 1. TOP PRIORITY FOR THE GIWA CONCERNS BY MEGA REGION

Mega region	Arctic Rim	Europe & Central Asia	Central America	South America	Sub-Saharan Africa	North Africa & Middle East	Northeast Asia	Southeast Asia	Australia & Pacific Islands
Number of regions and sub-systems assessed	9	4	12	8	19	3	6	7	9
Freshwater shortage	0	1	5	1	9	3	2	1	3
Pollution	3	2	3	2	5	0	1	1	3
Overfishing and other threats to aquatic living resources	2	0	1	2	3	0	2	4	3
Habitat and community modification	1	1	1	4	3	0	3	2	2
Global change	3	0	2	0	0	0	1	0	1

Microbial pollution is of particular concern in the freshwater ecosystems of tropical developing countries, but is also widespread in Large Marine Ecosystems (LMEs) with densely populated coasts. Microbial pollution is projected to increase due to population growth and urbanisation outpacing the provision of sewage treatment facilities.

Chemical pollution is also an issue of global importance, inflicting moderate to severe impacts in more than half of the regions assessed.

Overall, pollution is slight to moderate in most of the LMEs, with severe pollution limited to localised hotspots usually found in close proximity to point sources of pollution, such as sewage and industrial effluent outfalls and river mouths, as well as in areas with limited water circulation, such as semi-enclosed bays. Sea-based pollution is most prevalent in LMEs with a high concentration of oil and gas industries, and shipping activities.

Freshwater shortage

The overabstraction of water resources is resulting in the drying up of rivers, lakes and aquifers, leading to water shortages in many GIWA regions. For Sub-Saharan Africa, it is undoubtedly the top priority.

In arid regions, in particular, water diversions lead to significant reductions in crucial low flow periods. The regulation of stream flow by reservoirs changes natural water regimes. In many GIWA regions these changes adversely affect the productivity of downstream wetland ecosystems and subsequently the provision of their goods and services. The reduction in water inflow to enclosed water bodies can dramatically alter their ecosystems. For example, in the Aral Sea/24, water abstraction has reduced the volume of the sea by 60%.

The overexploitation of water resources and changes in river basin hydrodynamics are largely attributed to the agricultural sector, principally as a result of water impoundment by dams and groundwater abstraction for irrigation, deforestation and drainage of wetlands to expand agricultural areas and inappropriate agricultural land-use practices. About 70% of all abstracted water is utilised by irrigated agriculture, and since many developing countries expect agriculture to be the main sector driving economic growth, water scarcity is likely to become an even greater problem in the future. Regions experiencing freshwater scarcity often also face severe pollution, further intensifying water stress.

Salinisation was revealed by the regional assessments to be more widespread and severe than is generally perceived. Reduced stream flow, inappropriate irrigation practices and overabstraction of groundwater have increased the salinity of freshwater throughout the world. As a result, agricultural land is becoming too saline to support important crops, and salinisation has made many aquifers unsuitable as a source of water for drinking and certain economic purposes.

In arid and semi-arid areas, water shortages are predicted to be the most significant constraint for socio-economic development. Global climate change will only exacerbate this problem. The most frequent socio-economic impacts resulting from freshwater shortages are the displacement of people, declines in fisheries production and reduced supply of potable water.

The progress being made to meet the Millennium Development Goal (MDG) of halving the proportion of people without access to safe drinking water and basic sanitation by 2015 is a critical freshwater indicator. With 83% of the world's population having access to safe water, the international community, overall, is on track to meet the drinking water goal, with East Asia making the greatest progress. The MDG sanitation target is less likely to be achieved, with Sub-Saharan Africa and South Asia making the least progress.

Overfishing and other threats to aquatic living resources

Overexploitation of living resources was assessed as severe in more GIWA regions than any other GIWA issue. On a transboundary scale, large commercial fishing fleets are the major contributors to the problem, exploiting specific transboundary straddling and migratory stocks. However, the majority of fisheries in LMEs assessed by GIWA, especially in the tropics, are artisanal. They mostly operate on a geographically restricted scale, overexploiting many easily accessible nearshore species. A common environmental impact from overfishing is 'fishing down the food web', whereby fishers exhaust large predator populations, distorting the food web and forcing fishers to target smaller, less valuable species.

The environmental impacts of destructive fishing practices, including blast and poison fishing as well as bottom trawling in sensitive areas, are severe in most parts of the world. The issue of excessive by-catch and discards is most critical in Southeast Asia and South America. Discards represent an extraordinary waste of protein resources, with up to 90% of catches taken by shrimp trawlers thrown overboard.

With more than 200 million people relying on fisheries for their livelihood and over 1 billion people depending on fisheries for their protein supply, the world cannot achieve the MDG of hunger eradication without improving fisheries management. Inadequate fisheries statistics hamper reliable stock assessments and prevent effective fisheries management, particularly in developing regions. The socio-economic impacts of fisheries mismanagement are dramatic. The overexploitation of artisanal fisheries has the most detrimental social impacts, as the communities that depend on these fisheries frequently have no alternative livelihoods, and malnutrition often follows.

Aquaculture, which has been expanding rapidly for more than a decade, will supply an ever-increasing share of the global fish market. The question remains whether aquaculture will be undertaken in a sustainable manner. The GIWA assessments from Southeast Asia indicate otherwise; hundreds of thousands of hectares of mangrove forest have been converted to fishponds since 1990.

Overexploitation of fish is generally expected to intensify as a result of human population growth and an increasing demand for seafood, coupled with a continued lack of implementation and enforcement of regulations. On the other hand, the situation in some regions studied by GIWA, particularly in Northeast Asia and Central America, is expected to improve by 2020 due to the development and adoption of more sustainable fisheries practices.

Habitat and community modification

The world's aquatic habitats have been extensively modified, particularly on land, with a consequential reduction in biodiversity and an alteration of community structures in many regions throughout the world. Hydropower, drinking water, irrigation and flood mitigation are the major benefits of dams and other structures that modify stream flow. This water infrastructure, however, is the single largest driver of habitat modification in the world's rivers and a major factor affecting lake habitats. For example, in the Euphrates and Tigris River Basin/50 more than 50% of the Mesopotamian wetlands have dried out as a result of upstream water impoundment. The damming of rivers can also decrease sediment transport to estuaries, leading to additional coastal erosion and reduced productivity in marine ecosystems.

Land-use change (mainly the conversion of forests and wetlands to agricultural land) and the introduction of invasive species are the other major modifiers of freshwater habitats. Alien species are known to have impacted the structure of both marine and freshwater communities in almost half of the GIWA regions, but many more remain undetected.

In Southeast Asia, coral reefs have been seriously degraded by destructive fishing practices and coastal land reclamation. Mangrove forests are threatened by increased demand for timber, coastal development and aquaculture in Central America (the Caribbean), South America, Southeast Asia and Sub-Saharan Africa. The rate of mangrove destruction exceeds even that of tropical rainforests.

Modification of habitats is particularly severe in tropical LMEs, especially in Central America, East Africa and Southeast Asia. Direct conversion of habitats for urban and industrial development, mariculture, dredging, unsustainable harvesting, poor land use practices in adjacent drainage basins, and pollution are among the major causes of coastal and marine habitat modification. Transboundary effects are not uncommon, particularly if the habitats are nursery and spawning grounds for commercially important migratory fishes, marine mammals and birds.

Focusing on the critical tropical habitat of coral reefs, the GIWA regional assessments found degradation in all the tropical LMEs. Climate change, particularly increasing sea surface temperatures causing coral bleaching, has emerged as potentially the greatest single threat to coral reefs.

Habitat and community modification was most frequently identified as the priority concern in Northeast Asia and South America. Socio-economic impacts included loss of fisheries and tourism revenues, greater unemployment, and the costs of mitigation and treatment actions, e.g. water treatment and control of invasive species.

Linkages between the GIWA concerns including global change

The GIWA regional reports frequently note the negative synergies between the concerns, including global change. Considering the close links between many of the GIWA issues, habitat and community modification could often be considered a 'downstream' consequence of the impacts of the other GIWA concerns. Frequently, freshwater habitats are radically altered by changes in stream flow and nutrient transport resulting from the construction of dams and other structures. In marine areas, overfishing has changed food webs and destructive fishing has destroyed coastal habitats of high productivity and biodiversity. Pollution, mainly from agricultural run-off, industrial effluents and domestic wastes, impacts both freshwater and marine systems.

Linkages are present in most regions and aquatic systems. In Lake Victoria the introduction of Nile perch (*Lates niloticus)*, in combination with eutrophication and unsustainable fishing, has led to the extinction of several hundred species of cichlid fish, the largest recorded vertebrate extinction. On a broader scale, suspended solids, eutrophication, overexploitation and destructive fishing practices are degrading seagrasses and coral habitats in tropical marine regions. The socio-economic impacts from these negative synergies often spiral into increasing local poverty, declining health standards and growing conflict.

Recent mass coral bleaching events related to the El Niño Southern Oscillation are the most dramatic example of climate change affecting a specific type of ecosystem on a global scale. In future climate change scenarios, highly productive fisheries associated with climate mode-driven upwelling are at serious risk. At the regional level, freshwater availability will be affected by climate-induced changes to precipitation patterns, increasing in some regions, such as Southeast Asia, and decreasing in others, such as the subtropics. Higher temperatures will result in greater evaporation rates, thus threatening freshwater supplies and triggering additional droughts in arid and semi-arid regions. Furthermore, climate change is expected to intensify the effects of pollution, including an increase in the size and duration of oxygen-depleted zones. Rising sea levels are anticipated to increase saline intrusion in coastal aquifers and cause saltwater to reach further upstream in rivers. These expected changes are driven by major alterations in the global hydrological cycle, and may have severe impacts on human well-being. While few GIWA regional teams identified global change as their top priority at present, the majority predicted that this concern would become more serious by 2020.

Root causes

Population growth

Population growth is an important root cause of all water-related concerns. The world's growing population is increasing water stress. In Africa, for example, even though water consumption per capita is low, population growth, in combination with inadequate water and wastewater infrastructure, often leads to water shortages. From a consumption perspective, rising income levels are expected to increase fish consumption at nearly twice the rate of population growth in Asia.

Agricultural development and economic growth

GIWA regional teams identified expansion in the agricultural sector, and in particular irrigation, as the most significant cause of the transboundary concerns of freshwater shortage, pollution, overfishing and habitat modification. The environmental impacts associated with agriculture include eutrophication stimulated by fertilizer run-off, suspended solids from increased erosion following forest colonisation, and stream flow modification to provide water for irrigation. Globally, there has been an increased demand for agricultural products and a trend towards more water-intensive food, such as meat rather than vegetables, and fruits rather than cereals. Many developing countries also see the development of agriculture as the main engine for economic growth.

With nearly one-third of agricultural water used to produce export crops, trade is a critical factor. Several GIWA regional reports from Sub-Saharan Africa note that trade has increased the production of water-demanding crops, putting additional stress on water resources and the environment.

It is clear that irrigation will continue to expand, underscoring the need to increase efficiencies in water use and develop new approaches to demand management. The concept of virtual water may be an important tool for understanding and mitigating the impact of trade on water resources.

Water management policies have traditionally focused on water supply and ignored demand management. The freshwater shortages experienced in rapidly developing regions, such as Southeast Asia, illustrate the need to prevent water demand from growing in lockstep with economic development.

Lack of knowledge and public awareness

Detailed knowledge of resource stocks and yields, as well as demand patterns, is often deficient, particularly in developing countries. Aquifers represent the largest information gap, which is an increasingly significant hindrance for effective water management given the growing dependence on groundwater.

The dynamics of fish populations, especially in developing countries, are frequently unknown. In the industrial fisheries sector, inaccurate information, in combination with political and societal pressure to maintain fishing effort, has led to overexploitation and the collapse of many fisheries.

Public awareness of environmental problems is rather rudimentary at all levels of society in most developing regions as well as in many developed countries. Education and consumer information are required everywhere, from rural to urban communities and from primary schools to universities. The GIWA regional teams also highlighted the need for far broader multi-disciplinary, institutional and public/private sector communication in the management of international waters. The strengthening of professional capacity is important, not only for research and teaching but also for policy making and management.

Market failures

Throughout the world, most production inputs are underpriced compared with their full social and environmental costs. An egregious example is blast fishing, where the investment of one dollar for dynamite can generate an immediate 200-fold return for the local fishermen, but leaves a devastated reef that takes 50 years to recover. While developed countries have made some progress in reducing input subsidies, both developed and developing countries still commonly offer large subsidies on, for example, electricity, fuel, pesticides, fisheries and infrastructure. Political will to reduce inappropriate subsidies often fails in the face of potential job losses, lobbying by industry, and corruption.

Historically, water was regarded as an infinite and free resource; consequently, water is commonly underpriced in many GIWA regions, particularly in the agricultural sector, encouraging waste and discouraging infrastructure investment. Ecosystem goods and services are insufficiently valuated or considered when formulating development strategies. Many regional reports note that a key to improving management is to stop focusing only on the direct economic benefits of engineered structures, and to evaluate their long-term environmental, economic and social benefits and costs.

It is the very nature of common pool resources, such as the fisheries, that it is difficult to exclude newcomers, who have no knowledge of the resource they seek to exploit. A vicious spiral can begin, where increasing numbers of fishers chase smaller fish populations. To boost their meagre catches, these fishers frequently adopt destructive fishing practices, putting further pressure on beleaguered fisheries, and ultimately reducing household income, nutrition and health levels.

Policy failures

Policy failures commonly result from the inability of institutions to perform three key functions: (i) recognise signals of a problem and agree on its nature; (ii) reach agreements that balance the interests of stakeholders both within and in other countries; and (iii) implement and enforce these agreements.

The first function is hindered by knowledge deficiencies regarding aquatic resources and a lack of public awareness of their impact on aquatic ecosystems. Common indicators are needed to monitor the state of ecosystems and their interactions with human activities. International cooperation is constrained in many regions by the fact that politicians and other leaders do not even recognise aquatic systems and resources as being transboundary.

Even when reliable information is available, environmental considerations or broad stakeholder involvement are often disregarded in the decision-making process. Institutions responsible for specific sectors, such as fisheries, agriculture or transportation, generally dismiss concerns that transcend their limited sectoral goals.

Within most parts of the world, regional initiatives aimed at improving environmental management have been developed. These include the ratification of a number of international environmental conventions and the adoption of several non-binding frameworks. However, implementation and enforcement of agreements frequently fail due to: (i) weak human and financial resources; (ii) a lack of political commitment; (iii) weak institutional frameworks; (iv) inadequate information; (v) corruption; and, to a lesser extent, (vi) inappropriate regulations.

Given the difficulty in reaching and implementing agreements at the national level it is not surprising that efforts to establish transboundary policies, let alone management, remains an elusive goal in most regions. Weak international and regional commissions are testament to this fact, but there are success stories in both developed and developing regions, notably in fishery regulations and in water management in several major river systems.

Response options

The United Nations Convention on the Law of the Non-navigational Uses of International Watercourses provides a framework for intergovernmental river basin agreements. Although there have been positive developments in recent decades, only one third of the world's transboundary basins have established treaties, basin commissions or other forms of cooperative management frameworks. Even where intergovernmental agreements exist, they seldom address today's challenges to water management.

Policy options cannot be confined to actions that target natural and physical processes but should consider the human dimensions of water use as well. Policy measures must therefore be formulated to address the local situation. At the same time, it remains important to develop broad themes for devising policies and basin-wide management for the sustainable use of transboundary rivers.

First and foremost, it is necessary to reduce the impacts of water scarcity and habitat degradation by developing international governance frameworks for equitable water allocation in accordance with the above-mentioned Convention. Disputes and conflicts over water use can only be resolved through common strategies and commitments between upstream and downstream countries. An integrated approach linking water management to land management and economic management is also needed.

Improved policies and pricing, particularly for achieving increased user efficiency and socio-economic benefits, need to be implemented gradually, but these changes will vary widely on a regional rather than on a national scale. To implement such policies it is necessary to raise both public and political awareness of the importance of addressing water concerns and the associated socio-economic impacts. Such initiatives must be based on sound knowledge and multidisciplinary efforts, like GIWA, where the natural and the social sciences are united in a joint endeavour.

In the marine environment, the fishing industry overexploits the majority of living resources and degrades marine habitats, resulting in a loss of biodiversity and changes in community structure. Given the inability of past responses to halt the degradation of marine ecosystems, the concept of ecosystem-based management is increasingly adopted for the management of LMEs with support from the GEF. Ecosystem-based management requires the implementation of a combination of measures, including precautionary catch regulations, the introduction of sustainable rather than destructive fishing methods, the reduction of fishing effort and the reform of subsidies. Marine parks and zones which temporarily close or restrict access to fishers and other marine activities can protect sensitive habitats.

Many of the GIWA regional teams have recognised that ecosystem-based management, including integrated coastal zone management, is an effective policy response for halting or reversing the degradation of large marine and limnic ecosystems.

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KIUNGA NATIONAL MARINE RESERVE, KENYA
(PHOTO: G. HEMPEL)

Introduction

Only a small proportion of global freshwater can be used by humans for drinking, sanitation, agriculture and industry, as well as by the inland fisheries and aquaculture. The living resources exploited by marine fisheries and mariculture are predominantly restricted to the relatively narrow and shallow fringes of oceans. The various human activities increasingly compete for limited aquatic resources. The growth of human populations and their economies, urbanisation and the globalisation of trade, in combination with global climate change, will further increase this pressure.

Water and its resources are exploited at differing intensities and for various purposes in different parts of the world. Consequently, the impact of aquatic concerns, including freshwater shortage, pollution, habitat and community modification, and overfishing, vary in severity and extent. These concerns were traditionally assessed either on a national scale, individually on a global scale, or for a specific water body.

Many freshwater and coastal ecosystems are international; 263 river basins cross or delimit national borders, conveying about 60% of the world's freshwater flow and draining more than half the Earth's land area. Most Large Marine Ecosystems (LMEs) and large groundwater aquifers are shared by two or more countries. Downstream consequences of human activities can occur in regions some distance from the source of the problem. In order to address these water issues, they must be assessed from an international (or transboundary) perspective.

Over the past decade, the international community has increasingly acknowledged the need for a global approach to assessing transboundary aquatic resources and has recognised the importance of water for sustainable development. While aquatic environmental concerns are global issues, they are usually addressed on a regional scale, i.e. for each water system. Within the region, a holistic approach to assessment and management is required, as all aquatic concerns and their effects are interlinked and can be traced back to a number of common root causes.

The Global Environment Facility (GEF) has been established to inter alia "contribute primarily as a catalyst to the implementation of a more comprehensive, ecosystem-based approach to managing international waters and their drainage basins as a means to achieve global environmental benefits".

The absence of a worldwide comprehensive and integrated transboundary waters assessment has hampered the efforts of the GEF to meet its objective and to identify priority regions and issues for international support. Thus, the GEF commissioned UNEP to implement the Global International Waters Assessment (GIWA) project in order to develop a strategic framework that may be used by the GEF and its partners to identify priorities for remedial and mitigatory actions in international waters. See Annex I-III for further information on the GIWA project.

The GIWA project was executed by UNEP in partnership with the Government of Sweden, through the Swedish International Development Cooperation (SIDA). The Government of Finland later became a partner to the project. In 1999, they established the GIWA Core team at Kalmar University, Sweden.

GIWA focused on transboundary water issues in developing regions. However, in order to provide a more global coverage, comparable information was collated from regions containing developed countries that are not eligible for GEF interventions.

GIWA adopted a bottom-up approach involving regional experts. They evaluated the severity of transboundary ecological and societal impacts and their causes in international waters on a regional scale. The root causes, including global trends, policy, legislation, governance, institutional capacity and knowledge, were analysed by the experts. Finally, policy relevant conclusions were drawn from the assessments.

The GIWA project provides strategic information that can assist in meeting the Millennium Development Goals (MDGs), particularly for the eradication of hunger (Goal 1) and increased access to safe drinking water (Goal 7).

Project design

The transboundary regional approach to assessing global problems constitutes the backbone of GIWA. The inland water systems and shelf seas of the world were divided into 66 transboundary geographical regions, 41 of which are GEF-eligible. Each region comprises one or more international river basin and usually an adjacent LME. A few regions are land-locked, such as Lake Chad/43. Several regions were divided into sub-systems, which were assessed individually (see map on the inside of the front cover). The high seas were not assessed by GIWA.

The assessments were conducted by 1 500 scientists and administrative and managerial experts, who were organised into regional teams led by a focal point from the region. The multidisciplinary teams included representatives from each country in the region. The Core team was responsible for overall project management, methodology development, the coordination of the regional teams, and peer review and publication. The Core team, in cooperation with external experts, also produced this GIWA Final Report.

The GIWA assessment methodology

Globally comparable results were achieved by a common and consistent methodology applied by all of the regional teams. The GIWA methodology provides criteria for assessing water-related environmental concerns, and for identifying their immediate and root causes and potential policy options (see Annex II and III). Regional experts assessed and compared the severity of impacts from a regional perspective. The methodology was not developed for inter-regional comparisons of environmental quantitative data, such as pollutant concentrations or loss of mangroves. Instead, the GIWA determines regional priorities and allows a relative comparison of multiple impacts.

The numerous and complex transboundary water-related environmental problems were grouped into five major concerns:

1. Freshwater shortage
2. Pollution
3. Overfishing and other threats to aquatic living resources
4. Habitat and community modification
5. Global change

Global change largely causes impacts by affecting the four other concerns and many regional teams were unable to assess it due to a lack of data. Consequently, global change is integrated into the discussions on the other concerns in this report.

The GIWA methodology is comprised of four major steps (for further information and discussion on the GIWA methodology see Annex II, and for its theoretical background, Annex III):

Scaling defines the geographic boundaries of the GIWA region, which are generally demarcated by a large drainage basin and its adjacent marine areas. The boundaries of the marine parts of the GIWA regions often correspond with those of LMEs.

Scoping assesses and scores the severity of present and predicted environmental and socio-economic impacts caused by each of the GIWA concerns.

Causal chain analysis traces the cause and effect pathways from the socio-economic and environmental impacts back to their root causes.

Wherever possible, the causal chain analysis was followed by policy option analysis which outlined potential courses of action that aim to mitigate or resolve environmental and socio-economic problems in the region.

The GIWA provides baseline information at the regional level which will facilitate the preparation of Transboundary Diagnostic Analysis (TDAs) and Strategic Action Programmes initiated by GEF. At the same time, many GIWA regional assessments have benefited from completed TDAs.

The GIWA approach

Although GIWA is not the only assessment of the world's aquatic systems and resources, it has taken an original approach that will benefit a wide range of stakeholders. The number and diversity of regional experts, and the peer review process, has ensured transparency in the regional assessments. GIWA uses a holistic and ecosystem-orientated approach to assess the environmental and socio-economic impacts, and root causes behind environmental problems.

Traditionally, global assessments adopt a top-down approach; led by small teams of international experts with relatively limited inputs from local stakeholders. GIWA has taken the opposite approach, with local experts leading each regional assessment, thus building strong local ownership of the GIWA regional reports. By facilitating international cooperation and fostering trust among scientists and policy makers from neighbouring countries, GIWA has strengthened national assessment capacity and provided the basis for long-term collaboration in developing regions.

Throughout the process of undertaking the regional assessments and preparing the regional reports, the training of many young scientists served to strengthen scientific capacity in specific regions. GIWA not only assessed the available policy relevant information, but also identified key knowledge gaps that need to be addressed.

In addition to their own knowledge, the regional experts drew, to varying extents, from complementary assessments and initiatives, including: the UN World Water Development Report; the Millennium Ecosystem Assessment; the Millennium Development Goals; the UN Commission on Sustainable Development; Food and Agriculture Organization assessments; and national studies. There is considerable overlap in membership of the various assessment groups and in the data sources used.

The GIWA methodology brought together natural and social scientists and resource managers, often for the first time, to participate in the workshops, conduct the assessment and compile the regional report.

Each GIWA regional assessment followed the same process. Training courses for the regional teams ensured that they all possessed a common understanding of the GIWA methodology.

The regional assessments are the primary outputs of the GIWA project. Fifty-five regional assessments have been completed, forty of which include GEF-eligible countries. The present status of the GIWA regional reports is presented on the map inside the front cover. The reports are also available on the GIWA website (www.giwa.net).

GIWA has been the largest global assessment of ecosystem-wide water issues from a transboundary perspective, linking international river basins to their adjacent LMEs. It was designed to provide policy makers and managers with the information they need to improve transboundary resources management.

The GIWA Final Report

This report provides a synoptic review of the most important information from the regional reports. It is a technical rather than a comprehensive scientific publication. Prime references can be found in the regional reports, which are referenced in this report by GIWA region (name followed by number, e.g. Mekong River/55).

The book:

- summarises the major transboundary concerns and their impacts;
- assesses the root causes of the impacts; and
- provides policy relevant conclusions.

The GIWA scoring matrices in Annex IV present the scoring results of the five concerns for each region and sub-system. The severity of the GIWA concerns and issues are expressed using the terms 'severe', 'moderate', 'slight' and 'no reported impact', which are described in Annex II. 'Environmental impacts' represent the average weighted score for the environmental issues associated with the concern. 'Overall impacts' refers to the concern's final score including environmental, socio-economic and the anticipated future impacts. The predicted trends of the environmental impacts are represented by arrows in the overall impacts column.

For various reasons, some regional reports have not been published and were therefore unavailable during the drafting of the Final Report. Many GEF non-eligible regions were not assessed, mainly in Europe and North America. Some areas of the Middle East and Southern Asia are also unrepresented. Those gaps may give a misleading impression that there are no transboundary water problems in these regions.

This synthesis of all concerns, their issues and impacts provides a global perspective on their relative importance. Readers are encouraged to consult the regional reports for more information about the examples contained in this report. The Annexes provide additional information on the GIWA project and methodology.

IN THE BARREN DESERT OF WADI RUM CROPS ARE GROWN ON CIRCULAR IRRIGATED PATCHES OF LAND. (PHOTO: CORBIS)

FRESHWATER SHORTAGE

Today, freshwater is used unsustainably in the majority of the regions studied by GIWA. In two-thirds of the regions, water is predicted to become scarcer by 2020 due to demand continuing to grow in parallel with increased agricultural production, and population and economic growth. Global climate change will exacerbate this situation. On a global scale, the most widespread and adverse transboundary consequences result from the modification of stream flow by dams, reservoirs and river diversions, as well as by land-use changes in the catchment area. Downstream ecosystems and riparian communities are severely impacted by changes to the flow regime of international rivers. Inappropriate subsidies encourage inefficient water use, such as the growing of water-intensive crops in water scarce regions.

The growing recognition that entire river basins, estuaries and coastal areas are single planning units has led to a paradigm shift of water management towards more integrated approaches. Demand management was identified as an effective alternative to building new reservoirs and deeper wells. There is a need to move away from focusing exclusively on the direct economic benefits of engineered structures to understanding their actual environmental and socio-economic costs.

Freshwater is a highly valuable resource for a large number of competing demands, including drinking water, irrigation, hydroelectricity, waste disposal, industrial processes, transport and recreation, as well as ecosystem functions and services. Prior to the 20th century, human demand for water was relatively small compared to availability in most parts of the world. Water demand dramatically increased as a consequence of population and income growth, and the expansion of industry and irrigated agriculture, so that demand now exceeds supply in many developed and developing countries. Today, freshwater scarcity affects more than a billion people and the integrity of many of the world's ecosystems. The achievement of many of the UN Millennium Development Goals (MDGs) will depend on the improved management of freshwater resources. One goal focuses specifically on reducing the proportion of people without sustainable access to safe drinking water and basic sanitation by 50%. Managing water in transboundary river basins poses great challenges and requires comprehensive solutions that take into account the needs of both upstream and downstream countries (Box 1).

BOX 1. TRANSBOUNDARY FRESHWATER RESOURCES

- Approximately 60% of global freshwater flows and 50% of the Earth's land surface is located within the 263 international river basins.
- More than 40% of the world's population live within international river basins.
- Many of the world's largest lakes are transboundary, such as the Caspian Sea, Aral Sea, Lake Chad, Dead Sea, Lake Tanganyika, Lake Victoria and the Great Lakes of North America.
- Transboundary groundwater systems of global significance include the Guarani aquifer in South America, Chad Formation and Nubian Sandstone aquifer in North Africa, and Gangetic Plain Quaternary aquifer in Asia.
- More than 400 international treaties or agreements related to shared water resources have been signed since 1820, excluding agreements on navigation, fisheries, or the demarcation of borders. However, 60% of international basins do not have any cooperative management framework.

(SOURCE: UNEP 2002)

The GIWA methodology (see Annex II) provides a framework for evaluating three critical freshwater transboundary issues: (i) modification of stream flow; (ii) pollution of existing supplies; and (iii) changes in the water table. The results of the GIWA assessment for freshwater shortage are summarised in the global matrix in Annex III.

Global situation and trends

- Freshwater shortage was assessed as the priority transboundary concern in more GIWA regions/sub-systems than any other GIWA concern. Many of these regions are arid and either renowned drought-prone basins in Africa or subject to long-term unsustainable water management.
- More than half of the regions/sub-systems considered the overall environmental and socio-economic impacts of freshwater shortages to be moderate or severe (Figure 1).
- Impacts of the modification of stream flow caused by dams or river diversions were more widespread and severe than those caused by the pollution of existing supplies or changes in the water table.
- Water withdrawals by irrigated agriculture were identified by the GIWA regional teams as causing the most severe environmental and socio-economic impacts.
- Overextraction of aquifers is becoming severe in many areas that depend heavily on irrigated agriculture or are densely populated. The extraction of fossil water from deep aquifers is unsustainable as they will not be refilled on human time scales. Knowledge of aquifers is insufficient and further studies are needed in order to comprehensively assess transboundary aquifers.
- Agricultural land is becoming too saline to support important crops, the salinity of aquifers is too high for human use, and saline waters encroach further up rivers during dry seasons.
- Land-use changes, including deforestation and the cultivation of wetlands, affect the water budget, thus causing floods or droughts in many regions.
- The majority of GIWA regional teams predict that environmental problems related to freshwater shortages will increase by 2020.

ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS

Modification of stream flow

Nineteen GIWA regional teams identified the modification of stream flow as having severe impacts, particularly in Sub-Saharan Africa, North Africa, Northeast Asia, Central America and Europe & Central Asia (Figure 3). Table 2 summarises

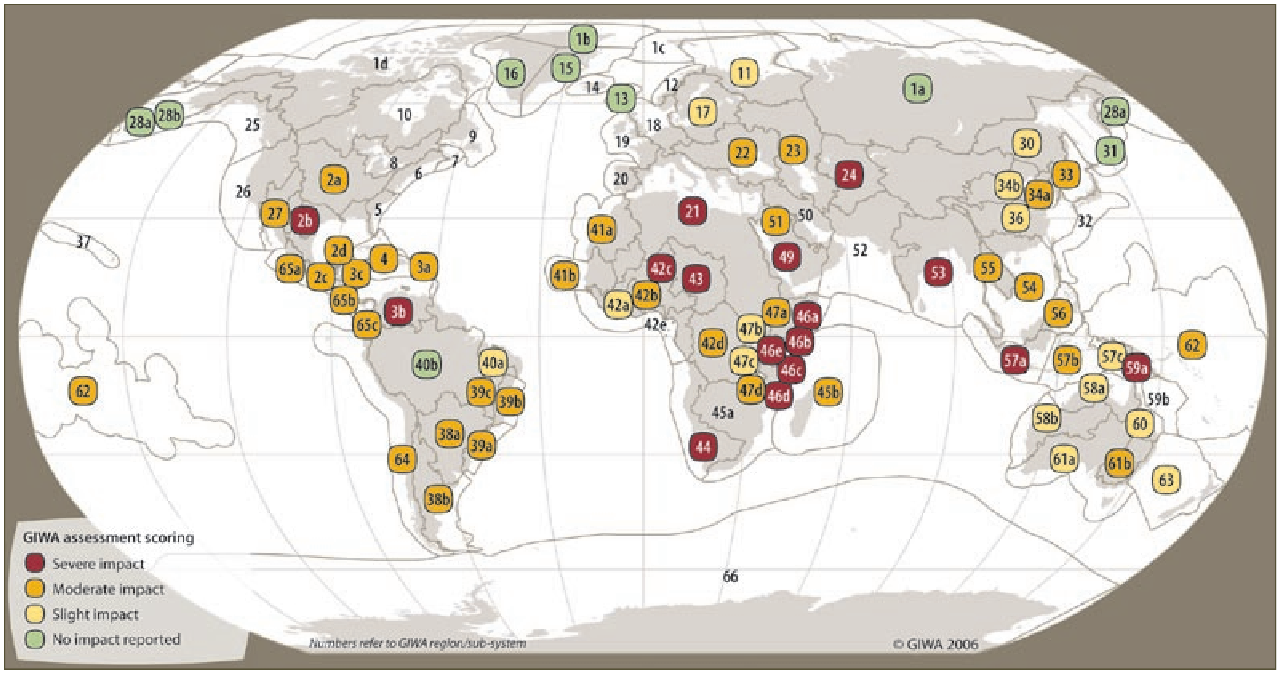


FIGURE 1. OVERALL ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF FRESHWATER SHORTAGE

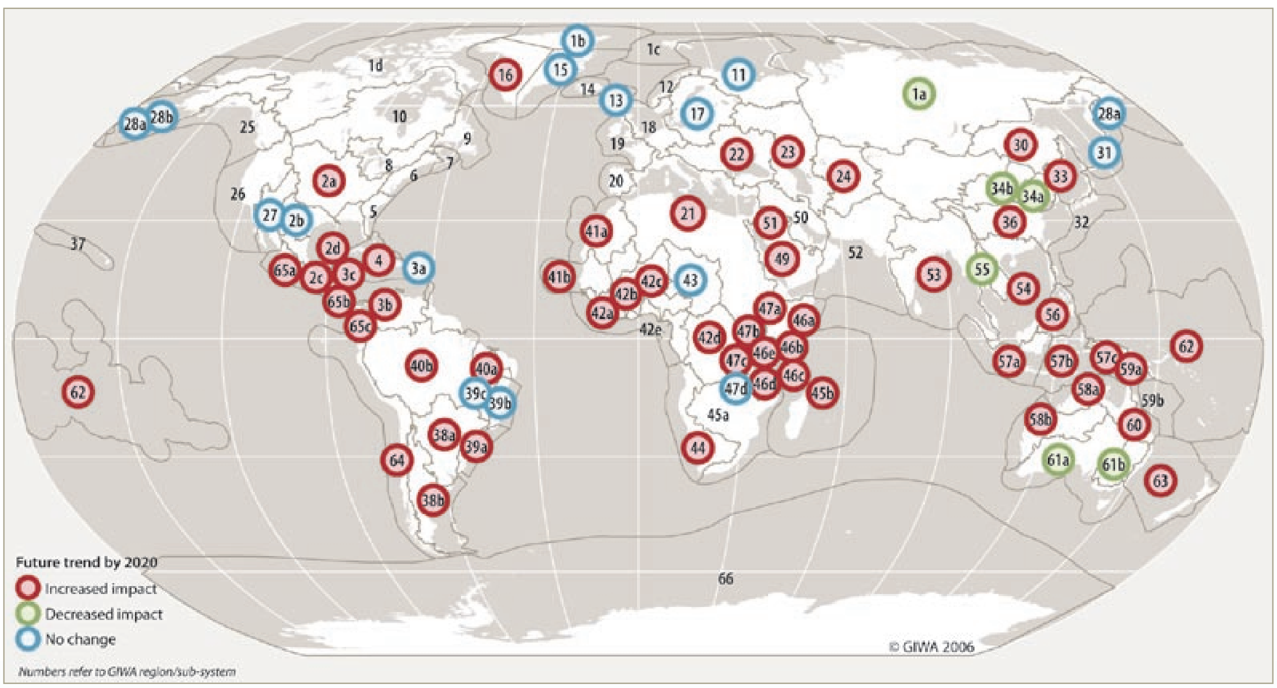


FIGURE 2. FUTURE ENVIRONMENTAL TRENDS OF FRESHWATER SHORTAGE

the environmental and associated socio-economic impacts assessed by GIWA for a selection of transboundary river basins.

Changes in the flow regime were principally attributed to the development of large dams (e.g. the Colorado River, Figure 4). River diversions, inter-basin transfers and other structures designed to supply water and energy also modify stream flow.

Dams change flow patterns by storing water in reservoirs during the wet season and releasing part of it during the dry season. The biodiversity of riparian and aquatic habitats changes in response to the alteration of the flow regime. Dams can also obstruct migration routes and reduce fish spawning habitat. For example, dams on the Volga River (Caspian Sea/23) have reduced the spawning habitat of

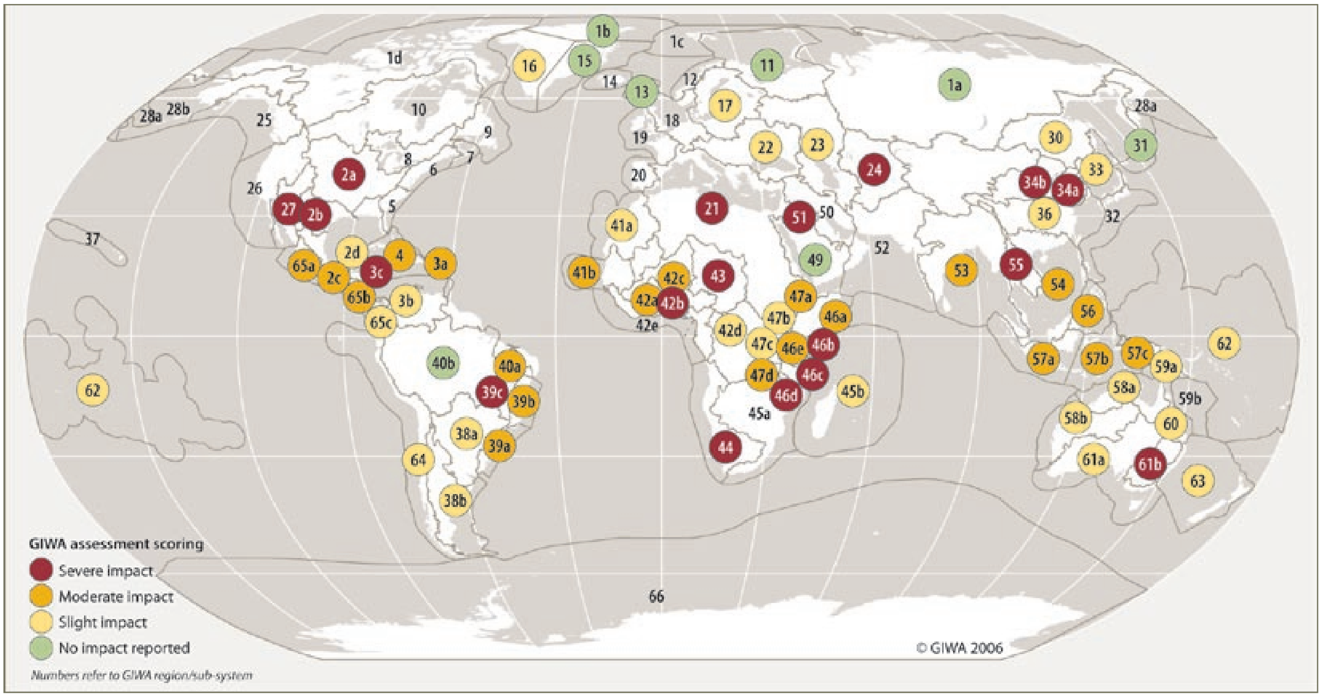


FIGURE 3. IMPACTS OF MODIFICATION OF STREAM FLOW

Caspian sturgeon, and these fish are now predominantly recruited in hatcheries.

Fragmentation of rivers results in the trapping of sediments in reservoirs which can lead to downstream ecological changes and erosion in floodplains, deltas, estuaries and the coastal zone. Land use changes, particularly deforestation, modify sedimentation and flooding regimes. The accumulation of sediments behind dams can affect downstream natural resources and associated livelihoods, and may impede the efficiency of dam infrastructure and reduce the storage capacity of reservoirs. For example, in the Save River in Zimbabwe, soil erosion and sedimentation has significantly reduced

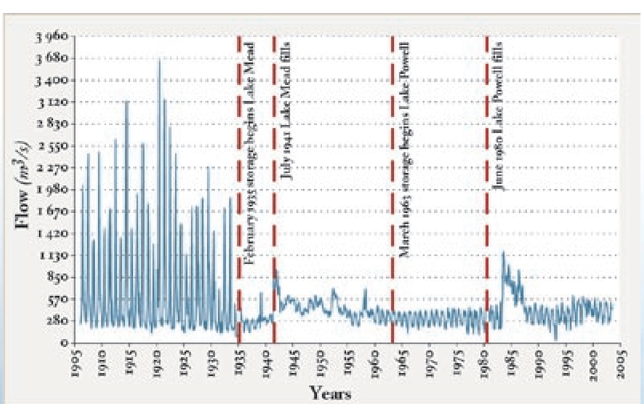


FIGURE 4. FLOW OF THE COLORADO RIVER BELOW THE HOOVER DAM 1905-2003
(SOURCE: USBR 2002)

the storage capacity of reservoirs, thus intensifying competition over water supplies (Agulhas Current/45a). In the Niger River (Guinea Current/42c), sedimentation in upstream reservoirs causes coastal erosion and reduces nearshore productivity as fewer sediments and nutrients reach the coast.

In addition to fragmentation and changed flow regimes, evaporation and water consumption have significant consequences for downstream ecosystems and societies. Globally, irrigated agriculture accounts for around 70% of freshwater withdrawals, followed by industry (21%) and domestic uses (10%). Not all water withdrawals are 'consumed', as return flows re-enter the hydrological system downstream. Irrigated agriculture, however, returns only 30% of its water withdrawals, while industrial and domestic users return 85-90% (FAO 2002). In Namibia's Eastern National Water Carrier canal, more than 70% of the water is lost through evaporation (Benguela Current/44). Freshwater shortage in the Benguela Current region illustrates the problems faced by arid coastal environments worldwide (Box 2).

Loss of freshwater inflow to enclosed water bodies has resulted in dramatic changes to many ecosystems, notably the shrinking of the Aral Sea/24 and the Dead Sea (Jordan/51) (Box 3). In the inland areas of the Canary Current/41 region, the Volta River Basin (Guinea Current/42b) and the Lake Chad/43 Basin, reduced rainfall over the last few decades

TABLE 2. IMPACTS OF MODIFICATION OF STREAM FLOW IDENTIFIED IN GIWA REGIONS

GIWA region	River basin or hydrological system	Environmental impacts	Social, economic and health impacts
27 Gulf of California	Colorado River	■ Decreased sediment transport to the coast ■ Erosion of the Colorado River Delta ■ Loss of wetlands ■ Loss of endemic plants	■ Lack of potable water ■ Loss of crops ■ Loss of fisheries ■ Loss of traditional livelihoods
2b Gulf of Mexico	Rio Grande/Rio Bravo, river and estuary	■ Increased salinity of estuarine habitats	■ Impacts on coastal fisheries ■ Conflicts over water resources
34a Yellow Sea	Yalu River, Huai River, Yongsan River, Taedong River, Imjin River, Han River, Kum River	■ Reduction in water flow ■ Pollution degrading nearby habitats and leading to annual mass fish kills ■ Pollution of water supplies ■ Salinisation of coastal aquifers	■ Interruptions in water supply ■ Increase in infectious diseases
39c Brazil Current	São Francisco, river and estuary	■ Decreased sediment transport to the coast and coastal erosion ■ Reduced primary productivity	■ Displacement of people ■ Loss of traditional livelihoods ■ Reduced availability of fish ■ Navigation impediments
42b Guinea Current	Volta River	■ Decreased sediment transport to the coast and erosion ■ Loss of marine biodiversity	■ Loss of farmland and infrastructure ■ Reduced agricultural output ■ Displacement of people ■ Increased water-related diseases ■ Loss of traditional sites
43 Lake Chad	Komadugu-Yobe River Basin	■ Loss of floodplain ecosystems and wetlands	■ Reduced productivity of farmland ■ Degradation of grazing lands ■ Reduced availability of fish ■ Acute freshwater shortage ■ Food insecurity in downstream areas ■ Increased water-related diseases ■ Upstream/downstream conflicts ■ Political disputes ■ Displacement of people ■ Increased vulnerability to flooding
	Chari-Logone River Basin	■ Loss of floodplain ecosystems and wetlands	
	Lake Chad	■ Shrinking of Lake Chad ■ Loss of plant species ■ Decreased fish stocks and diversity	
44 Benguela Current	Orange-Vaal River Basin	■ Changed hydrological regime	■ Increased water-related diseases ■ Displacement of people ■ Disruption of family and community structures
46d Somali Coastal Current	Rufiji/Ruvuma River Basin	■ Changed flow and flood patterns ■ Increased salinity in the Rufiji Delta	■ Displacement of people ■ Malnutrition during periods of relocation ■ Social conflicts
24 Aral Sea	Amu Darya River, Syr Darya River, Aral Sea	■ Shrinking of the Aral Sea ■ Fish extinctions ■ Salinisation of soil and water resources	■ Deteriorating human health ■ International disputes ■ Loss of agricultural productivity ■ Loss of fisheries ■ Displacement of people
51 Jordan	Jordan River, Dead Sea	■ Shrinking of the Dead Sea ■ Salinisation of water resources	■ Lack of potable water ■ Increased water-related diseases

NOTE: THE TABLE PRESENTS A SELECTION OF REGIONS WHERE THE GIWA ISSUE MODIFICATION OF STREAM FLOW HAS BEEN ASSESSED AS SEVERE.

BOX 2. DESERTS BEHIND THE SEA: FRESHWATER SHORTAGE IN THE BENGUELA CURRENT REGION

In GIWA region 44, the land areas adjacent to the Benguela Current are arid or semi-arid, with rainfall dropping below 50 mm in coastal Namibia and parts of Angola. Evaporation rates exceed mean annual runoff in most of the region. Standing water is limited, and few permanent rivers enter the Benguela Current. Freshwater systems of transboundary significance include the Cunene and the Orange-Vaal systems.

The GIWA regional team considered the anthropogenic impacts on water resources and associated social and economic processes to be severe. The natural aridity, coupled with highly variable rainfall and the geographic disparity between water availability and the distribution of human settlements and activities, has led to the construction of many dams and inter-basin water transfer schemes. The Orange-Vaal Basin is considered to be the most modified river system in southern Africa, with annual flow data indicating a 50% reduction in flow since 1935. Overabstraction of water for agriculture, industry and urban supply has placed enormous stress on water resources, and severely modified stream flow and subsequently the aquatic ecosystems of the region. Pollution from a variety of sources also threatens the ecological integrity of freshwater systems. Furthermore, there is growing concern regarding the presence of aquatic alien species and the overabstraction of aquifers which have slow replenishment rates.

The region's freshwater resources are unsustainably exploited due to a number of anthropogenic factors, including: population growth, particularly in dry, coastal urban areas; irrigated agriculture, which is inappropriate and wastes large quantities of water; and increased demand from the expanding industrial and mining sectors.

Although there are existing measures to address freshwater shortage in the region, the situation is likely to further deteriorate due to increasing demand for water and decreased supply resulting from predicted changes in rainfall patterns.

(SOURCE: BENGUELA CURRENT/44)

BOX 3. SHRINKING LAKES: CASE OF THE DEAD SEA

In 1933, freshwater inputs to the Dead Sea averaged 1.37 km³. Since then, the overexploitation of water resources and the construction of dams and canals in the catchment area have reduced the annual flow to less than 0.2 km³. Discharges by the Jordan River comprise of mostly poor quality irrigation return flows, inter-catchment run-off and discharges from saline springs.

The surface area of the Dead Sea has reduced by over one-third, and its water level has dropped by over 20 m and continues to fall by up to 1 m per year. Groundwater extraction for development activities has lowered the water table in surrounding areas, leading to land subsidence.

(SOURCE: JORDAN/51)

(PHOTO: IMAGE PROCESSING, UNEP/GRID-GENEVA 2002)

BOX 4. IMPACTS OF CLIMATE CHANGE ON FRESHWATER RESOURCES

Predicted climate change, including changes to temperatures, weather systems, and sea level, will alter the global hydrological cycle. Impacts on freshwater resources that can be confidently predicted include:

- In river basins strongly influenced by snow or glacier melting, peak stream flows will occur earlier in the year, winter run-off will increase, summer run-off will decrease, and flooding events will become more intense. These changes are already occurring in several drainage basins in Eastern Europe, Central Asia, Canada and California.
- In arid or semi-arid regions, small changes in precipitation can significantly affect run-off. Even if precipitation rates do not change, higher temperatures would increase evaporation rates, reduce stream flow and cause additional droughts. This has serious implications for areas like the Volta Basin, where a large volume of water is lost through evaporation from reservoirs; in Burkina Faso, almost 85% of the total volume of most reservoirs is lost by evaporation (Guinea Current/42b).
- Lakes are particularly vulnerable to climate change due to their dependence on climatic variables, such as precipitation, evaporation, wind conditions and ice formation. Enclosed river basins with no outflow are most sensitive to climate changes, including the Caspian Sea/23, Aral Sea/24, Lake Chad/43, Lake Balkhash (Aral Sea/24) and Lake Titicaca (Humboldt Current/64).
- Sea level rise will cause greater saline intrusion in coastal aquifers. Low-lying islands are particularly vulnerable, with the mean global sea level predicted to increase by 0.09 to 0.88 m by 2100 compared with 1990. In the Pacific Islands/62, global warming is expected to: increase the salinisation of the limited groundwater supplies; cause human migration due to the inundation of coastal areas; and increase the frequency of storm surges and cyclonic events resulting in property and infrastructure damage.
- The small islands of the Indian Ocean Islands/45b region are preparing for the impacts of climate change. The majority of the population inhabits the coastal plateau which is only about 2 m above mean sea level. As the sea rises, many communities will be displaced and economic activity, which is concentrated on the coast, will be disrupted. The loss of beaches will have a significant impact on regional tourism. Water shortages resulting from saline intrusion in aquifers will require the importation of water or desalination, both expensive alternatives.
- While many water-scarce regions in the sub-tropics will have decreased water availability, other regions will have greater precipitation, including Southeast Asia. In many regions, climate change is predicted to increase the pressure on water resources, particularly for irrigated agriculture. Africa appears to be the most vulnerable to the impacts of climate change on water supplies due to widespread poverty, recurrent droughts and the dependence on rain-fed agriculture.

(SOURCE: IN ADDITION TO THE GIWA REPORTS MENTIONED, THIS BOX INCLUDES INFORMATION FROM ARNELL ET AL. 2001) has magnified the effects of water withdrawals for irrigation and water diversion schemes. Discharges by the Chari-Logone River, which is the major inflow for Lake Chad, have decreased by 55% over the last 40 years. In the future, global warming will increase evaporation rates and pose a considerable threat to the supply of freshwater in many regions (Box 4).

Loss of freshwater inputs to coastal ecosystems has also severe transboundary impacts in many areas. As a consequence of upstream water withdrawals, the Berg River estuary in South Africa experiences intrusions of high salinity waters which affect many species of fish, benthic invertebrates and birds (Benguela Current/44). In the Rio Grande/Rio Bravo Basin (Gulf of Mexico/2b), irrigation diverts nearly 90% of the Rio Grande's average annual flow which has adversely affected many estuarine species, including commercially important fish and shellfish. This region, which has low precipitation rates, is therefore extremely vulnerable to drought.

The reduction of water downstream can have substantial socio-economic impacts, including the displacement of people due to a loss of traditional livelihoods, declines in fisheries production, a loss of water supply, health impacts related to schistosomiasis and other water-borne diseases, and the provocation of conflicts over water allocation (Table 2). Many of these issues are exemplified in the Ganges-Brahmaputra River system (Bay of Bengal/53). Bangladesh receives 90% of its stream flow from its upstream neighbours; India, Nepal and Bhutan. More than 30 dams, barrages and river diversions have been constructed upstream, reducing dry season flows in Bangladesh by up to 60%. Additional dams in Bangladesh also contribute to the problem. The consequences are manifold: acute water shortages; loss of inland fisheries; salinisation and reduced productivity of agricultural lands; the encroachment of sea water further upriver in the dry season; and loss of goods and services provided by mangrove forests. The livelihood and nutritional levels of nearly 30 million people in Bangladesh have been adversely affected as a result of stream flow modification. The water-sharing treaties signed in 1996 between India and Nepal, and Bangladesh and India have reduced, to a degree, the severity of the impacts, particularly on the downstream population in Bangladesh. However, the recently proposed 'river linking' project is expected to transfer a significant proportion of the flows from the Ganges-Brahmaputra-Meghna River system to other rivers in India.

FIGURE 5 THE HOOVER DAM ON THE COLORADO RIVER, USA.

Prolonged water shortages can provoke conflict between water users and force the population to adapt, as observed in the Lake Chad/43 region. In the Komadugu-Yobe Basin, disputes were provoked as a result of upstream Nigerian states allocating insufficient water to the downstream riparian states of Borno and Yobe, and Niger. Many fishermen in the basin have tried to compensate for declining fish production caused by the contracting lake by turning to farming the fertile soils left by the receding lake.

In tropical regions, particularly in Africa, reservoir development often leads to a greater prevalence of water-related diseases, including malaria, yellow fever, guinea worm and schistosomiasis. The latter almost always increases dramatically as reservoirs facilitate the transmission of the disease from snails to humans. The construction of the Akosombo Dam on the Volta River in Ghana increased the proportion of schistosomiasis infected children from 5 % to 90% (Guinea Current/42b). Even in temperate regions, water-borne diseases are correlated with the level of access to safe water and sanitation. In the Caspian Sea/23, 30% to 70% of all illnesses in the region are attributable to the quality and availability of drinking water.

Pollution of freshwater supplies

Pollution reduces the availability of water for human use. Chemical pollutants, microbial contamination, increased concentrations of organic matter and elevated nitrates in drinking water can result in health problems, higher water treatment costs and freshwater shortages. Overall, pollution of freshwater supplies was assessed as severe in 12 and as moderate in a further 30 of the transboundary river basins assessed by GIWA (Figure 6). For a holistic assessment of transboundary pollution refer to the chapter on pollution.

In the Aral Sea/24 region, a considerable proportion of available water resources consist of return waters from irrigated cotton plantations that are heavily contaminated with agro-chemicals. Approximately 15% of surface water supplies in the Aral Sea Basin are polluted, severely affecting the human and ecological functions of many reservoirs. In addition to persistent organic pollutants, 60 million tonnes of salt are carried by the rivers annually, causing concentrations in the delta to exceed 2 g/l. This situation has caused severe human health problems. As the Aral Sea recedes, it leaves behind chemical pesticides and natural salts which are blown into noxious dust storms, seriously affecting the health of the local people. Pollution puts further pressure on communities already burdened by water shortages and the loss of large areas of valuable ecosystems, as well as the retreat of the Aral Sea and the collapse of its fisheries (see the chapter on habitat and community modification).

The Vaal River, a tributary of the Orange River in South Africa, is severely polluted by microbes, nutrients, chemicals and acid mine drainage from agricultural, urban and industrial return flows (Benguela Current/44). Average salinity at the Vaal Barrage has more than tripled since the 1930s. As a result, water at several locations has become unsuitable for human use and Rift Valley fever and sheep blindness is prevalent along the Vaal River.

In addition to the economic costs of water-borne illnesses, many GIWA reports note that water pollution incurs significant direct economic costs, from accessing ever-deeper groundwater and improving water treatment facilities, to consumers paying more to buy water from private suppliers.

In the Patagonian Shelf/38 region, contaminated groundwater and a lower water table have increased water treatment costs and required the exploitation of alternative sources of water. The loss of surface and groundwater sources for large cities, such as São Paulo and Buenos Aires, affects millions of people and disrupts crucial industries. Additionally, the exploitation of fluoride and arsenic contaminated groundwater can lead to poisoning. For example, 80 million of the Bangladesh population live in arsenic-contaminated areas (Bay of Bengal/53).

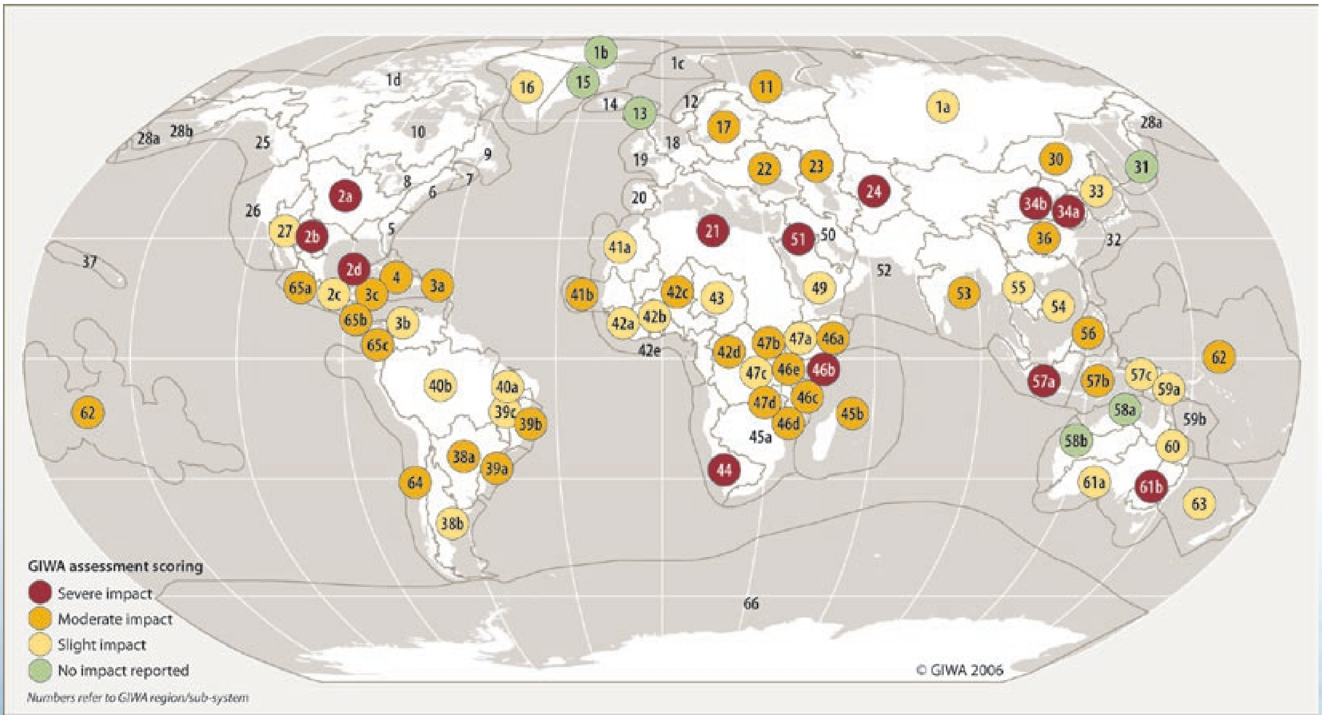


FIGURE 6. IMPACTS OF POLLUTION ON TRANSBOUNDARY FRESHWATER SUPPLIES

In the Colorado River (Gulf of California/27), the economic impacts of freshwater shortages are substantial. Saline waters require expensive purification systems (demineralisation, softening, etc.) that have direct economic impacts on industrial, residential and agricultural water users in both Mexico and California.

Changes in the water table

Most of the world's available freshwater is found in the water-saturated zones of the lithosphere. These groundwater systems supply drinking water to more than 2 billion people and provide irrigation water which is used to generate nearly 40% of global food production (WMO 1997). Despite their global significance, there is a dearth of knowledge regarding aquifers, especially in developing countries.

When water withdrawals from an aquifer system exceed the long-term rate of replenishment, water tables lower and water resources are said to be 'mined'. This is a common problem in many regions on all continents that have low rainfall and rely on groundwater for irrigated agriculture and domestic uses (Figure 7). In the Jordan/51 region, the majority of aquifers are overexploited and often saline; water tables have fallen as rapidly as 0.6 m/year in the Azraq basin. Inefficient irrigation practices can lead to waterlogging and the salinisation of soils and aquifers. This has already affected approximately 40 million ha of farmland. In Namibia, particularly in the vicinity of the Karstveld aquifer, the water table has dropped several metres (Benguela Current/44).

Over the past 25 years the water table in the Volta River Basin (Guinea Current/42b) has significantly lowered, 60-80% of which is attributed to excessive pumping from aquifers for irrigation, domestic water supply and other urban requirements. The lower water table leads to a scarcity of potable water, forcing inhabitants to use surface water which may be polluted or infected.

Water withdrawals from coastal aquifers can lead to seawater intrusion, causing irreversible salinisation. This is a growing concern in many small island developing states (SIDS) of the South Pacific and Caribbean. In the Pacific Islands/62 region, subterranean lenses of freshwater are the primary sources of drinking water for many small islands, particularly atolls. Burgeoning human populations are placing extreme pressure on this limited resource, often resulting in drinking water shortages. These problems are often exacerbated by dilapidated pipes and storage facilities. Suva, the capital of Fiji, is experiencing increasing disruptions to its municipal water supplies, partly due to the failure of old piping systems, but also because of the rapidly increasing population.

The Caribbean Islands/4 also depend on groundwater as a source of potable water. However, groundwater resources

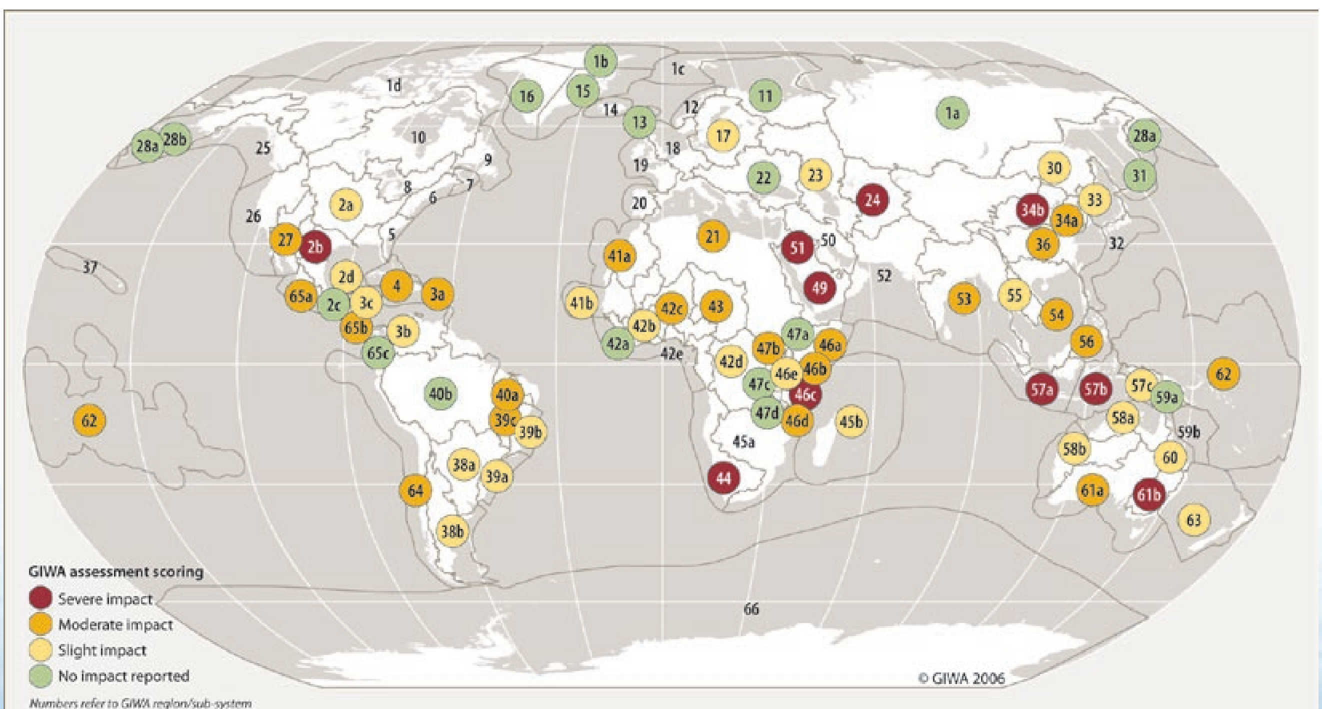


FIGURE 7. IMPACTS FROM CHANGES IN THE WATER TABLE ON TRANSBOUNDARY AQUIFERS

are being eroded by saltwater intrusion resulting from sea level rise and overuse of groundwater reservoirs. In some agricultural regions of Cuba, saltwater intrusions into aquifers extend up to 30 km inland.

Saline intrusion in coastal aquifers is also a serious problem in the East China Sea/36 region and other coastal regions with intense groundwater abstraction for irrigation or the cultivation of marshes and swamps.

The interactions between freshwater shortage and the other GIWA concerns are highlighted in the case of Lake Chad (Box 5).

BOX 5. INTERACTIONS BETWEEN FRESHWATER SHORTAGE AND THE OTHER GIWA CONCERNS: CASE OF LAKE CHAD

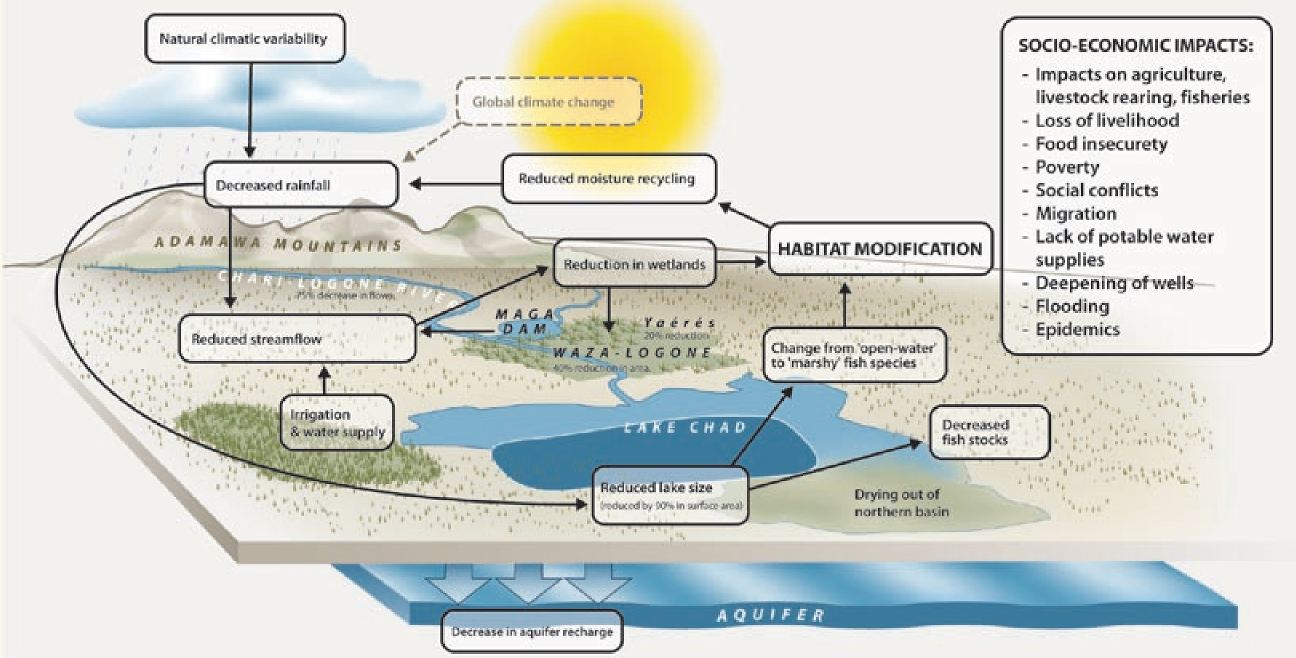
There are strong inter-linkages between freshwater exploitation and the other GIWA concerns, as illustrated in the Lake Chad/43 Basin. The water resources of the Basin are shared primarily by Cameroon, Chad, Niger and Nigeria.

Over the last 30 years, numerous dams and irrigation projects were developed in the Chari-Logone and Komadugu-Yobe river basins, particularly in Nigeria and, to a lesser extent, Cameroon. Over the same time period, the Sahel has experienced a dramatic and sustained decline in rainfall. Lake Chad shrunk by 90% and severe reductions in stream flow from the droughts, as well as the development projects, have severely modified many aquatic habitats, particularly the lake, wetland and floodplain ecosystems.

Previously, high-quality floodplain pastures sustained livestock rearing during the dry season; the third largest source of household income in the basin. Most of the former flooded pastures have lost their perennial grass cover, leaving only degraded grasslands. This has encouraged herders to shift from grazing animals to browsing animals which reduce woody vegetation cover.

The dramatic shrinking of Lake Chad has changed the fish community structure from open water species to wetland species, and reduced fisheries productivity. In the Waza-Logone floodplains, fish yields have declined by 90%. The reduction in fisheries production and the decline in the fertility of agricultural land have contributed to regional poverty and food insecurity. Many households have been forced to migrate to other regions or to urban slums. Freshwater shortages in the Lake Chad Basin have resulted in severe ecosystem degradation and compromised human well-being and economic development.

(SOURCE: LAKE CHAD/43)



ROOT CAUSES

GIWA regional teams conducted 17 causal chain and policy option analyses related to freshwater shortage. The modification of stream flow caused the most severe environmental and socio-economic impacts of the three freshwater issues, and was predominantly chosen as the target for the causal chain analysis (Table 3 and 4). Agriculture, especially irrigation, was the sector most responsible for all three freshwater issues.

This section examines four intertwining categories of root causes of freshwater shortage: (i) demographic and economic development trends; (ii) market failures; (iii) policy failures; and (iv) knowledge gaps and lack of public engagement.

Demographic and economic trends

The most important trends affecting the level of freshwater usage are (i) population growth and urbanisation; (ii) agricultural demand; (iii) hydropower demand; and (iv) industrial demand and trade.

Population growth and urbanisation

Population growth is one of the main drivers of freshwater demand. Most projections estimate that the world population will stabilise at between 8 and 9.5 billion people by around 2050 and that most of this growth will take place in the developing world (UNDP 2004). Population growth not only triggers direct domestic water consumption but also the consumption of agricultural, industrial and other products, and energy use. The population of the world has tripled in the last century, but global water use has increased six-fold (WWC 2000).

TABLE 3. IMMEDIATE CAUSES OF FRESHWATER SHORTAGE

	Targeted issues *																						
	Modification of stream flow													Pollution of existing supplies				Changes in the water table					
	Immediate causes							Main sectors involved						Immediate causes		Main sectors involved		Immediate causes				Main sectors involved	
GIWA region	Increased diversion	Reduced rainfall	Deforestation	Changed return flows	Changed peak flows	Increased sediment load	Changes in land use	Agriculture (irrigated)	Hydropower production	Industry	Domestic supply	Infrastructure (flood protection)	Forestry	Point and non-point effluents	Poor wastewater treatment, agricultural run-off	Agriculture	Industry and/or domestic	Changed return flow or rainfall patterns	Excessive extraction	Reduced recharge	Stream flow modification	Agriculture (irrigated)	Domestic supply
2b Rio Grande/Rio Bravo (Gulf of Mexico)	✓							✓						✓		✓	✓						
24 Aral Sea	✓			✓				✓	✓					✓				✓					
27 Colorado River (Gulf of California)	✓			✓	✓			✓	✓														
34 Yellow Sea	✓							✓		✓		✓		✓		✓	✓						
41a Souss Aquifer (Canary Current North)																		✓	✓	✓	✓	✓	
41b Senegal River basin (Canary Current South)	✓	✓	✓					✓															
42b Volta Basin (Guinea Current)	✓	✓						✓	✓	✓	✓												
43 Lake Chad	✓	✓						✓															
44 Orange-Vaal River Basin (Benguela Current)	✓							✓															
46b Tana/Ahti/Sabaki (Somali Coastal Current)	✓						✓	✓	✓														
46d Rufiji/Ruvuma(Somali Coastal Current)	✓			✓	✓			✓	✓														
51 Jordan	✓							✓						✓		✓	✓		✓			✓	
59a South PNG and Papua (Coral Sea Basin)														✓		✓	✓						
62 Pacific Islands	✓					✓		✓			✓		✓					✓	✓			✓	✓
65b Central Equatorial Pacific (Eastern Equatorial Pacific)			✓	✓		✓		✓	✓					✓	✓	✓	✓						

NOTE: THE TABLE PRESENTS A SELECTION OF GIWA REGIONS WHERE THE REGIONAL TEAM HAS CONDUCTED A CAUSAL CHAIN ANALYSIS ON THE GIWA CONCERN FRESHWATER SHORTAGE. * WHEN ONLY ONE SECTOR IS LISTED, IT IS RESPONSIBLE FOR MORE THAN 50% OF THE IMPACT ON THE TARGETED ISSUE.

Higher incomes stimulate greater consumption of goods and services, the production of which requires water. Income levels are rising in many countries, particularly in China and India, in parallel with economic growth. Decoupling income growth from water consumption is one of the greatest challenges to water management.

Urbanisation is another demographic trend resulting in greater water use. The proportion of the world's population residing in cities was only 14% in the early 1900s and still only 29% in the 1950s. Since then, the urban population has grown rapidly, and more than 60% of people are expected to live in cities by 2030 (UNDP 2004). Urbanisation has had two critical impacts on transboundary freshwater use. Firstly, many cities divert enormous volumes of surface water or overexploit aquifers. Secondly, untreated or inadequately treated sewage from these cities is a major source of pollution.

Along the Rio Grande/Rio Bravo border between Mexico and the United States, population growth and the expansion of industrial and agricultural activities has led to unsustainable water use (Rio Grande/Rio Bravo (Gulf of Mexico/2b)). A major study in 2002 predicted that the total population of the Las Cruces/El Paso/Juarez region could leap from 2 million to 6 million by 2025. Such growth would put great stress on the region's water resources. Even today, the major cities rely on deep wells to abstract water from aquifers. The discharge of inadequately treated wastewater in Mexico and non-point pollution sources on both sides of the border further degrades the region's limited water resources.

Agricultural demand and trade

A growing population consumes more food which, in turn, requires larger volumes of water. Irrigation-based agriculture has contributed 80% of the increases in food production since the 1960s. In most areas, the diversion of rivers and increased water storage capacity has facilitated irrigation development. In a few areas, including parts of South Asia, groundwater extraction makes irrigation possible. In the drought-prone Canary Current region/41, irrigated agriculture consumes close to 80% of water withdrawals (Box 6).

Irrigation water is often used extremely inefficiently. For example, in the arid Senegal River Basin, less than 50% of the water is used productively, particularly in rice and market gardening crop fields. Many farmers do not recognise the economic cost of wasting water or lack the capital to install appropriate irrigation systems.

BOX 6. EXPORTING GROUNDWATER: CASE OF THE SOUSS-MASSA RIVER BASIN

The Souss-Massa River Basin in Morocco covers an area of 27 000 km². Although the basin lies within only one country, much of its water is used to produce high value export crops, and such consumption patterns illustrate the concept of virtual water discussed in Box 7. Intensive irrigation development to supply the vegetable and citrus fruit export industry, in combination with urban, tourism and industrial growth, led to chronic water scarcity in this arid to semi-arid region.

The Souss and Massa rivers are the primary sources of surface water in the Basin. Available surface water normally ranges from 341 to 635 million m^3 annually, but can be as low as 35 million m^3 in dry years. Groundwater is obtained from two major aquifers:

- The Souss aquifer, which covers 4 150 km^2 and has an estimated capacity of 30 billion m^3.
- The Chtoukas aquifer, which covers 940 km^2 and has an estimated capacity of 1 billion m^3.

The causal chain analysis undertaken by the regional team identified that the following root causes resulted in the lowering of the water table in the Souss-Massa Basin:

- Inefficient irrigation systems and inappropriate well-digging techniques: flood irrigation still supports nearly 50% of irrigated land.
- Population growth and increasing personal consumption levels: the population of the basin is expected to almost double by 2020 compared with 1994; and domestic water use per capita is expected to increase from 75 to over 120 litres per day by 2020.
- Socio-cultural constraints: water was traditionally considered a public and free resource, which has led to water being heavily subsidised and used wastefully.
- Poor governance and enforcement of water regulations: top-down decision-making and weak institutional capacity have hampered local participation in the decision-making process and constrained regulatory enforcement.

However, there is hope for the future, as Morocco has radically changed its water policies. The 1995 water law is based on the principles of Integrated Water Resources Management (IWRM), and emphasises basin-wide water management. The government is also encouraging the use of micro-irrigation and other efficient irrigation methods. Advanced irrigation systems are now commonly used in greenhouses for export crops. Other improved practices, such as integrated pest management, are also becoming more common. The water law needs to be fully implemented, so that traditional and modern water harvesting systems are considered in future plans for drainage basin and water resources development.

(SOURCE: CANARY CURRENT/41)

BOX 7. THE CONCEPT OF VIRTUAL WATER

Producing goods and services requires water: virtual water is a term recently developed to describe the water used to produce agricultural or industrial products. It is an important concept for calculating the total water consumption of a country, or its water footprint, which is equal to total domestic use, plus virtual water imports, minus virtual water exports.

Trade in virtual water has increased steadily over the last 40 years: about 15% of water used worldwide for export is virtual water. The global virtual water trade is estimated to be more than 1 000 km^3 annually, 67% of which is from crops, 23% from livestock and 10% from industrial products.

Virtual water trade not only generates water savings for importing countries, but also global real water savings from differentials in water productivity, which may amount to 385 billion m^3 for food trade alone.

SOURCES: (DE FRAITURE ET AL. 2004, ZIMMER & RENAULT 2004)

The Aral Sea/24 region needs to modernise its irrigation systems and practices, which were inherited from the Soviet era. The GIWA regional team identified critical obstacles to improving water management, including:

- Absence of inter-state agreements, which are necessary given the transboundary nature of the major drainage basins;
- Continuation of centralised planning and regulation of water resources;
- Poor condition of irrigation systems;
- Smallholder farms cannot introduce modern large-scale water saving technologies.

Environmental problems from irrigation are not limited to developing countries. In the Australian Bight & Muray Darling Basin (Great Australian Bight/61), more than a century of agricultural development has required the construction of more than 4 000 dams and weirs. Up to 80% of water flow has been diverted, primarily for agriculture, resulting in the extensive alteration of riverine ecology. Irrigation has also changed the water table and caused the widespread salinisation of groundwater, which has degraded cropland, damaged infrastructure and caused widespread loss of wetlands and biodiversity.

Trade poses both risks and opportunities for transboundary water resources. It can promote more efficient use of water by encouraging water abundant regions to produce water-intensive goods. On the other hand, the increased price of export crops following trade liberalisation can lead to the expansion of water-demanding agricultural activities. In Morocco, for example, water abstraction to irrigate export crops has increased foreign exchange but at the cost of lowering the water table of the Souss Aquifer (Canary Current/41). A similar problem is reported in the Rufiji-Ruvuma sub-system in East Africa.

The concept of virtual water is proving useful in understanding the volume of water implicitly traded via goods or services (Box 7).

Hydropower demand

Hydropower accounts for almost 20% of worldwide electricity production, and there is potential for further growth, especially in developing countries.

Although hydropower has been at the centre of successful regional and national development projects, many of these projects have resulted in unnecessarily high environmental, social and economic costs. Downstream countries and their ecosystems are the most impacted by the associated water flow changes. Of all the GIWA regions that conducted a causal chain analysis related to the modification of stream flow, Aral Sea/24, Gulf of California/27, North Canary Current/41a, Guinea Current/42 and Somali Coastal Current/46 identified hydropower and irrigation as main sectors responsible for increased diversion of freshwater resources. In the Somali Coastal Current/46 region, less than 50% of the potential hydropower is harnessed, yet the downstream impacts of hydropower developments on freshwater availability are already apparent.

The potential for hydropower development has only just begun to be utilised in many developing regions. In the Mekong River/55 Basin, only 11 hydropower facilities have been constructed, representing 5% of potential development. An additional 250 000 GWh per year could be exploited, mainly in the Yunnan Province of China, Lao PDR and Cambodia, to meet surging electricity demand in Southeast Asia and China. Many of the probable environmental and social costs from future hydropower projects could be avoided if improved practices and designs were adopted, taking into account the recommendations by the World Commission on Dams.

Market failures

Market mechanisms do not automatically lead to the sustainable use of water resources. Two market failures are particularly notable for transboundary issues. Firstly, preventing users from accessing water resources through institutional and physical means is difficult, resulting in overuse and under-investment. Secondly, water consumption by upstream users reduces the quantity and sometimes the quality of water for downstream users.

In the Lake Chad/43 region, there is little evidence that the large irrigation and water development projects in Nigeria provide any net economic benefits. In fact, it is likely that the projects have generated negative returns because of the large capital costs and the extensive loss of environmental goods and services previously provided by downstream wetlands. It is estimated that the decline in the wetlands represent an economic cost to the downstream communities of approximately 9 million USD (discussed in Box 5).

The prices consumers from industrialised countries pay for crops imported from the southern hemisphere do not include the actual costs of excessive water use.

Policy failures

Policy interventions frequently create or aggravate environmental problems, such as establishing inappropriate subsidies that encourage the overexploitation of water. The subsidies and trade distortions of the United States and EU severely impact agriculture and the water economy of developing countries. The failure of governments to take action can also affect international waters. For example, in the Yellow Sea/34 region investment in pollution prevention and wastewater treatment, and stronger enforcement of regulations may have averted some of the social and economic costs caused by pollution.

Policies implemented by governments in the Aral Sea/24 Basin failed to reduce water withdrawals for cotton farms, causing the Aral Sea to shrink to a fraction of its former size. The policy failures include: (i) inadequate use of scientific information in the decision-making process; (ii) the lack of a clearly formulated legal framework; (iii) water prices that do not reflect the full costs of water use; and (iv) the absence of a regional water strategy.

Inappropriate economic incentives

Prices, subsidies and taxes often inadvertently discourage efficient water use. Governments in developing countries give out 75% of the world's water subsidies, amounting to 45 billion USD annually (Pearce 2002). Irrigation farmers are the main recipients and in many GIWA regions in the southern hemisphere they are not charged for this water. Subsidised irrigation water is a problem in the majority of the GIWA causal chain analyses of freshwater shortage, including the Aral Sea/24, Gulf of California/27, Canary Current/41, Lake Chad/43 and Benguela Current/44.

Water subsidies allow farmers to grow water-intensive crops, like alfalfa, citrus or rice, in water scarce regions, and gives them no incentive to invest in water saving devices and new technologies. Furthermore, irrigation subsidies also tend to favour wealthier rather than poorer farmers and consumers.

Water is greatly underpriced in the Yellow Sea/34 region. In China, industrial water use is 5 to 10 times less efficient than in industrialised countries, and only 25-30% of irrigation water is effectively utilised, resulting in an annual loss of 2.5 million tonnes of grain. The GIWA regional team noted that market-based pricing of water would help increase efficiency and encourage the use of new technologies.

Irrigation water charges in the Souss-Massa Basin (Canary Current/41) are averaging only one-tenth of urban water charges and generating revenues less than 10% of the actual cost of the water. This policy encourages farmers to waste water and generates insufficient funds to upgrade irrigation systems. The government's recent pricing reforms aim to gradually increase water irrigation prices, but at a rate too slow to achieve any short-term results.

Efforts to privatise water supply and wastewater treatment in developing countries has proved challenging as local users often strongly resist price increases (which reduce subsidies).

Additional agricultural subsidies, especially for energy, fertilizers and pesticides, also have considerable impacts on water use. These subsidies are especially high in developed countries, averaging 335 billion USD annually in the late 1990s, compared with 65 billion USD in non-OECD countries (Pearce 2002). Energy subsidies for extracting water from aquifers have resulted in lower water tables in several regions, such as the Bay of Bengal/53, Gulf of Mexico/2 and Gulf of California/27.

Knowledge gaps and lack of public engagement

Knowledge gaps regarding freshwater resources have been identified by many GIWA regional teams. A strong knowledge base is essential for understanding the nature of water resources and human needs and for identifying priorities for policy makers to address. Unfortunately, a lack of technical and financial resources, and fragmented organisations are considerable obstacles to building a knowledge base, especially in developing countries.

Information on transboundary aquifers is particularly deficient. In reflection of this substantial knowledge gap, GIWA regional teams often assessed changes in the water table only by using indirect indicators, such as the construction of deeper wells and the degradation of subsurface water quality. Many hydrogeologists and international organisations have acknowledged that the lack of information on transboundary aquifers is a major impediment to water resources management. It has led to the establishment of the International Shared Aquifer Resource Management (ISARM) project in 2000, with the support of UNESCO, IAH, FAO and UNECE.

Information needs to be communicated to stakeholders, including local communities. The Pacific Island/62 regional experts recognised the need to increase public awareness of water use issues and of the impact of poor land management. Similarly, Senegalese communities downstream of sugar processors are poorly informed of the dangers posed by the contamination of their water supply (Canary Current/41).

Those excluded from participating in the decision-making process are often the most affected by unsustainable water management, e.g. the Senegalese communities discussed above. Stakeholder participation is not only a matter of equity; it also has implications for policy efficiency, implementation effectiveness and the longevity of an initiative. The major irrigation projects in the Lake Chad/43 Basin, in both Cameroon and Nigeria, are classic examples of failed stakeholder engagement. In both countries, consultation was limited to government officials with project proponents ignoring floodplain communities, which ultimately were the most affected by the projects (the impacts are described in Box 5).

POLICY RELEVANT CONCLUSIONS

The GIWA regional teams predicted that freshwater shortage will increase in severity in over two-thirds of the GIWA freshwater systems by 2020. In the arid and semi-arid GIWA regions, the accumulative impact of increased water consumption, greater pollution and global climate change may cause extreme water scarcity. In many parts of the world, a shortage of clean water is predicted to be the most serious threat to future socio-economic development.

The apparent difficulties in managing freshwater resources have led to the development of a framework: Integrated Water Resources Management (IWRM). According to the Global Water Partnership (GWP 2000), IWRM is "a process that promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". Sustainable development is impossible without better environmental management, particularly of freshwater resources. There are widespread demands for the decoupling of environmental pressure from economic growth. This is crucial considering the likelihood of rapid economic growth in developing countries with large populations. More efficient infrastructure should be developed to facilitate the sustainable use of water resources. Solutions must improve environmental quality whilst maintaining human welfare and economic development.

The paradigm shift of water management towards integrated approaches is closely linked with the recognition that entire river basins and their estuaries and adjacent coastal areas are single planning units. There is also a greater appreciation for demand-side management, rather than increasing supply by building new infrastructure. It complements the move away from focusing exclusively on the direct economic benefits of engineered structures to understanding their full environmental, economic and social effects. Inappropriate subsidies which benefit a minority of water users are also slowly giving way to water prices that reflect the actual costs.

Demand management

Demand management aims to change the way people and institutions use water in order to improve efficiency and reduce the need for expensive infrastructure development. The GIWA regional teams identified demand management as an alternative or complement to the conventional approach of increasing supply by expanding infrastructure.

The GIWA experts who prepared the Guinea Current/42 regional report stressed the importance of demand management. Specific actions recommended for the urban water sector included: (i) minimising distribution losses; (ii) encouraging industries to introduce water saving technologies and practices; and (iii) optimising reservoir management. Their counterparts in the Central Equatorial Pacific (Eastern Equatorial Pacific/65b) recommended implementing water reuse practices and providing users with guidance for optimising their water use. In the Benguela Current/4, the three national governments have historically impounded water as a means to control the highly variable supply, but only recently have they begun to manage water demand.

The provision of appropriate economic incentives, mainly through the reformulation of subsidies, is a fundamental component of any effective demand management programme. Although subsidy reforms are plausible, they are difficult to implement politically. Whilst many regional reports discuss the need to reduce water subsidies, concrete examples remain rare. Hungary successfully rolled back domestic water subsidies in the 1990s, which reduced household water consumption by around 50% (Black Sea/22). Demand management in agriculture means the replacement of water-intensive crops, like citrus fruits and bananas, by less water demanding crops or grassland, despite reduced revenues. National campaigns for "turning the desert green" by irrigation have largely proved unsustainable.

GIWA regional experts also suggested subsidies that encourage the adoption of environmentally friendly practices. The Gulf of Mexico/2 regional team recommended introducing eco-payments, in which wetland owners are paid for the wastewater treatment services provided by their wetlands. Subsidies to implement water conservation measures were recommended for farmers in locations as diverse as northern Nigeria and Southwest United States (Lake Chad/43 and Gulf of California/27).

International cooperation

Upstream and downstream countries may have different, but legitimate, interests regarding water use and management which can potentially lead to conflict. The international community has devised principles for the use of water in order to avoid such conflicts. These principles are proclaimed in the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (1977) and the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992). However, the practicality of

TABLE 4. POTENTIAL POLICY INSTRUMENTS RELATED TO FRESHWATER SHORTAGE

Contributing sector	Underlying root causes	Potential policy instruments	
		Short-term	Long-term
Modification of stream flow			
Agriculture	▪ Inadequate integration of environmental considerations ▪ Lack of clear water strategy ▪ Unclear legal framework ▪ Inadequate planning of water usage ▪ Inadequate incentives ▪ Insufficient land use management	▪ Development of normative concepts and legislation ▪ Implementation of appropriate water-economising technologies ▪ Campaigns to raise public awareness	▪ Inter-state cooperation ▪ Adoption of modern water saving technologies ▪ Grant subsidies for implementing water conservation measures ▪ Institutionalise water market ▪ Encourage public participation in the planning and implementation of development activities ▪ Improved land use and management practices
Energy production	▪ Common pool resources ▪ Inadequate implementation of improved technology ▪ Ineffective promotion of compliance	▪ Monitoring and treatment facilities for rehabilitation of water quality ▪ Improved efficiency of dams and stream flow	▪ International legal agreements ▪ Enhancement of enforcement mechanisms ▪ Convert electricity subsidies ▪ Promote energy-saving technology
Domestic water supply	▪ Rapid population growth ▪ Migration ▪ Lack of land use planning	▪ Initiate shared management of water resources ▪ Set up viable networks for information collection	▪ Regional international cooperation agreements ▪ Integrated management ▪ Strengthen family planning programmes ▪ Development of land use plans
Pollution of existing supplies			
Industry	▪ Inadequate laws and enforcement for mining activities and industrial waste management ▪ Insufficient investment in wastewater treatment	▪ Encourage the use of green production technology	▪ Enhancement of laws and enforcement mechanisms
Agriculture	▪ Lack of public awareness ▪ Lack of regulation for exploitation of aquifers	▪ Adoption of regulations and enforcement mechanisms	▪ Public awareness campaign programmes ▪ Legal framework to control use of pesticides and fertilisers
Changes in the water table			
Agriculture	▪ Insufficient management of groundwater use	▪ Salinity targets	▪ Integrated catchment and coastal management ▪ Increased cooperation between government and non-governmental organisations

NOTE: THE TABLE PRESENTS ROOT CAUSES AND POTENTIAL POLICY INSTRUMENTS IDENTIFIED BY GIWA REGIONAL TEAMS.

these conventions has been limited by their vague and sometimes contradictory language and the lack of proper enforcement mechanisms. Consequently, the impact they have made on international water management has not met expectations. The Atlas of International Freshwater Agreements (UNEP 2002) notes that "the presence or absence of institutions [such as treaties] has proven to be one of the most important factors influencing co-riparian water relations, exceeding such traditionally cited variables as climate, water availability, population density, political orientation, and levels of economic development."

Despite the complexity of transboundary river basin management and the potential conflicts of interest, countries that share international waters are generally keen to cooperate and often maintain productive relationships. This is demonstrated in many GIWA regions, including the Black Sea/22, Gulf of California/27, Amazon/40b, Canary Current/41 and Benguela Current/44.

At the international level, there is a need for a harmonised strategy for the implementation of conventions and declarations related to water. The GIWA regional assessments confirm the need for greater cooperation between riparian countries. A cooperative management framework is absent in 60% of international basins, and in many GIWA regions water allocation agreements do not exist or have not been implemented. In the Lake Chad/43 Basin the regional experts recommended the creation of a water allocation agreement, which would provide a legal framework for the equitable sharing of the Basin's water resources. Over 80% of international agreements involve only two countries, even though other countries may also share the river basin (UNEP 2002).

Successful agreements not only allocate water but address a wide range of other issues, such as hydropower, tourism and regional development. A fair distribution of benefits is more likely to result in a win-win agreement, whereas focusing solely on water volume can stall negotiations because the water received by one country equals the water loss of its neighbour. The Pacific Islands/62 experts explicitly note that all stakeholder groups, in addition to the environment, must benefit from new water resources strategies in order for them to succeed.

The mechanisms to promote participation, compliance, enforcement and conflict resolution are especially important. In addition to crucial monitoring and enforcement efforts, GIWA regions, such as the Central Equatorial Pacific (Eastern Equatorial Pacific/65b) and the Pacific Islands/62, recognised the need for education to change the behaviour of producers, particularly farmers, and domestic water consumers. Finally, agreements must consider the specific and evolving cultural, political, economic and hydrological conditions of riparian states.

International conflicts over water are becoming more common. Disputes over access to rivers and inland seas are occurring in Africa, Central and South Asia, and the Middle East. For example, conflict has been provoked by development projects reducing the flow of the Jordan/51 River by 90%.

Freshwater policy and global climate change

Farsighted international and national freshwater policies need to account for global climate change in addition to the direct human root causes of freshwater related problems. Global climate change will have varying impacts in different parts of the world, effecting vegetation and agriculture by temperature increases and shifts in the distribution and severity of droughts, precipitation and natural disasters, e.g. flooding. Global warming will also cause sea levels to rise. Changes in freshwater availability will be one of the most serious consequences of global climate change (see Box 4), which is predicted to gain momentum unless drastic measures are taken to reduce greenhouse gas emissions. The Kyoto Protocol is a step in the right direction.

Water management must adapt to the effects of climate change by adopting a holistic approach to managing ecosystems on a regional basis. Several GIWA teams advocated an integrated approach to regional freshwater management.

Capacity building for sustainable freshwater management

A new generation of scientists and managers is needed to address freshwater shortages and the other water problems. To develop and implement integrated concepts, natural and social scientists, and policy makers, need to cooperate locally and regionally. Existing expertise has to be enhanced and coordinated. However, in most parts of the world there are insufficient human resources. According to the GIWA assessments, scientific and technical capacity regarding water research and management needs strengthening. Training programmes should instil an understanding and appreciation of the complex interactions between freshwater shortage, climate change, pollution, overfishing, and habitat modification.

CHEMICAL OUTFLOW PIPE, NEW ZEALAND.
(SOURCE: K.ADAM/UNEP/STILL PICTURES)

POLLUTION

Ocean currents and rivers transport various pollutants over large distances with transboundary consequences. Complex synergies between the various contaminants can increase the overall environmental impact. Globally, the severity of the various pollutants varies considerably. Suspended matter, resulting mainly from deforestation and agricultural activity, has degraded aquatic ecosystems the most extensively, particularly in the tropics and subtropics.

While eutrophication is widespread in temperate regions, hotspots of microbial pollution are extensive in Central America, North Africa & Middle East and Europe & Central Asia. Solid wastes are dumped into rivers, lakes, coastal waters and the high seas throughout the world, but are particularly prevalent in Sub-Saharan Africa. Chemical pollution, originating predominantly from agricultural run-off and industrial and domestic effluents, is severe in several regions. At a mega-regional level, oil spills and radio-nuclides were not considered to cause severe transboundary impacts.

The root causes of pollution are again agricultural development, population growth, urbanization and industrialization, as well as market and policy failures. In most regions it is not the lack of regulations but their weak enforcement that hinders progress. Appropriate economic incentives and greater public awareness are therefore required.

The GIWA focuses on eight critical transboundary pollution issues (see Annex II):

(i) suspended solids; (ii) eutrophication; (iii) microbial pollution; (iv) solid wastes; (v) chemical pollution; (vi) oil spills; (vii) radionuclides; and (viii) thermal pollution. This last issue is not discussed further in this report as it was generally not considered to be a transboundary issue.

Pollution is often transboundary as hydrological interlinkages between river basins, marine ecosystems and the atmosphere result in effects far from the source of emissions (Box 8). This global synopsis provides a broad overview of transboundary pollution based on the GIWA regional reports. Many of the reports assess pollution impacts on smaller geographic scales and should be consulted for more detailed information.

BOX 8. TRANSBOUNDARY POLLUTION

All pollutants can be transported through the aquatic environment and atmosphere, and many accumulate in downstream water bodies and their biota. The probability that pollution will cause transboundary impacts depends on the location of its source in relation to national boundaries, as well as the time it takes for a given pollutant to degrade. In general, microbial pollution is primarily a local problem, whereas suspended solids, hydrocarbons and nutrients pose a risk over larger spatial areas. The risk of transboundary impacts tends to be highest for persistent organic pollutants (POPs), particularly substances that readily migrate between water and air (such as DDT and mercury). Although other persistent pollutants, such as PCBs and heavy metals (e.g. cadmium), are less mobile, they also have transboundary aspects. As pollution transcends national boundaries, international cooperation is required to reduce human and environmental health risks.

Global situation and trends

- Transboundary pollution is the top priority concern in a quarter of all GIWA regional reports, and a further third of the regional teams ranked it as the second most serious concern.
- Pollution has a severe overall impact in more regions than any other concern (Figure 8).
- Suspended solids, which have increased mainly as a result of deforestation and agricultural practices, severely affect coral reefs, seagrasses and riverine habitats in one fifth of the GIWA regions/sub-systems, including the Caribbean Sea/3, Brazil Current/39 and East African Rift Valley Lakes/47, and all regions in Southeast Asia.
- Microbial pollution, primarily from untreated or inadequately treated human and livestock sewage, is a severe health issue in many parts of Sub-Saharan Africa, Southeast and Northeast Asia, and Central and South America.

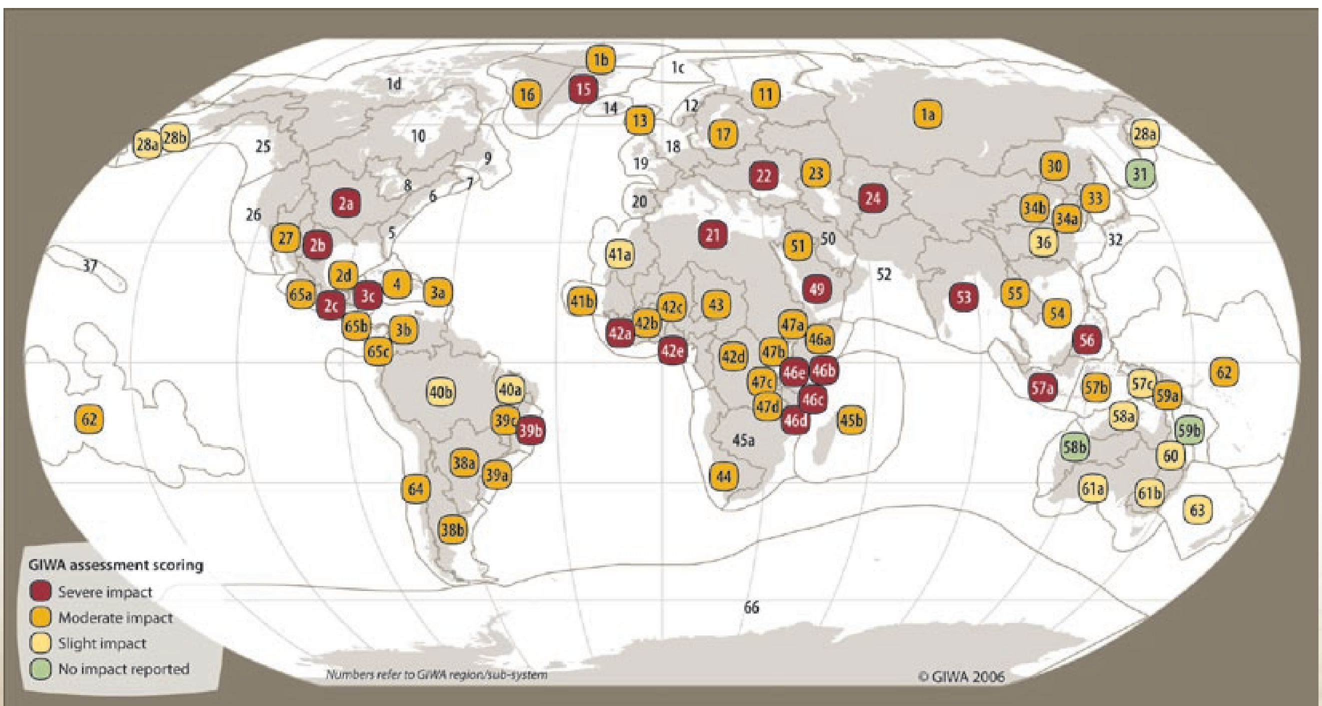


FIGURE 8. OVERALL ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF POLLUTION

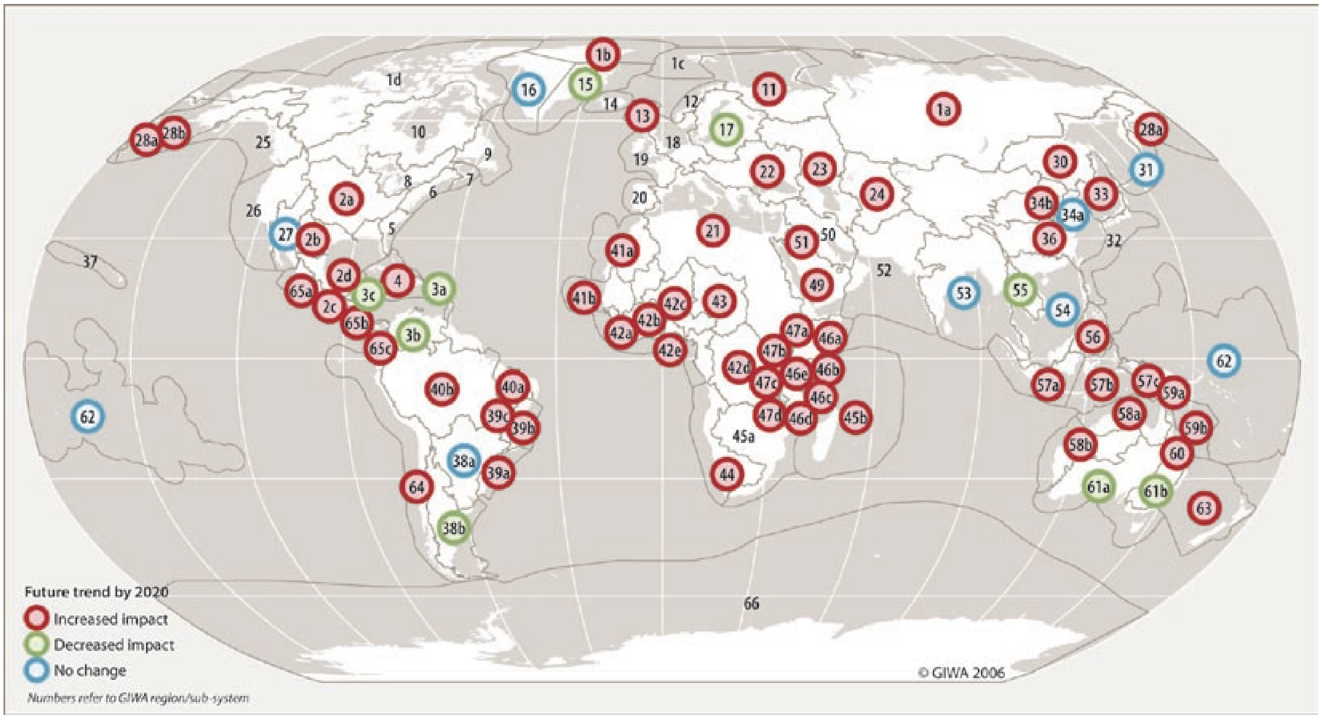


FIGURE 9. FUTURE ENVIRONMENTAL TRENDS FOR POLLUTION

- Eutrophication is prevalent in many of the lakes, rivers and semi-enclosed seas of Europe & Central Asia and Sub-Saharan Africa. Evidence from Northeast Asia and the Gulf of Mexico indicates that eutrophication is an emerging problem in open coastal marine environments.
- The dumping of solid wastes is a priority issue in many rivers and coastal areas of Sub-Saharan Africa, in Small Island Developing States (SIDS), parts of the Indonesian Seas/57 and along stretches of the Rio Grande (Gulf of Mexico/2b).
- Chemical pollution is a transboundary issue at several hotspots in Central America, West Africa, South Asia, and Southeast Asia, as well as the Jordan River/51, Aral Sea/24 and the Arctic Rim.
- The impact of oil spills was assessed as severe in the Caribbean Sea/3, Niger Basin/42c and Benguela Current/44.
- By 2020, the environmental impacts of pollution are predicted to increase in severity in over three-quarters of GIWA regions/sub-systems, making this the most negative future outlook for any of the GIWA concerns (Figure 9).

ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS

Suspended solids

More than half of the GIWA regional teams identified suspended solids as having severe or moderate impacts, concentrated particularly in tropical regions (Figure 10). Increased erosion and sediment mobilisation, caused by agricultural practices, deforestation and construction, is resulting in higher concentrations of suspended solids. Conversely, river diversion and damming often results in reduced sediment transport. Excessive suspended solids increase turbidity and siltation, while reduced sediment yields may lead to coastal erosion and lower primary productivity as nutrients are often bound to suspended solids. The same water body may experience environmental impacts from both increased and decreased suspended solids, but in different locations.

Sediments can smother coral reefs, seagrass beds and riverine gravel beds that are important spawning habitats for fish. A high concentration of suspended solids also tends to decrease the productivity of an ecosystem by reducing the penetration of sunlight through the water column, particularly affecting benthic ecosystems. Increased sediment trans-

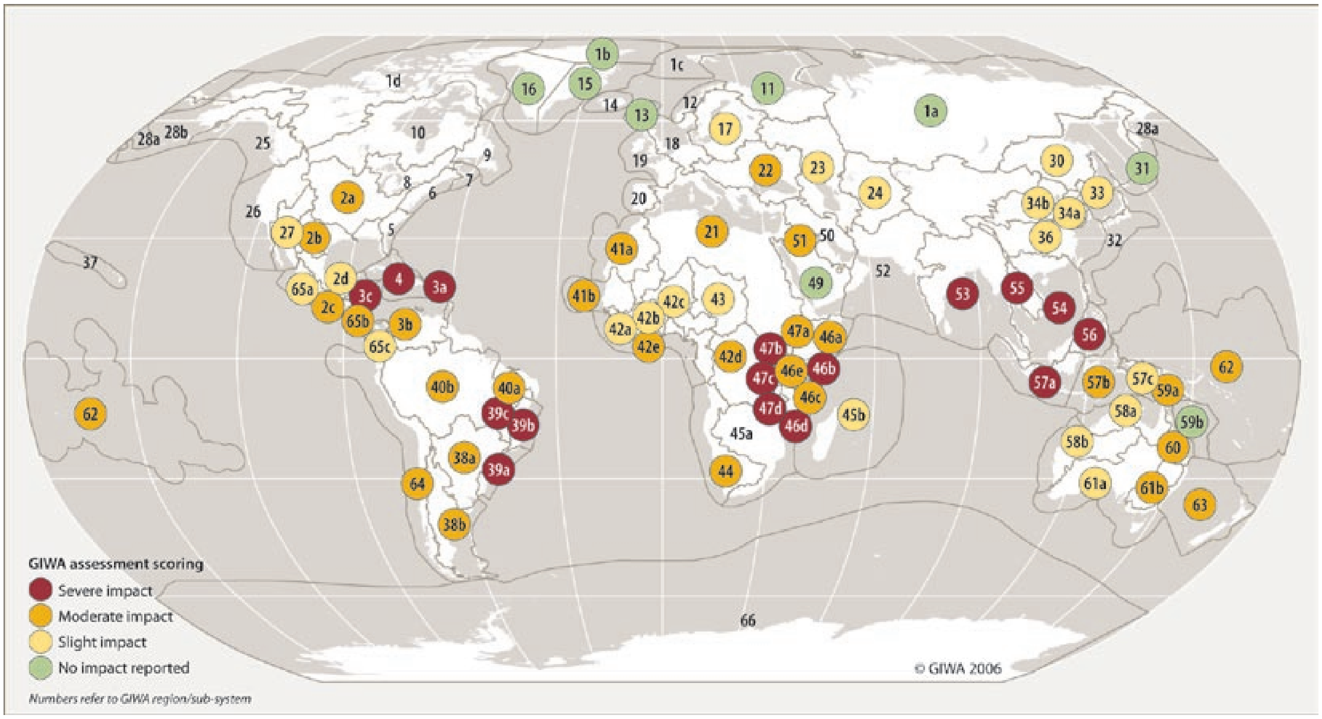


FIGURE 10. IMPACTS OF SUSPENDED SOLIDS

port related to intensive deforestation can change downstream floodplains and river deltas, thus impacting flora and fauna.

The Brazil Current/39 region illustrates both the complexity and the potential severity of the impacts of increased suspended sediments. The deforestation of large areas for agriculture and mining has increased riverbed and coastal zone siltation, which is impeding navigation along the heavily transited São Francisco River. Erosion from land-use changes in Paraná state (Brazil) has increased river turbidity considerably, resulting in higher water treatment costs for over 200 cities. The diversion and damming of waterways has

FIGURE 11. RUN-OFF FROM BAUXITE MINING IN JAMAICA
(PHOTO: CORBIS)

trapped sediments in reservoirs, which has negatively affected the sediment erosion-accretion dynamics of most rivers in the eastern part of the region. Extensive erosion of the coastline resulting from reduced sediment accretion is destroying the fringes of mangrove forests and dunes.

In the Caribbean, deforestation, inappropriate management of agricultural land, mining and urbanisation have increased erosion rates and resulted in greater sediment loads in streams, rivers and coastal waters (Figure 11). Deforestation to clear land for agriculture is considered the most significant cause of erosion, particularly in Jamaica and Haiti. The prevalence of suspended sediments has decreased biodiversity, severely degrading shallow coastal waters. For example, increased sedimentation and turbidity have adversely affected coral reefs by reducing light penetration necessary for photosynthesis, as well as scouring and smothering corals. Greater turbidity in coastal waters and elevated algal cover on reefs is attributed to nutrient enrichment and sedimentation from coastal development, particularly in Puerto Rico and the Bahamas.

Large quantities of sediment enter Lake Tanganyika (East African Rift Valley Lakes/47) as a result of increased erosion caused by land-use changes in its catchment. Satellite images revealed that, as early as 1991, 40-60% of the original forest cover in the Lake's central basin and almost 100% in the northern basin had been cleared. Increased erosion resulting from the same pattern of converting forests to farms has also affected Lake Malawi. The loss of soil not only threatens agricultural production for rural communities but negatively impacts water quality. The increasing sediment

FIGURE 12. DEFORESTATION ON JAWA, OCTOBER 2002
ISLANDS OF FOREST APPEAR GREEN AGAINST THE PALER LANDSCAPE. IN NEARLY EVERY PATCH ACTIVE FIRES CAN BE SEEN (RED DOTS).
(PHOTO: NASA)

and nutrient loads have transformed significant stretches of Lake Tanganyika's shoreline from rocky substrates to mixed or sandy substrates.

In the Indonesian Seas/57 region, the limited size of river catchments and high rates of deforestation leads to extensive sediment run-off (Figure 12). In the Java Sea, enormous quantities of sediment are discharged into coastal waters, carrying particle-bound nutrients which stimulate widespread eutrophication. Figure 13 shows reefs at risk due to sedimentation in the region. Sedimentation has been detrimental to tourism, the artisanal fisheries and aquaculture.

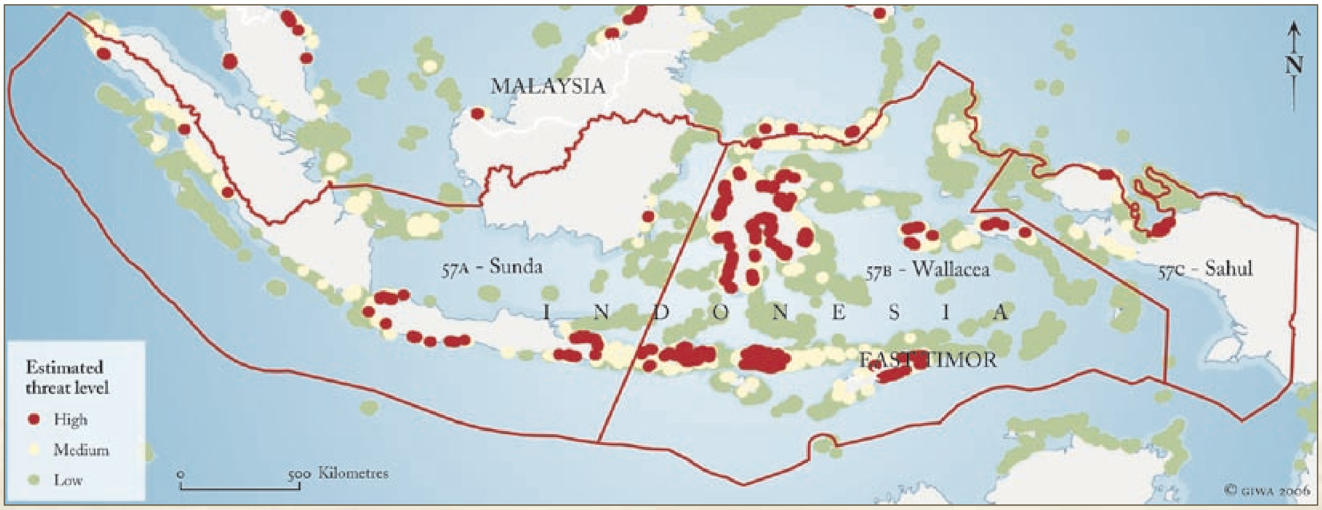


FIGURE 13. CORAL REEFS AT RISK FROM SEDIMENTATION IN THE INDONESIAN SEAS REGION
(SOURCE: BURKE ET AL. 2002)

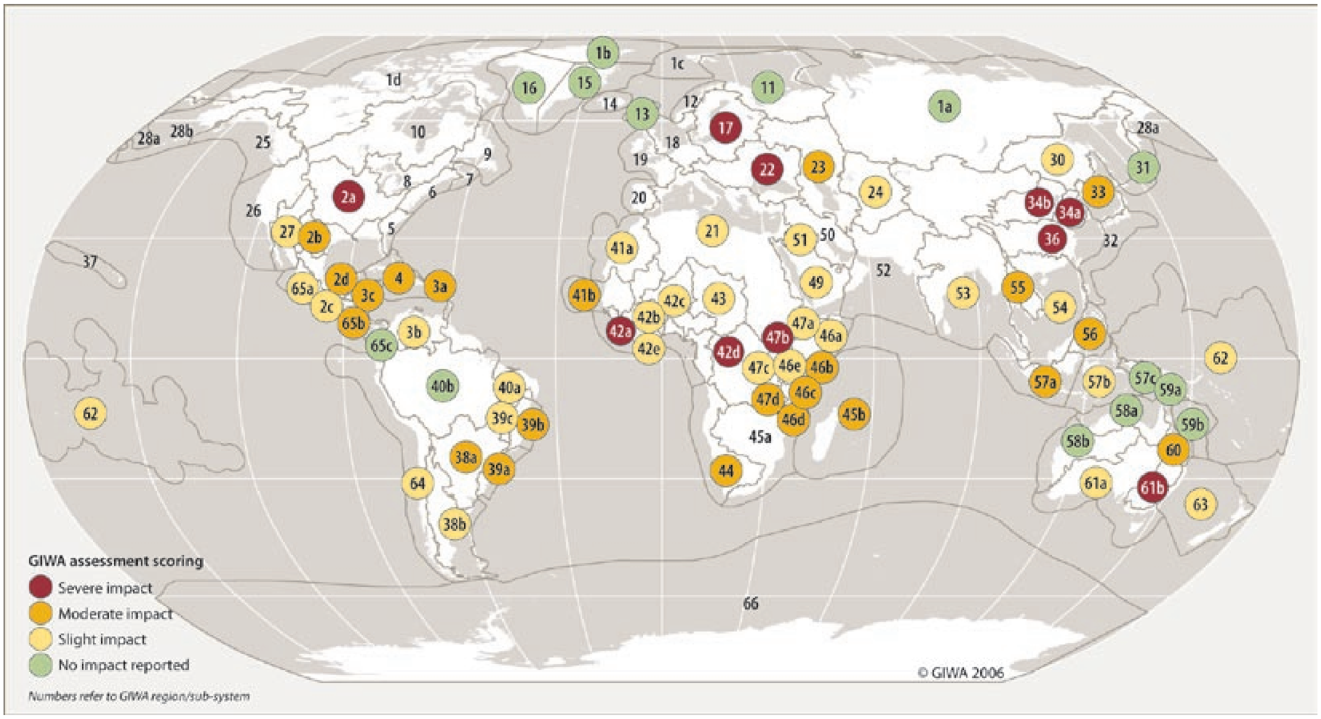


FIGURE 14. IMPACTS OF EUTROPHICATION

Eutrophication

Elevated concentrations of nitrogen and phosphorus in aquatic systems has resulted from the increased application of fertilizers, the discharge of industrial and domestic waste, animal production, the combustion of fossil fuels and nutrient mobilisation due to land clearing. These additional nutrients stimulate algal growth and alter the balance between the production and decomposition of organic matter, leading to eutrophication in many parts of the world (Figure 14).

The proliferation of fast-growing algae increases fish stocks in the short-term but decreases species diversity. Oxygen concentrations are depleted when large volumes of organic matter decompose, causing the widespread degradation of aquatic habitats. Eutrophication can generate large hypoxic zones, a phenomenon which is increasing in frequency and severity on a global scale (Box 9). A number of GIWA regional teams have noted that hypoxic zones and harmful algal blooms (HABs) are the most visible ecosystem reactions to eutrophication (e.g. Black Sea/22, Gulf of Mexico/2, Baltic Sea/17, Brazil Current/39 and Pacific Islands/62). More subtle changes include shifts in the food web, resulting in changes to phytoplankton, zooplankton and benthic communities, as well as fish populations. The initial increase in primary and secondary production often leads to a decline in the mean trophic level of the food web, comparable to the concept of 'fishing down the food web' (see the chapter on overfishing and other threats to living resources).

The transboundary inland and semi-enclosed seas of Europe are significantly affected by land-based pollutants, especially nutrients from excessive fertilizer application in their catchments, which tend to accumulate in the waters and

BOX 9. THREATS FROM HYPOXIC ZONES

Hypoxia occurs when the decomposition of organic matter causes the concentration of dissolved oxygen to fall below 2 ml/l. As a result, aquatic organisms are deprived of oxygen and many die. Several GIWA regional assessments reported dead zones consisting of hundreds or even thousands of square kilometres of hypoxic water. They have become increasingly common in the world's lakes, estuaries and coastal zones, with serious impacts on local fisheries, biodiversity and ecosystem functions. Extensive dead zones have been observed for many years in the Baltic Sea/17, Black Sea/22 and Gulf of Mexico/2.

The GIWA assessment has compiled information on dead zones in the Southern Hemisphere, including several lagoons in the Brazil Current/39 region, coastal locations in the Humboldt Current/64 region, and in the Yangtze River estuary located in the East China Sea/36 region.

sediments due to limited water exchange. In the Baltic and Black Seas, the increased frequency of algal blooms followed by extended hypoxic events has affected the ecosystems of the region (Box 10).

The GIWA assessments highlighted the widespread transboundary effects of eutrophication in freshwater systems. This is evident in lakes, such as Lake Victoria, where eutrophication combined with overfishing and the introduction of alien species has altered the Lake's ecosystem and consequently decreased the variety of endemic cichlid fishes. Wetlands in the Congo River Basin are also suffering from eutrophication, which is attributed to the flat morphology of the coastal plains and the discharge of insufficiently treated wastewater from the many cities in the Basin (Guinea Current/42d).

Although the extent of eutrophication in coastal marine areas is largely restricted to estuaries and inner shelf areas, its expansion into open marine areas, such as the Gulf of Mexico/2, is recognised as a future threat. Higher water

BOX 10. EUTROPHICATION: CASE OF THE BLACK SEA

The Black Sea is one of the world's largest inland seas, with twenty-three countries partially or completely contained within its catchment area. Three of the four largest rivers in Europe flow into the Black Sea, namely, the Danube, Dnipro and Don, and more than 160 million people live in its catchment area.

In the past 30 years, human activity has transformed the Black Sea from a diverse ecosystem supporting varied marine life to a eutrophic plankton-based system. Eutrophication was identified by the GIWA regional team as the most critical environmental issue, primarily caused by excessive nutrient loading from agricultural run-off (80%) and sewage discharges (15%). The application of fertilizers in the Black Sea drainage basin increased rapidly during the second half of the 20th century. Today, nearly 650 000 tonnes of nitrogen and more than 50 000 tonnes of phosphorus enter the Black Sea annually. Communities in the basin discharge 2 500 million m^3 of wastewater every year, much of it untreated.

The high nutrient loads have resulted in extensive eutrophication in the northwest of the Black Sea, the Azov Sea and the lower sections of the Danube and Dnipro rivers. In 2000, a hypoxic area of 14 000 km^2 covered shallow parts of the Black Sea in addition to the permanently hypoxic deep waters of the Black Sea basin. Harmful phytoplankton blooms and toxic red tides have become a regular occurrence in the last 25 years. While native species diversity has been reduced by eutrophication, invasive species, introduced via ship ballasts, have proliferated at the detriment of native species (see Box 26 in the chapter on overfishing).

The degradation of the Black Sea has resulted in substantial economic costs. For example, tourism revenues have declined by an estimated 360 million USD annually, and coastal communities lose 120 million USD every year from reduced fishing yields.

The countries surrounding the Black Sea increasingly recognise the need to cooperate in addressing pollution. National water policies are being adapted to conform to the EU Water Framework Directive. This will create greater harmonisation and integration regarding environmental protection and water management, and ultimately, improve the environmental conditions of the Black Sea.

Despite this progress, eutrophication and harmful algal blooms are expected to increase in prevalence and severity by 2020. Although additional sewage treatment facilities are planned, the region will still lack the capacity to treat increasing quantities of wastewater. Improvements in agricultural practices owing to the adoption of EU environmental policies will reduce nutrient loading in the Danube River Basin. On the other hand, greater fertilizer application in Russia, Belarus and the Ukraine will increase nutrient loads discharged by the Don and Dnipro rivers. This differing outlook for the region's various river basins highlights the need to adopt integrated transnational approaches to rehabilitate the entire Black Sea.

(SOURCE: BLACK SEA/22)

temperatures resulting from climate change may exacerbate eutrophication.

The Humboldt Current/64 region, shared by Chile, Ecuador and Peru, produces more than 20% of the world's total fisheries output. The numerous fish processing plants, which discharge their wastes directly into the ocean, are a major source of nutrient enrichment in coastal waters. This causes eutrophication and hypoxia in semi-enclosed bays, particularly in Peru, which are also susceptible to toxic algal blooms. The growing aquaculture sector is another important source of nutrients for eutrophication. The amount of waste produced by Chilean salmon farms is comparable to that generated by a city of over 2 million inhabitants. For more information on the fisheries and aquaculture industry, see the chapter on overfishing and other threats to living resources.

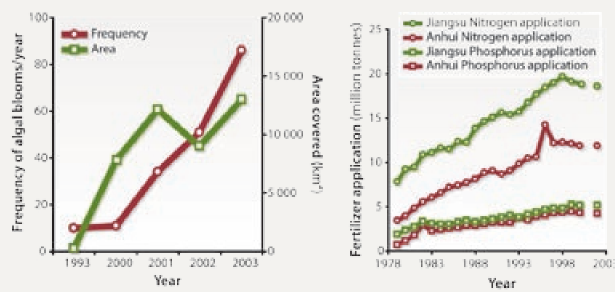
Eutrophication favours the development of HABs, including red tides. Red tide events, originally referring to reddish-coloured algal blooms, is now a term used to characterise the explosive growth of toxin-producing microbes that can cause disease or mortality in fish, wildlife and consumers of contaminated shellfish. In eutrophic freshwater systems, blooms of cyanobacteria and other potentially harmful algae are common. For example, hepatotoxins released by algal blooms in eutrophic reservoirs of Brazil have poisoned hundreds of people. In the Yellow and East China Seas, increases in the frequency, extent and duration of HABs since the 1970s are correlated with increased use of fertilizers (Box II). Even if HABs are confined to relatively restricted areas, they are often transboundary in nature as the nutrient source is from another country and/or the contaminated shellfish are exported. Furthermore, HAB organisms are transported over long distances by shipping traffic.

Eutrophication has been a contributing factor in reducing fisheries production. In the Yellow Sea/34, for example, it has caused drastic declines in catches of penaeid shrimps (*Penaeus* spp.) and scallops (*Pecten* spp.). In many parts of Sub-Saharan Africa, including the Comoe River, Niger Delta and East African Rift Valley Lakes, eutrophication of rivers and lakes has contributed to the "explosion" of aquatic weeds, particularly Water hyacinth (*Eichhornia crassipes*). These weeds have clogged waterways, disrupted navigation routes, reduced hydroelectric power generation and increased water treatment costs. The GEF, UNDP and the World Bank are funding projects to control invasive aquatic weeds in Lake Victoria and the Comoe Basin.

BOX II. HARMFUL ALGAL BLOOMS: CASE OF THE EAST CHINA SEA

Between 1993 and 2003, the number of harmful algal blooms (HABs) in the East China Sea have increased from 10 to 86 events per year and they cover an area of up to 13 000 km². The blooms have caused the mortality of fish and benthic animals, resulting in considerable environmental and socio-economic costs. The blooms mostly occur in the inner shelf of the Yangtze (Changjiang) River. This has been attributed to a 250% increase in fertilizer application in the catchment area, particularly in the upstream and coastal provinces of Anhui and Jiangsu.

(SOURCE: EAST CHINA SEA/36)



The Sea of Japan/33, which is bordered by China, Japan, North and South Korea and Russia, is also experiencing harmful effects from eutrophication, including a decline in the aesthetic value of lakes and reservoirs, reduced drinking water quality and HABs. Although all the countries in the region recognise that inadequate treatment of human waste and agricultural run-off are the major causes of eutrophication, the developing countries cannot afford secondary and teritary treatment that is necessary to reduce the nutrient and organic loads of rivers, lakes and the sea.

Microbial pollution

In many GIWA regions, inadequately treated human sewage is the major source of microbial pathogenic pollution. Improved sanitation is one of the fundamental Millennium Development Goals (MDGs), which is discussed further in the chapter on freshwater shortage. Animal wastes are also an important contributor, especially near large industrial farms such as those located around the Upper Uruguay River in Brazil (Patagonian Shelf/38). The contamination of public water supplies or bathing waters by infectious pathogens creates serious health problems, particularly in low-income areas with inadequate drinking water treatment, sanitation facilities or drainage basin protection. Pathogens can accumulate in filter-feeding molluscs and other seafood, posing health risks to human consumers.

Microbial pollution is normally localised, but its root causes and consequences can be transboundary. According to the GIWA regional teams, many international freshwater systems suffer from severe microbial pollution. Marine microbial pollution was assessed as severe in the Gulf of Mexico/2, Caribbean Small Islands/3a, Comoe Basin (Guinea Current/42a), Indonesian Seas/57a and the Eastern Equatorial Pacific/65c. The high bacterial counts recorded in many bays of the Small Islands/3a were attributed to failed septic systems, inadequate or lacking wastewater treatment and discharges from vessels, including cruise liners. In Indonesia, all major rivers in Jawa and Sumatra, as well as coastal areas in the Jawa Sea, have elevated coliform concentrations, and consequently the incidence of bacterial gastro-enteric disorders has recently increased due to the consumption of contaminated fisheries products.

The aquaculture industry in many developing regions, such as the Bay of Bengal/53, Humboldt Current/64 and South China Sea/54, has been adversely affected by transboundary microbial pollution as the contamination of seafood has resulted in reduced exports.

Microbial pollution is extensive in the Humboldt Current/64 region, with high coliform concentrations recorded along the entire Southeast Pacific coastline. Over 80% of wastewater from Peru, Ecuador and Chile is discharged without treatment. Diarrhoea, caused by poor sanitation conditions, is mainly responsible for the high rates of child mortality and morbidity in Ecuador and Peru. Municipal wastewater treatment is also inadequate in the Patagonian Shelf/38 region. The coastal states of Brazil, Argentina and Uruguay only have the capacity to treat 20-30% of their effluent. Intensive poultry and swine breeding facilities in Brazil also contribute large quantities of microbial pollutants to the Uruguay River Basin.

Solid wastes

Solid wastes, such as fishnets, and plastics and rubbish from households and industry, are a major aesthetic nuisance and can harm fish and other wildlife. They are a transboundary problem as rivers and ocean currents transport land-based and ship-borne wastes across vast distances. Improperly disposed solid wastes provide breeding environments for vermin, which may, in turn, become disease vectors. GIWA regional teams determined that solid wastes are a common problem in the majority of GIWA regions, but are particularly severe in many regions of Africa, the Pacific Islands/62 and on Sunda in the Indonesian Seas/57 region.

FIGURE 15. SOLID WASTE ON BEACH, GRAND COMORES (PHOTO: R. PAYET)

Solid waste is the most severe pollution issue for the Indian Ocean Islands/45b. At least 2.8 million tonnes of solid waste is generated annually in the region, of which only 30% is collected routinely. In addition to impacting coastal and marine ecosystems, solid wastes also affect local tourism, damage fishing nets and jeopardise the safety and livelihood of fishers and recreational boaters. Solid wastes, especially containers, provide a habitat for mosquitoes, and have subsequently increased the prevalence of malaria in Madagascar and Comoros.

In the Caribbean Islands/4 region, a large proportion of marine debris originates from shipping traffic. In addition to locally produced solid waste, an estimated 700 000 tonnes of solid waste is generated annually by the 35 million tourists who visit the Caribbean, many on cruise liners. The ports in the region lack waste collection facilities and many ships dump their waste at sea. The large quantity of marine debris deposited on beaches impacts tourism, the cornerstone of the region's economy.

Chemical pollution

In the GIWA methodology (see Annex II), chemical pollution refers primarily to persistent organic pollutants (POPs) (e.g. PCBs, dioxins, furans, DDT and toxaphene) and heavy metals (e.g. mercury and cadmium). These toxic chemicals are ubiquitous as they travel long distances dissolved in water, adhered to sediments, transported by air or transferred in the food chain, but usually only in small concentrations. However, there are chemical pollution hotspots which pose significant health risks to humans and wildlife. Although chemical pollution was considered severe in only nine regions, in a further 35 the impacts were assessed as moderate.

In the Arctic, the presence of persistent pollutants transported by the atmosphere and currents is a major concern. Marine organisms, and consequently food, obtain POPs from the surrounding environment and indirectly through biomagnification in marine food webs, resulting in consumption restrictions for specific species. Exposure to POPs in some Greenland districts is among the highest ever measured. Neurobehavioural effects from POP exposure have been observed in children in some areas of the Arctic.

One of the most heavily polluted river systems in the world is the Ganges-Brahmaputra, where chemical and microbial pollution is prolific. The concentrations of several chemical contaminants, including chromium, cadmium, mercury and lead, exceed health standards by between 10 and 100 times in both India and Bangladesh. The Ganges River is a major recipient of industrial waste from Indian factories. Downstream in Bangladesh, about 6 000 large- and medium-scale industries and another 24 000 small-scale industries also discharge their waste directly into the river.

In Central America, pesticides applied to sugar cane, banana and coffee plantations have caused human mutations, miscarriages and sterility in local populations. Pesticide contamination is also partly responsible for reduced fish stocks in the Nicoya Gulf of Costa Rica. An ongoing GEF/UNEP project addresses these problems by reducing the use of agricultural pesticides in Colombia, Costa Rica and Nicaragua. In the adjacent Small Islands of the Caribbean Sea region, agriculture is also the primary sector causing water pollution, mainly through agro-chemical leaching, direct agro-chemical influx from aerial spraying and improper disposal of solid wastes. This situation is exacerbated by the increasing use of low-lying wetlands for rice cultivation, which requires heavy pesticide use. Fish mortality in the neighbouring Caribbean Islands/4 region is often higher downstream from agricultural areas known to use pesticides. In Jamaica, for example, an increase in fish mortality in coastal areas occurs seasonally when pesticides are applied to coffee plantations.

Oil Spills

Oil tankers, vessel accidents, coastal oil refineries and pipelines are all potential sources of spills which can cause significant, although mostly short-term, impacts on the environment. Lakes and semi-enclosed seas, such as the Black Sea/22, Caspian Sea/23, and Baltic Sea/17, are particularly vulnerable to the impacts of oil spills due to limited or no water exchange.

The impact of oil spills was assessed as severe in most of the transboundary waters of the Caribbean Sea/3, Niger Basin (Guinea Current/42c) and Benguela Current/44. In the future, oils spills are most likely in areas already intensely exploited for oil and around oil fields currently under development.

Nearly 5 000 oil spills in the Niger River delta were reported between 1976 and 1996, releasing nearly 375 000 tonnes of oil in total. This has resulted in groundwater contamination and a loss of biodiversity in the vicinity of oil installations. Oil

BOX 12. POLLUTION SYNERGIES AND INTERACTIONS: CASE OF THE PATOS/MIRIM LAGOON SYSTEM

Pollution is often just one of several human stressors affecting an ecosystem. An example of a transboundary system affected by multiple anthropogenic activities is the Patos/Mirim Lagoon system, located on the border between Brazil and Uruguay. The lagoon system includes extensive estuarine habitats that in the past provided Brazil with over 25% of its fish catches.

Over the last 30 years, rice cultivation has become the principal agricultural activity and now uses 97% of the water withdrawn from the Mirim Lagoon. In addition, large amounts of biocides and fertilizers are applied to the rice paddies. The contaminated run-off pollutes water supplies and increases water treatment costs. The Patos Lagoon is further polluted by the discharge of domestic sewage and industrial effluents.

Deforestation to clear land for agricultural expansion and urban development has resulted in greater sedimentation, increased dredging to maintain navigation routes, reduced tourism and increased water treatment costs. It has also invoked conflict over water quality between Uruguay and Brazil. The increased water turbidity has decreased primary productivity, which combined with overfishing and pollution has reduced fish stocks.

The Patos/Mirim Lagoon system is an all too common example of synergies between multiple stressors where the combined impacts are greater than the sum of the impacts from individual stressors. In this case, as in many others, pollution often drives other environmental changes, such as habitat modification.

(SOURCE: BRAZIL CURRENT/39)

spills frequently occur in the Russian Arctic/1a and the Sea of Okhotsk/30 due to the use of antiquated equipment. Every year, about 300 spills are officially recorded in western Siberia, but the actual figure could be significantly higher. The degradation and dissipation of hydrocarbons tends to be slowed by low temperatures, so Siberia and other cold regions, such as the Barents Sea and the rest of the Russian Arctic, face disproportionately higher impacts from oil spills.

Emergency response and clean-up operations for large oil spills are extremely costly. In the Caribbean Islands/4, the spill off San Juan, Puerto Rico in 1994 (Figure 16) required more than 1 000 workers and more than 87 million USD for clean-up operations. Surveys carried out in Cuba, Puerto Rico and the Dominican Republic showed that tourism revenues have been reduced due to the pollution of beaches by marine debris and tar balls.

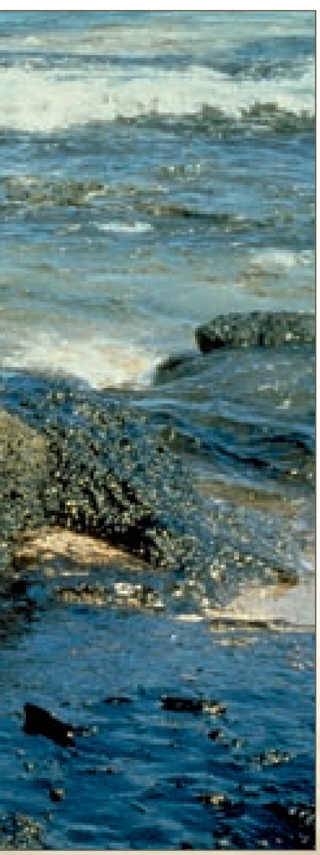


FIGURE 16. OIL SPILL CAUSED BY THE BARGE MORRIS J. BERMAN OFF SAN JUAN, PUERTO RICO 1994
(PHOTO: NOAA)

Radionuclides

The transboundary impact of radionuclides was assessed as severe in only two GIWA regions: the Pacific Islands/62 and the Benguela Current/44. In the Pacific Islands/62, there is concern over recent nuclear weapons testing by France on Muroroa and past tests by the United States on the Marshall Islands. In the Benguela Current/44 region, uranium mining may have contaminated freshwater ecosystems in East Rand, South Africa. The large amount of radioactive waste and the numerous nuclear submarine bases in areas of Russia bordering the Barents Sea and the Arctic Seas also require careful management.

The interactions between the various pollutants and the other GIWA concerns are highlighted in the case of Patos/Mirim Lagoon system (Box 12).

ROOT CAUSES

A causal chain analysis for pollution was conducted for 22 GIWA regions (Tables 5 and 6). Eutrophication, chemical pollution and suspended solids were the issues most frequently targeted for analysis.

TABLE 5. IMMEDIATE CAUSES OF THE GIWA CONCERN POLLUTION

	Targeted issues															
	Suspended solids		Eutrophication					Microbiological pollution			Chemical pollution					Oil spills
	Immediate causes															
GIWA region	Deforestation	Agricultural land use	Agricultural run-off	Transport and energy sector atmospheric inputs	Aquaculture effluent	Industrial and domestic discharge	Deforestation	Agricultural run-off	Industrial and domestic discharges	Discards from beach users and cruise ships	Long-range atmospheric transport	Industry and mining discharges	Waste discharges	Agricultural run-off	Leaking landfills	Oil extraction, refining and transport
1a Russian Arctic											✓	✓				
2a Mississippi River (Gulf of Mexico)			✓									✓		✓		
4 Caribbean Islands			✓			✓			✓	✓						✓
11 Barents Sea																✓
13 Faroe Islands											✓					
15 East Greenland Sea											✓	✓	✓			
17 Baltic Sea			✓	✓		✓										
22 Black Sea			✓			✓										
30 Sea of Okhotsk																✓
33 Sea of Japan			✓		✓											
36 East China Sea			✓		✓	✓										
39a Mirim Lagoon (Brazil Current)	✓	✓	✓											✓		
39b Doce River Basin (Brazil Current)	✓	✓				✓			✓				✓		✓	
42a Comoe Basin (Guinea Current)			✓			✓	✓									
42e Guinea Current LME (Guinea Current)												✓			✓	
47b Lake Victoria (East African Rift Valley Lakes)		✓	✓			✓		✓	✓		✓	✓		✓		
64 Humboldt Current			✓			✓			✓			✓		✓		
65a Southwest Mexico (Eastern Equatorial Pacific)								✓	✓							

NOTE: THE TABLE PRESENTS A SELECTION OF GIWA REGIONS WHERE THE REGIONAL TEAM HAS CONDUCTED A CAUSAL CHAIN ANALYSIS ON THE FIVE MOST FREQUENTLY ANALYSED ISSUES OF THE GIWA CONCERN POLLUTION.

This section groups the root causes of pollution into three broad and interlinked categories: (i) demographic and economic trends; (ii) market failures; and (iii) policy failures.

Demographic and economic trends

Water consumption and wastewater generation increases in parallel with population growth and urbanisation. Many GIWA regional assessments found that urban wastewater treatment coverage has failed to increase at the same rate as urban growth in developing regions (Figure 17). Untreated urban wastewater was identified as a major source of microbial pollution and nutrients in Lake Victoria. Other regional teams that highlighted discharges from urban areas as an important source of pollutants include the Humboldt Current/64, Eastern Equatorial Pacific/65, Indian Ocean Islands/45b, Guinea Current/42, East China Sea/36 and Black Sea/22.

In the Humboldt Current/64 region, the urban population has increased rapidly and now accounts for 74% of the total population of 41 million. Migration to urban areas was

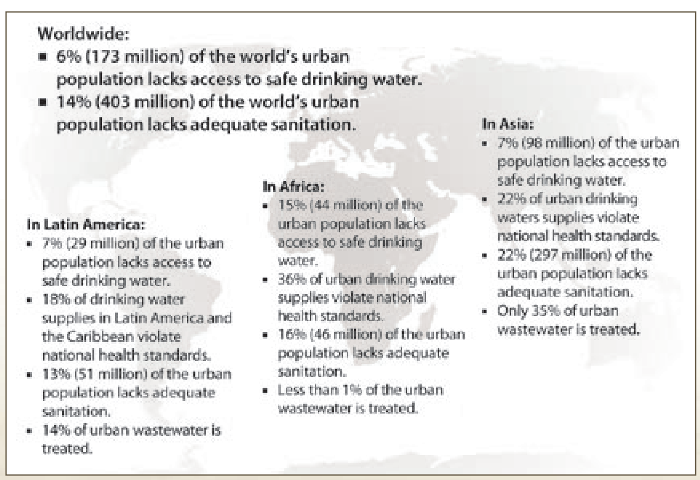


FIGURE 17. PROPORTION OF TREATED URBAN WASTEWATER IN DIFFERENT CONTINENTS OF THE WORLD
(SOURCE: WHO/UNICEF 2000)

TABLE 6. POTENTIAL POLICY INSTRUMENTS RELATED TO THE GIWA CONCERN POLLUTION

Contributing sector	Underlying root causes	Potential policy instruments	
		Short-term	Long-term
Eutrophication			
Agriculture	▪ Subsidies for chemical fertilizers ▪ Lack of awareness and training of farmers on the use of fertilizers	▪ Redesign agricultural subsidies to foster efficient use of inputs ▪ Information campaigns ▪ Promote the adoption of effective bio-substitutes	▪ Encourage alternative fertilizing techniques ▪ Encourage R&D for bio-fertilizers ▪ Establish riparian buffer zones ▪ Eco-payments for natural filtering habitats
Urban sewage	▪ Limited funding for treatment infrastructure ▪ Lack of incentives to operate existing infrastructure	▪ Provide additional infrastructure and complementary technology to treat wastewater	▪ Integrate sewage infrastructure in future development
Industry	▪ Lack of appropriate technology for treatment of industrial waste ▪ Lack of regulation, compliance and enforcement	▪ Introduce effluent charges ▪ Provide additional infrastructure and cost-effective technologies.	▪ Introduce clean industrial technologies
Chemical pollution			
Industry and mining	▪ Lack of regulations and enforcement regarding industrial leaks and discharges ▪ Absence or lack of treatment infrastructure	▪ Regulate and enforce ▪ Introduce effluent charges ▪ Provide necessary infrastructure ▪ Introduce assurance bonds ▪ Introduce financial incentives for clean operating industries	▪ Integrate the cleaning of industrial effluents into sector planning ▪ Initiate participatory measures ▪ Introduce cost-effective clean technologies
Agriculture	▪ Limited awareness of how to use chemicals appropriately ▪ Lack of resources for supervision and control of chemical inputs	▪ Information campaigns ▪ Promote the adoption of effective bio-substitutes ▪ Redesign agricultural subsidies to foster efficient use of inputs	▪ Encourage R&D for bio-fertilizers ▪ Promote alternative agricultural practices
Suspended solids			
Forestry, coastal development, mining	▪ Lack of land use planning and governance	▪ Improve watershed planning and management ▪ Improve regulations and enforcement ▪ Provide cost-effective filtering infrastructure ▪ Establish eco-payments to improve land use ▪ Mobilise resources to enforce existing regulations	▪ Coordinate stakeholders in participatory process ▪ Upgrade governance. ▪ Establish eco-labelling
Solid waste			
General public	▪ Lack of collection and disposal infrastructure ▪ Low awareness of impacts ▪ Low compliance with regulations	▪ Revise regulations ▪ Apply fines ▪ Participatory measures ▪ "Deposit-refund" measures for selected items	▪ Awareness campaigns
Industries, municipalities, transportation	▪ Lack of regulations ▪ Low compliance and enforcement ▪ Limited capital and technology	▪ Review regulations ▪ Provide designed disposal areas and infrastructure ▪ Enforce via fines	▪ Provide waste treatment and recycling infrastructure ▪ Information campaigns
Oil spills			
Oil exploitation, transportation, infrastructure	▪ Lack of compliance with IMO rules ▪ Lack of cleaning and waste infrastructure ▪ Lack of contingency planning at regional level ▪ Lack of enforcement capabilities at national level	▪ Build reception facilities ▪ Strengthen compliance and enforcement with IMO rules ▪ Foster regional dialogue and spill preparation ▪ Improve surveillance and traffic monitoring	▪ Regulate and enforce standards for refineries ▪ Improve accident response and clean-up
Microbiological pollution			
Urban sewage	▪ Limited resources for treatment ▪ Lack of incentives to operate existing infrastructure ▪ Lack of local regulations and compliance	▪ Provide and sustain infrastructure, technology and manpower ▪ Include treatment costs in price of water	▪ Integrate sewage infrastructure in future urban development ▪ Promote use of treated water

NOTE: THE TABLE PRESENTS ROOT CAUSES AND POTENTIAL POLICY INSTRUMENTS IDENTIFIED BY GIWA REGIONAL TEAMS.

triggered by low agricultural productivity and profitability, violence in the countryside and open access to urban lands. These new and, in most cases, informal settlements create a tremendous demand for sanitation, health care and other services, which governments find hard to meet. The discharge of untreated wastewater from these settlements has deteriorated the coastal waters.

Agriculture was identified as the major cause of nutrient enrichment in nearly all GIWA regions that conducted a causal chain analysis related to eutrophication (Table 6). The use of fertilizers has dramatically increased global food production, but it is the main source of nitrate pollution, with up to 80% of the nitrogen fertilizer resulting in environmental contamination rather than improving yields. The quantity of fertilizer nutrients entering the environment is closely connected to the extent appropriate technologies have been employed in agricultural production. Agriculture is also a source of phosphate pollution and persistent organic pollutants, such as pesticides.

Industrial effluents, particularly in developing countries, are usually discharged directly into water bodies and can pollute large volumes of water and infiltrate aquifers. In western South America, like in many developing regions worldwide, effluent treatment is frequently inadequate in the mining, petrochemical, fishmeal and cannery industries. Industrial pollution can be transported in the atmosphere for thousands of kilometres before being deposited. Emissions from Europe, Asia and North America are the major sources of chemical contamination in the Arctic. Reducing these sources requires significant international effort to control emissions and to enforce existing agreements.

Market failures

Transboundary pollution is rarely caused deliberately by individuals or organisations, but is usually the result of negligence or actions taken to protect private interests, such as avoiding financial costs for waste treatment. The social and environmental costs of pollution caused by production processes are not included in the price of products.

In the Caribbean Islands/4 region, waste treatment is costly for cruise line operators and there is an absence of economic incentives to discourage them from dumping wastes at sea. The countries of the region are reluctant to penalise these polluters due to their dependence on foreign exchange from tourism.

In the Baltic Sea/17 region, consumer prices for water and water treatment vary considerably between the riparian countries. Ideally, prices should include indirect costs to ensure sufficient investment in wastewater treatment and to minimise pollution. However, in the Baltic region, even the direct costs related to water services are only fully recovered in Finland and Sweden. In Denmark and Germany, the degree of cost recovery is high, whereas in Estonia, Latvia, Lithuania, Russia and Poland, it remains low. It is anticipated that new legislation in these countries will gradually lead to the full recovery of costs for water services.

Policy failures

The GIWA regional teams stressed the importance of policy-driven root causes of transboundary pollution. Policy failures commonly result from the inability of institutions to perform three key functions:
(i) identify the indicators of a problem and agree on its nature; (ii) reach agreements that balance the interests of stakeholders both within and across countries; and (iii) implement and enforce these agreements.

A scientifically reliable understanding of an environmental problem is insufficient to trigger mitigatory actions. For example, despite acknowledging the negative affects of deforestation on aquatic ecosystems and subsequently human well-being, governments rarely take action to control forestry.

When formulating policies, governments commonly disregard environmental and stakeholder concerns. In the Aral Sea/24 Basin, the centralised planning policies of the former Soviet Union subsidised agricultural inputs in order to increase cotton production, which led to excessive fertilizer application. The governments also failed to deter cotton farmers from withdrawing excessive quantities of water. Consequently, the Aral Sea shrank to a fraction of its former size and the coastal zones of Kazakhstan and Uzbekistan are heavily polluted.

Agreed goals and actions that address transboundary issues are often inadequately implemented and/or enforced. Sea-borne pollution is still extensive in the Caribbean Islands/4 region despite the adoption of the International Convention for the Prevention of Marine Pollution from Ships (MARPOL). Enforcement of MARPOL is the responsibility of national governments, but they lack the capacity and the political will to fulfil their obligations. Ships can therefore avoid compliance with the regulations.

Chile, Ecuador and Peru are faced with an urban waste crisis because waste treatment is already subsidised to such an extent that they cannot afford to extend or upgrade the treatment infrastructure. There is an absence of an incentive framework, which could include clean technology subsidies and regulatory enforcement. In Chile, industries have stepped forward to partially address this policy failure through industry self-regulation.

The implementation of a bilateral integrated management plan for the Mirim Lagoon Basin failed due, partly, to a lack of harmonisation between the legal instruments of Brazil and Uruguay. With both countries finding it difficult to obtain national agreement on pollution management, it is not surprising that the bilateral agreement was difficult to implement. Furthermore, State agencies charged with pollution management lack autonomy and the capacity to control pollution in the lagoon.

In the former Soviet states, governments and international agencies pursued decentralisation before establish-

BOX 13. POLLUTION AND POLICY FAILURE: CASE OF THE AMUR RIVER BASIN

The Amur River is one of the largest rivers in Asia, with a catchment area of 2 million km^2. The basin has a population of 75 million; over 90 % live in China. Three other countries also share the river basin; Russia, Mongolia and North Korea.

The quality of surface water in the Amur River Basin ranges from pure in the upstream mountainous regions to highly contaminated in the downstream urban areas. Agricultural run-off and sewage from urban areas contribute excessive quantities of nutrients and organic matter to the rivers. Consequently, a considerable portion of the population is forced to consume polluted surface water, which has resulted in a high prevalence of water-borne illnesses.

The GIWA regional team identified the main root causes of eutrophication to be inadequate water management policies and a lack of long-term and inter-sectoral planning. In addition, they noted that short-term economic interests have taken priority over sustainable development. More specifically, insufficient revenues are generated from water due to low taxation and underpricing which prevents the adequate financing of water monitoring and water treatment facilities. National water laws are also absent or inadequate, and institutional capacity is weak and undermined by corruption, resulting in ineffective enforcement. With such weak national frameworks, it is not surprising that there are no basin-wide intergovernmental agreements for the management and protection of the Amur River.

To address these policy failures, the GIWA regional team recommended adopting Integrated Water Resources Management (IWRM) principles. Their recommendations include:

- Creation of an intergovernmental agreement on the use and protection of the Amur River Basin's water resources;
- Establishment of a basin commission to oversee the agreement and to report and monitor progress;
- Revision of national water laws based on IWRM principles;
- Implementation of appropriate water pricing.

(SOURCE: SEA OF OKHOTSK/30)

ing legal frameworks for environmental management and building institutional capacity. In the Black Sea, the repeated amendment of water laws and regulations has made long-term planning difficult and discouraged investment in infrastructure. Under decentralisation, new water and sewage facility ownership structures have made services more unreliable and impaired water resources management. Box 13 outlines the policy failures behind pollution in the Amur River Basin.

POLICY RELEVANT CONCLUSIONS

Population growth, urbanisation, industrialisation and agricultural development will increase pollution loads in the international waters of more than three-quarters of the GIWA regions by 2020. Nevertheless, interventions by governments, communities, industries and NGOs can reduce or control pollution, depending on political will, available financial resources and technological developments.

Eutrophication is likely to intensify in many regions, primarily in response to the increased application of fertilizers, especially in Asia and Africa. It will also increase in prevalence due to the growth in the aquaculture industry, increasing quantities of human sewage, the generation of nitrogen from fossil fuel combustion, and, potentially, as a result of global warming. However, many technical and political options are available to reduce fertilizer use, decrease nutrient run-off, encourage sustainable aquaculture and enhance sewage treatment.

Similarly, suspended solids will continue to be a widespread problem. The implementation of afforestation schemes and the adoption of sustainable agricultural and land use policies can reduce erosion in the catchment area.

Microbial pollution related to sewage is also projected to increase due to population growth and urbanisation, particularly in Asia, Africa and Latin America. This trend may be averted by investing in sewage treatment facilities, industries adopting cleaner technologies and by strengthening the institutions responsible for waste management.

Pollution in international waters can be reduced, as demonstrated by the substantial reduction in hazardous substances and microbial pollution in the Baltic Sea/17. According to UNEP's Global Environmental Monitoring System (GEMS), other successful examples include reductions in organic loading in Europe and Australia, lower phosphate levels in North America and Europe, and reduced nitrate levels in the Danube Basin. The GIWA regional teams emphasised that to address transboundary pollution, governments must recognise the need for action, increase stakeholder participation, provide appropriate incentives, improve regulations,

BOX 14. LACK OF INTERNATIONAL ENFORCEMENT: CASE OF THE CASPIAN SEA

Agricultural run-off is one of the main sources of pollution in the Caspian Sea, with pesticides causing the most severe impacts. Chemical pollution hotspots are located in the dense agricultural areas of Iran's river deltas. Agricultural activities and associated pollution are also prominent in the Ural, Volga and Kura river basins, with the Volga thought to contribute the majority of the total pollution load into the Caspian Sea.

While DDT was prohibited in 1970 in the Soviet states, the GIWA regional team reported that supplies are still readily available. Small-scale farmers have become dependent on pesticides, including DDT, to maintain production on infertile arable land. They have little understanding of the ecological consequences of pesticide use. Clearly, enforcement of the 30-year-old DDT ban must be strengthened, which requires building capacity in the institutions responsible for enforcement. One approach is to improve regional control functions and to give local officials adequate authority and resources to prohibit and seize local supplies and sales. The enforcement of the ban is expected to be highly feasible and effective as DDT is easily identified and confiscated.

(SOURCE: CASPIAN SEA/23)

and cooperate with other nations sharing an international water. In many regions, capacity building is required to better monitor and enforce regulations related to transboundary aquatic pollution.

Table 6 summarises the root causes behind pollution and potential policy instruments identified by the GIWA regional teams. It also lists other instruments that have been successfully used by international and national programmes.

Regulations

Regulations are the most common instruments used to address water pollution due to their simplicity and ability to satisfy the interests of both the authorities and the private sector. Conditions that favour the use of regulations include:

- Unacceptably high economic and/or environmental costs resulting from even minor contamination;
- A small number of polluters;
- The existence of a more environmentally friendly and economically viable technology.

The GIWA regional reports note that regulators are often unwilling or do not have the resources to enforce regulations. As discussed in Box 14, DDT is widely used in the Caspian Sea/23 region despite being prohibited by governmental regulations.

In the Humboldt Current/64 region, many pollution related laws are obsolete, whilst others are inappropriate or have weak sanctions that do not motivate violators to improve their practices. The various national and local institutions often have overlapping responsibilities concerning environmental management. This has often impeded the enforcement of regulations. Global quality systems and certification (e.g. ISO, clean production, organic production) can complement regulations, but generally receive inadequate governmental support.

Economic incentives and public engagement

Economic incentives can be highly effective in changing behavioural patterns. The Benguela Current LME project uses economic incentives to promote environmentally friendly technologies and practices, phase-out subsidies and introduce user fees. Table 7 illustrates the main economic policy instruments for addressing water pollution, with examples from GIWA regions.

TABLE 7. ECONOMIC INCENTIVES AND DISINCENTIVES FOR ADDRESSING WATER POLLUTION WITH EXAMPLES FROM GIWA REGIONS

Instrument	Examples
Reduced subsidies or surcharges (taxes)	Reduced subsidies for fertilizers and pesticides Reduced taxes on waste separation and treatment technologies (Indian Ocean Islands/45b)
Targeted subsidies	Subsidies to promote natural buffer zones to capture nutrients from agricultural run-off Tax reductions on less harmful pesticides (Caspian Sea/23) Subsidies provided to the municipality to commence a waste collection service, and to the private sector to facilitate investment in waste minimisation/treatment (Indian Ocean Islands/45b) Tax incentives to encourage the use of recycled products (Indian Ocean Islands/45b)
User charges	Levy water effluent charges based on the amount of pollutants Tax the disposal of industrial solid wastes (Indian Ocean Islands/45b) Taxes and fines on oil pollution (Caspian Sea/23) Establish market-based fees and charges (Volta Basin (Guinea Current/42b))
Deposit refund systems	Consumers pay a refundable deposit for plastic bottles, batteries, etc. (Indian Ocean Islands/45b)
Performance bonds	Users of hazardous pollutants post a refundable bond to cover potential environmental damage
Insurance markets	The price for insuring potentially damaging activities depends on the expected loss. Insurance companies may also ask their clients to use certain technologies or follow certain procedures

TABLE 8. DIRECT GOVERNMENT INSTRUMENTS FOR ADDRESSING WATER POLLUTION WITH EXAMPLES FROM GIWA REGIONS

Instrument	Examples
Understanding pollution problems and developing solutions	Strengthening institutions responsible for enforcement of maritime regulations (Caribbean Islands/4) Information system on water resources in the Madeira River Basin (Amazon Basin/40b) Training and environmental education programmes (Amazon Basin/40b) Develop national/regional HAB contingency plans (Comoe Basin (Guinea Current/42a)) Develop coordinated river and coastal management (Guinea Current LME (Guinea Current/42e) Establish a water quality and aquatic environment institutional network (Guinea Current LME (Guinea Current/42e)
Infrastructure	Municipal water treatment plants Improve design and maintenance of purification systems (Guinea Current LME (Guinea Current/42e)) Provide sufficient waste receiving and treatment infrastructure at ports (Amazon Basin/40b, Caribbean Islands/4) Allocate funding for solid waste management (Indian Ocean Islands/45b)
Protection	Develop protected areas that serve as buffer zones Reach agreement among governments for the creation of special protection areas (Small Islands (Carribean Sea/3a)) Strengthen national policies, regulations and law enforcement for protection of water resources (Jordan/51)
Transboundary agreements	Reach agreement on common environmental standards (Small Islands (Caribbean Sea/3a), Sea of Japan/33, and Humboldt Current/64) Integrate sector policies with environmental policy proposed by the various international conventions (Baltic Sea/17) Develop comprehensive water policies and institutions for transboundary river basins and coastal zones (widespread, including Small Islands (Caribbean Sea/3a), Baltic Sea/17, Uruguay River Basin (Patagonian Shelf/38), Brazil Current/39, Amazon Basin/40b, Volta Basin (Guinea Current/42b), Guinea Current LME (Guinea Current/42e) and Jordan/51)

Many GIWA regional teams emphasise the importance of stakeholder engagement for addressing complex transboundary issues.

Direct government investment

Government investment can be effective in reducing pollution. For example, the construction of wastewater treatment plants in the Baltic Sea/17 region has improved coastal water quality. As a result, nearly all of the beaches along the southeastern coast of the Baltic Sea that were closed in the late 1980s were re-opened in the mid-1990s. Initiatives often involve the construction of infrastructure and the creation of protected areas. Governments, however, often cannot afford to make the investments or are unable to charge users for the services. The main governmental instruments for addressing transboundary water pollution are presented in Table 8.

COD CATCHES ON A FISHING BOAT OFF THE LOFOTEN ISLANDS, NORWAY
(PHOTO: GETTY IMAGES)

OVERFISHING

AND OTHER THREATS TO AQUATIC LIVING RESOURCES

The international community cannot achieve the Millennium Development Goal of hunger eradication without improving fisheries management. Almost two-thirds of the GIWA regional teams predicted that the effects of unsustainable fishing practices would increase in severity in their region by 2020. Overfishing was identified as the priority concern in many parts of East Asia and Australia & the Pacific Islands. Virtually all of the mega-regions determined that the overexploitation of fish and other aquatic living resources, and the use of destructive fishing practices are major concerns. By contrast, excessive by-catch and discards were only determined to be critical at the mega-regional level in South America and Southeast Asia. Excessive fishing effort and the employment of destructive fishing practices are attributed to a complex web of root causes, including the common pool nature of fisheries resources, poverty, insufficient knowledge regarding the status of the fisheries, inappropriate subsidies, a lack of appropriate incentives and weak enforcement of fisheries regulations.

Today, the fisheries industry employs over 200 million people and exploits virtually all international waters. The achievement of the Millennium Development Goal (MDG) to eradicate hunger will be partly dependent on the ability of the fisheries and their ecosystems to supply animal protein to the populations of most developing countries. However, there is widespread concern over the sustainability of the fisheries. The Food and Agriculture Organization reports that 52% of the world's marine fish stocks are fully exploited, 16% are overexploited and 7% are depleted (FAO 2005). Furthermore, many of the ecosystems that support critical fisheries are degraded.

GIWA assessed the sustainability of international fisheries (Box 15) by targeting the following issues: (i) overexploitation; (ii) excessive by-catch and discards; (iii) destructive fishing practices; (iv) decreased viability of stocks through pollution and disease; and (v) impact on biological and genetic diversity.

BOX 15. TRANSBOUNDARY FISHERIES

GIWA uses the following characteristics to define international fisheries:

- River basins, lakes, and marine ecosystems that are divided by political borders which do not match the distribution and migratory patterns of fish stocks;
- Fleets operating in the Exclusive Economic Zone (EEZ) of foreign countries;
- Two or more countries disputing the location of their respective EEZs;
- Consumers buying fish caught in another country's EEZ;
- Fleets fishing on the high seas, which are international commons (the high seas were not assessed by GIWA).

Global situation and trends

- Overfishing and other threats to aquatic living resources were assessed as the priority concern in over one-fifth of the GIWA regions/sub-systems.
- Almost 60% of the GIWA regional teams assessed overexploitation as severe. In nearly every lake and Large Marine Ecosystem (LME) assessed by GIWA, several fish stocks are overexploited.
- Overfishing is primarily caused by the excessive fishing effort of industrial fishing fleets, but small-scale fishers also overexploit nearshore fish stocks.
- Excessive by-catch and discards exacerbate overfishing and can threaten endangered species; trawling fisheries in the North Atlantic and in numerous tropical regions typically have significant by-catch.
- In three-quarters of GIWA regions/sub-systems, destructive fishing practices are degrading habitats and communities that support fisheries.

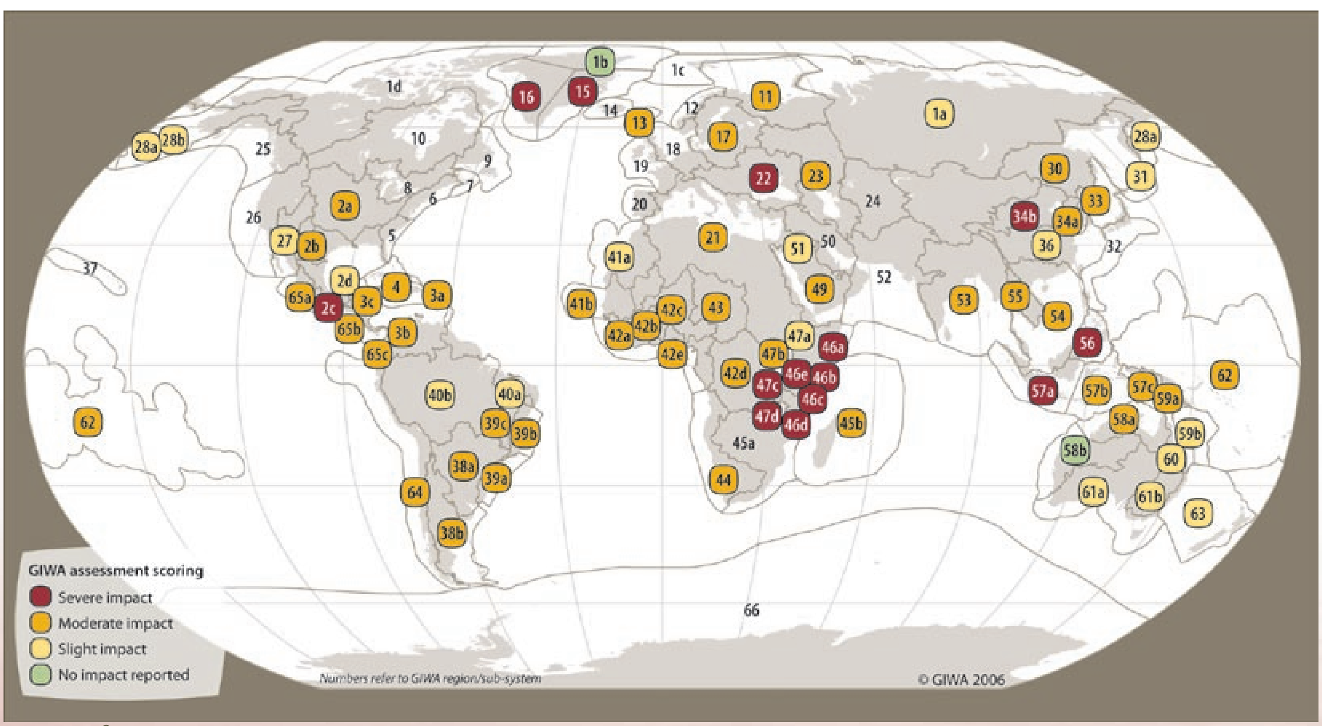


FIGURE 18. OVERALL ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF OVERFISHING AND OTHER THREATS TO AQUATIC LIVING RESOURCES

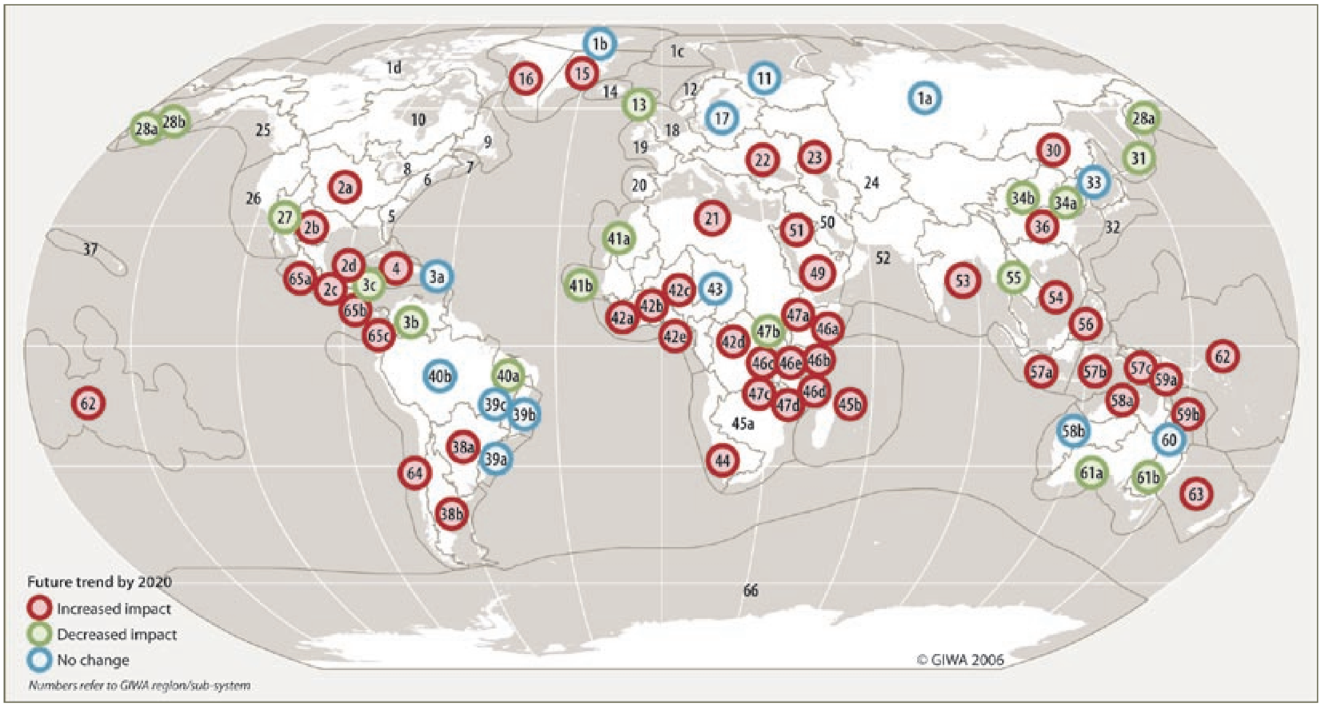


FIGURE 19. FUTURE ENVIRONMENTAL TRENDS OF OVERFISHING AND OTHER THREATS TO AQUATIC LIVING RESOURCES

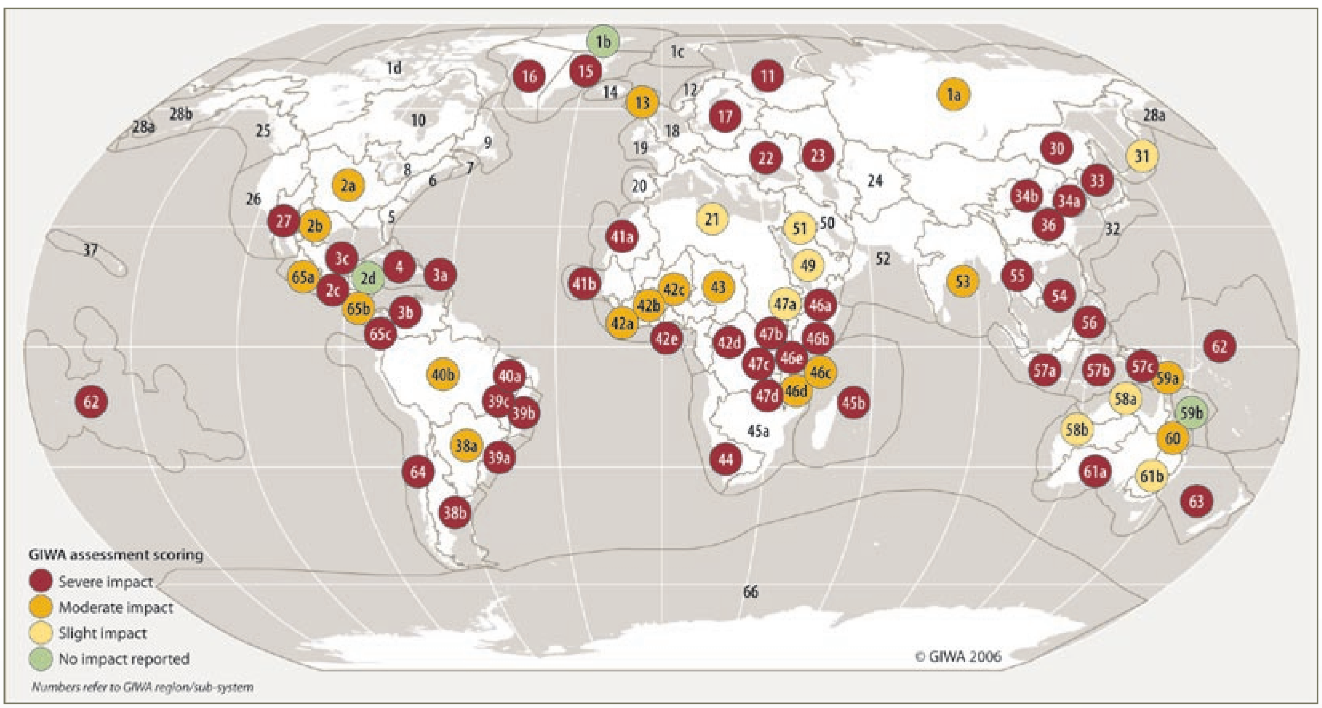


FIGURE 20. IMPACTS OF OVEREXPLOITATION OF FISH

- Aquaculture is the fastest growing animal-based food-producing sector, particularly in developing countries. However, the widespread environmental and social drawbacks of the industry need to be addressed.
- Although the majority of the GIWA regional teams predicted that the impact of overfishing and other threats to aquatic living resources would increase in severity, the situation in over 20% of GIWA regions/sub-systems is expected to improve by 2020 following the adoption of sustainable management practices (Figure 19).

ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS

Overexploitation

Overexploitation occurs when fish and other living resources are caught at a rate which exceeds the maximum harvest that allows the population to be maintained by reproduction. Overexploitation of fish was assessed as severe in more regions than any other environmental issue evaluated by GIWA. It is a geographically widespread problem, affecting most LMEs and many lakes, including the East African Rift Valley Lakes/47b,c,d.

Overexploitation firstly affects large, slow-growing predatory fish, such as cod, halibut and grouper, and high-value invertebrates, such as shrimp, lobster and large shellfish. In many GIWA regions the depletion of large predators has led to 'fishing down the food web', whereby the average catch composition is gradually replaced by short-lived, fast-growing, plankton-eating fish and invertebrates at lower trophic levels, as the predatory fish populations succumb to intensive fishing effort (Pauly et al. 1998). The Argentinean hake (*Merluccius hubbsi*), for example, was the species principally targeted in the South Atlantic Drainage System (Patagonian Shelf/38b). After years of overfishing, hake stocks finally collapsed in 1997, whilst stocks of the short-lived and fast-growing Anchoita (*Engraulis anchoita*) tripled over the same period. The collapse caused extensive unemployment in the fishing industry, severely impacted fish processing plants and reduced export revenues.

In the Caribbean Small Islands region (Caribbean Sea/3a), fisheries production escalated to unsustainable levels, from 9 000 tonnes in 1950 to 60 000 tonnes in 2000 (Figure 21). Many commercial species are currently at risk as a result of overexploitation and a loss of critical habitats for fish and shellfish reproduction, such as mangroves, seagrass beds and reefs.

It is often difficult to determine the degree to which fish stocks are depleted as a result of overexploitation or climatic variability. For example, the cod stocks of the Greenland Seas are sensitive to changes in water temperature, and have subsequently declined over the last 30 years (East Greenland Shelf/15 and West Greenland Shelf/16). According to Sherman (2003), climate is the key controlling factor of fishing yields in about half of the world's LMEs. However, overexploitation exacerbates the effects of climate variability, such as in the major upwelling areas of the Benguela Current/44, Canary Current/41 and Humboldt Current/64 (Box 16).

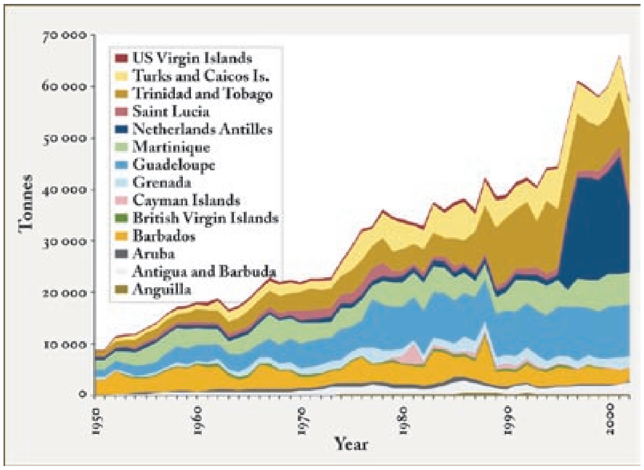


FIGURE 21. TOTAL CAPTURE OF FISH, CRUSTACEANS AND MOLLUSKS IN THE CARIBBEAN SEA/SMALL ISLANDS SUB-SYSTEM
(SOURCE: FAO FISHSTAT 2003)

The affect of overfishing on the trophic structure of fish communities is exemplified in the Barents Sea/11. In the 1980s, overfishing and natural fluctuations drastically depleted Capelin (*Mallotus villosus*) stocks. Cod (*Gadus morhua*), the most commercially important fish in the Barents Sea, preys mainly on Capelin. The subsequent lack of prey and continued overfishing of cod itself reduced the cod spawning stock biomass, and catches declined to 20% of their highest levels. Although cod stocks were restored during the early

BOX 16. CLIMATE VARIABILITY AND FISHERIES: THE EL NIÑO SOUTHERN OSCILLATION (ENSO)

Fish biomass and catches are strongly linked to climatic variability, particularly in high latitude and upwelling Large Marine Ecosystems (LMEs).

Many studies have explored the relationship between fisheries, climate, and climate modes. The latter are dynamic patterns of climate variability, such as the El Niño Southern Oscillation (ENSO). ENSO dominates the inter-annual climatic variability of the southern Pacific Ocean and influences global climate. Several ecosystem responses to the ENSO affect the fisheries. In the Humboldt Current/64 LME, cold nutrient-rich upwelling ceases in El Niño years. The consequences are dramatic, including reduced primary production, the collapse of the anchovy fisheries and the migration of jack mackerel (*Trachurus murphyi*) to inshore waters where they are subjected to high predation.

BOX 17. SOCIO-ECONOMIC IMPACTS OF THE UNSUSTAINABLE EXPLOITATION OF FISH: CASE OF THE SOUTH CHINA SEA

The GIWA assessment of the South China Sea/54, which includes the EEZs of nine countries, highlights the range and severity of the socio-economic effects of overfishing. Throughout the region, the reduction and collapse of the fisheries has led to a widespread loss of income and employment.

In many areas, particularly around the Philippines and Indonesia, fish are mostly exported causing local fish consumption to decline by a third. This has contributed to the malnutrition of many children. In coastal communities, alternative livelihoods are rarely available. Injuries and deaths from blast fishing and diving are common. Conflicts provoked as a result of declining fish stocks are frequent among local fishing groups, and with foreign fishers.

It is estimated that fishing effort will need to drop by 50% to restore many fisheries to sustainable levels, particularly near urban areas. The major deficit in wild-caught fish production is expected to lead to increased aquaculture to meet growing demand (see Box 18).

(Source: South China Sea/54)

to mid-1990s, intense fishing during the late 1990s depleted stocks again. At the end of the 1980s, 75 000 people were employed in the fisheries sector in northwest Russia, but this figure had dropped to only 30 000 a decade later. Coastal settlements experienced food insecurity, further unemployment and reduced income in other sectors of the regional economy.

Nearshore stocks are also increasingly overexploited by artisanal fishers. The number of artisanal fishermen in India is unsustainable, having increased by 300% over the past 20 years (Bay of Bengal/57). Artisanal fishing communities are particularly vulnerable to the impacts of overfishing. In the Guinea Current/42 region, 60% of landings are made by artisanal fishers, and since a downturn in fisheries production, unemployment has increased and conflict has been provoked between artisanal fishers and commercial trawlers. In the adjacent Canary Current/41 region, overfishing has led to 80% unemployment in the Senegalese fisheries sector.

Overexploitation of living resources affects many sectors of the economy. In the Bahamas (Caribbean Islands/4), as in many SIDS and other regions dependent on coastal resources, the fisheries are critical for economic development, tourism and food security. The exploitation of living resources for export results in local communities losing their best source of protein. The decline in the nutritional value of the local diet leads to protein deficiency.

The effects of destructive fishing practices and overfishing are also evident in many freshwater systems. Fish account for 25-40% of total animal protein supply in the Lake Tanganyika Basin. Rapid population growth and poor management of the resource has reduced per capita fish consumption in Malawi by over 40%, leading to malnutrition in some areas. Destructive fishing activities and overfishing put a substantial proportion of those employed in Lake Malawi's commercial fisheries (nearly 290 000) at risk. In Lake Tanganyika, overfishing and destructive fishing practices have led to large-scale unemployment following the collapse of Burundi's industrial fishing fleet in the early 1990s.

Excessive by-catch and discards

By-catch refers to the incidental capture of non-target fish, invertebrates, marine mammals, sea turtles, and seabirds, as well as under-sized specimens of target species. But discards refer to undesired by-catch thrown overboard; the survival rate of most species discarded is extremely low. In many of the regions assessed by GIWA, excessive by-catch accompany overexploitation.

By-catch changes the age structure of fish populations, disrupts food webs and threatens endangered species. In the transboundary waters of many tropical and subtropical GIWA regions, by-catch, particularly from shrimp trawling (see figure 22), was assessed as having severe environmental impacts. In the Somali Coastal Current and South African waters, the ratio of prawns to by-catch is 1:7 and 1:4 for trawlers, respectively. By-catch of endangered species is also a concern, particularly in the Pacific Islands/62 and Somali Coastal Current/46.

By-catch and discards can have serious socio-economic implications. In the Sea of Okhotsk/30, fleets discarded large quantities of juvenile pollock during the 1990s, which destabilised the age structure of the stock. The volume of pollock catches have subsequently declined by one-third over the last 10 years. In 2000, fishing companies lost revenues in excess of 100 million USD.

FIGURE 22. BY-CATCH FROM SHRIMP TRAWLING IN THE GULF OF MEXICO
(PHOTO: MINDEN PICTURES)

Discards also create major transboundary problems if the discards from one fishery include species which are valuable to another. For example, foreign fishers dominate offshore fishing in the Somali Coastal Current/46 region, and discard significant amounts of edible by-catch. When rotting fish carcasses are carried shoreward, local fishermen complain that foreigners are destroying their fisheries.

Destructive fishing practices

Destructive fishing methods, including bottom trawling, blast fishing, fishing with poisons, muro-ami nets, and several other locally employed fishing methods, significantly degrade aquatic habitats. Almost three-quarters of GIWA regional teams reported that destructive fishing practices cause moderate to severe impacts (Figure 23).

Although bottom trawling was originally developed for use in deepwater in the North Atlantic, it is now also employed when fishing shallow seagrass beds in tropical regions, causing extensive damage. However, deepwater and hard seabed bottom trawling is also highly destructive to benthic habitats and communities. In the Gulf of California/27, the recurrent use of trawling nets has severely altered the composition of benthic communities.

Blast or bomb fishing, which uses small explosives to kill or stun fish, is predominantly used in tropical regions where it destroys the structure of coral reefs and can subsequently cause the collapse of reef fisheries. Poison fishing with toxic chemicals, such as bleach and cyanide, is also highly destructive to coral reefs. The GIWA assessment found blast and poison fishing to be major problems throughout Southeast Asia, as well as in the Brazil Current/39, Caribbean Sea/3 and Somali Coastal Current/46. Cyanide is widely used in the live reef food fishery and the ornamental aquarium fishery in East Africa, East Asia and Southeast Asia.

Destructive fishing practices are the greatest threat to the reefs of the Sulu-Celebes Sea/56 region. While the short-term benefits to fishermen are high, often returning 15-40 USD for a 1-2 USD investment, the social and environmental costs are considerable. Blast fishing is expected to cost Indonesia at least 3 billion USD over the next 20 years, and cyanide use a further 50 million USD. A sustainable hook and line fishery, in contrast, could create net benefits of 320 million USD. In some regions, human consumption of poisoned fish has led to hospitalisation, and even death.

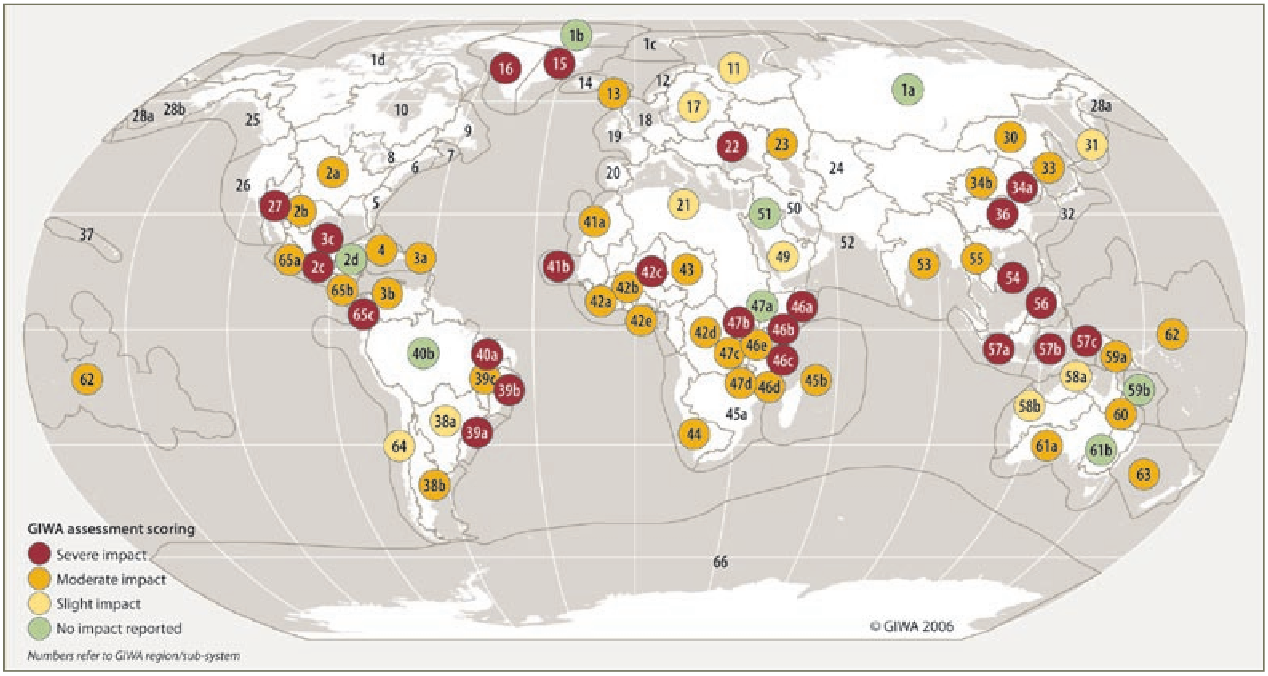


FIGURE 23. IMPACTS OF DESTRUCTIVE FISHING PRACTICES

Decreased viability and biodiversity impacts of aquaculture

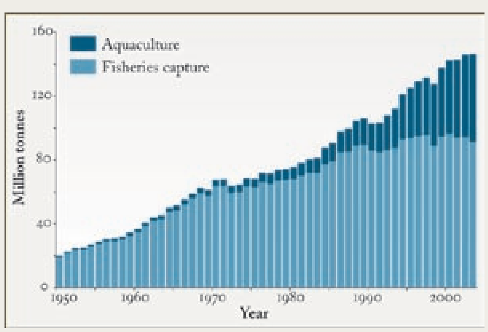
Bacterial or viral diseases can spread from aquaculture stocks and decrease the viability of wild commercial stocks. The introduction of disease through shrimp aquaculture in North Sumatra has resulted in the collapse of wild shrimp stocks. In the Humboldt Current/64, outbreaks of disease in shrimp farms have cost 600 million USD annually, excluding the subsequent economic impact on wild stocks.

Aquaculture or restocking programmes that introduce alien species or genetically modified organisms can affect the biological diversity and structure of ecosystems, as observed in several regions in Central America and South East Asia. In the Philippines and Vietnam, introduced species have extirpated native species. Box 18 discusses the characteristics and impacts of the aquaculture industry.

BOX 18. AQUACULTURE INDUSTRY

Aquaculture, both inland and coastal, is one of the fastest growing food producing sectors in the world, with the annual growth rate exceeding 9% since 1970. Individuals or corporations own aquaculture stocks, whereas wild fisheries are open access. Aquaculture is playing an increasingly important role in meeting the growing demand for fish protein in many tropical and subtropical areas. China accounts for over 70% of the world's aquaculture production, primarily from traditional small-scale systems for local markets. The cultivation of high-value fish and shrimp by industrial aquaculture is growing rapidly.

Exports of aquaculture products provide substantial foreign exchange for many coastal states. Unfortunately, this is often earned at high social and environmental costs. Aquaculture farms often require the clearance of coastal habitats, such as mangroves, and can cause eutrophication and other pollution. Some aquaculture operations have introduced diseases, parasites and alien species into wild fisheries. Aquaculture can cause the overfishing of wild species as cultivated predatory fish and shrimp require protein-rich feed. Social repercussions can include the loss of traditional fisheries, and lower standards of living and reduced food supply for local fishers and farmers. While the continued growth of aquaculture is inevitable, it will only be sustainable and maximise its benefits to society if it is integrated into broader ecosystem-based management.



GLOBAL FISHERIES CAPTURE AND AQUACULTURE PRODUCTION 1950-2003.

(SOURCE: FAO 2004)

BOX 19. INTERACTIONS BETWEEN THE FISHERIES AND OTHER GIWA CONCERNS: CASE OF THE BLACK SEA

Over the past 50 years, industrial fishing, pollution, habitat modification and the introduction of species have increased. It is often difficult to determine the degree to which each of these inter-related causes affect fish stocks. The collapse of the pelagic fisheries of the Black Sea provides an illustrative example.

Prior to the 1970s, overfishing depleted the top predators of the Black Sea which led to 'fishing down the food web'. Since the 1970s, urban and industrial expansion, intensive fertilizer use and atmospheric deposition resulted in severe eutrophication, hypoxia and bottom-up impacts on the food web. Additional stressors during the 1970s and 1980s included chemical pollution, the alteration of the inflowing rivers and continued overexploitation of fish populations.

In the late 1980s, ship ballast water introduced the invasive comb jellyfish (*Mnemiopsis leidyi)*. By 1989, they had spread throughout the Black Sea, reaching densities of 1.5-2 kg/m^2. *Mnemiopsis* voraciously consumed anchovy eggs and larvae, while eutrophication and intensive fishing of anchovies and other small pelagic fish continued, resulting in the collapse of the pelagic fisheries of the Black Sea. Total catches of European anchovy (*Engraulis encrasicolus*), estimated at 534 000 tonnes in 1986, had fallen to only 88 000 tonnes by 1991, resulting in the loss of an estimated 150 000 jobs.

By the mid-1990s, the invasion of another comb jellyfish (*Beroe* sp.) somewhat controlled the population of *Mnemiopsis*, allowing anchovy stocks to partially recover. However, they decreased again in the late 1990s, due perhaps to the affects of climate warming on the food web.

(SOURCE: BLACK SEA/22)

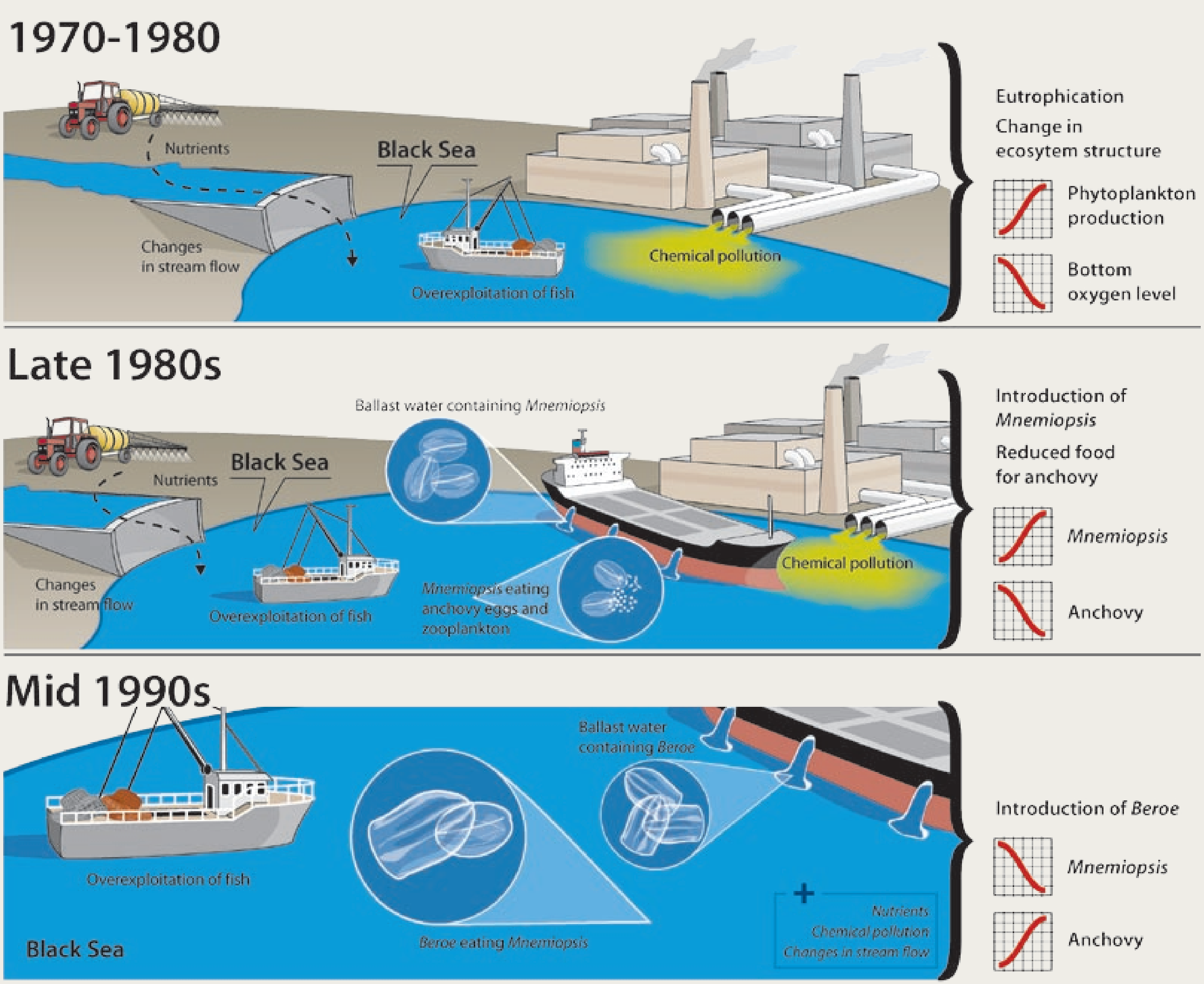


FIGURE 24. FISH FARM, CHINA.
(PHOTO: STILL PICTURES)

ROOT CAUSES

More than 20 GIWA regional teams selected overfishing and other threats to aquatic living resources as the top priority for their region (Table 9 and 10). Overfishing was predominantly attributed to excessive fishing effort, often in combination with destructive fishing practices. The GIWA regional assessments confirm that, despite evidence of severely depleted fish stocks, governments continue to permit large and efficient fishing fleets to overexploit fish resources.

Common pool resources

The fisheries are common pool resources and are thus difficult to protect from exploitation. As a result, fishing is frequently undertaken when alternative employment opportunities are unavailable. Another common pool attribute is that fishing by one user reduces the size of fish stocks available for others. Many fish stocks are not "owned" by a single country but are instead fished by several nations. The common pool nature of fisheries resources therefore results in overfishing and a lack of interest in maintaining fish habitats.

Three forms of property rights have been used to limit access to common pool resources and define rights and responsibilities of beneficiaries. However, inadequate enforcement, inappropriate incentives and knowledge deficiencies regarding the fishery may result in overexploitation despite a property rights framework.

The GIWA regional experts concluded that overfishing in the Indonesian Seas/57 region is caused by the lack of awareness amongst fishers of the impacts of destructive fishing and having the viewpoint that 'if I don't exploit the fisheries, someone else will'. In Lake Victoria (East African Rift Valley Lakes/47b), weakly enforced fishing regulations permit overfishing and the use of destructive fishing practices, which has resulted in reduced catch per unit effort.

In many parts of the world, particularly inland and nearshore fisheries in developing countries, increasing numbers of artisanal fishers are using destructive fishing methods

TABLE 9. IMMEDIATE CAUSES OF OVERFISHING AND OTHER THREATS TO AQUATIC LIVING RESOURCES

	Targeted issues								
	Overexploitation							Destructive fishing practices	
	Immediate causes								
GIWA region	Excessive effort and fleet capacity	Fishing above recommended quotas	Poor recruitment of fish stocks	Improved fishing technology	Poaching	Biomass shift (related to climatic changes)	Destructive fishing practices	Excessive effort and fleet capacity	Inappropriate fishing gear
11 Barents Sea	✓	✓							
13 Faroe Plateau	✓		✓						
16 West Greenland Shelf	✓			✓				✓	
17 Baltic Sea	✓	✓							
30 Sea of Okhotsk	✓				✓				
31 Oyashio Current	✓				✓				
33 Sea of Japan	✓								
34 Yellow Sea	✓			✓				✓	✓
36 East China Sea	✓		✓				✓		✓
38 Patagonian Shelf	✓							✓	✓
41b Canary Current South	✓						✓		✓
42e Guinea Current LME	✓					✓			
44 Benguela Current	✓			✓					
46 Somali Coastal Current	✓			✓	✓		✓	✓	✓
47b Lake Victoria (East African Rift Valley Lakes)	✓			✓				✓	
54 South China Sea	✓		✓						✓
57 Indonesian Seas	✓								✓
64 Humboldt Current	✓		✓						
65c Pacific Colombia (Eastern Equatorial Pacific)	✓					✓			

NOTE: THE TABLE PRESENTS A SELECTION OF GIWA REGIONS WHERE THE REGIONAL TEAM HAS CONDUCTED A CAUSAL CHAIN ANALYSIS ON THE TWO MOST FREQUENTLY ANALYSED ISSUES OF THE GIWA CONCERN OVERFISHING AND OTHER THREATS TO AQUATIC LIVING RESOURCES.

GIWA concerns, while others are specifically relevant for the fisheries.

Several GIWA regional teams from different parts of the world identified population growth as one of the main factors driving demand for fish products and subsequently the overexploitation of fish.

Rising incomes per capita increase the demand for higher value, more nutritious and prestigious food, including fish and seafood. This is of particular concern in Asia, where rapid economic growth over the past 30 years and the preference of the population for fish products has resulted in a doubling of fish consumption.

With nearly 40% of fish production traded internationally (FAO 2004) and export of processed fish far greater than domestic consumption, international market trends often determine the nature of fisheries exploitation (Figure 25). An increasing number of fishers throughout Asia are using destructive fishing methods to meet the growing and lucrative export market for live seafood in China and other parts of Asia (Indonesian Seas/57). Prized reef fish, like grouper and Napoleon wrasse (*Cheilinus undulatus*), are driven into corals where divers use cyanide-filled bottles to stun the fish and crowbars to break the coral structure. The fish are sold in the live reef fish markets in an attempt to halt the decline in their catches which, in turn, reduces fish populations and degrades the habitats which support the fisheries. In response, fishers increase fishing effort and adopt further destructive practices. This situation is prominent in the Somali Coastal Current/46 region, where it has resulted in the reduction of household income and nutrition levels, and a growing frustration which often escalates into conflict between artisanal fishers and other stakeholders, especially the tourism industry and conservationists.

Global trends

Several global trends are underlying root causes of the overexploitation of transboundary fisheries, of which population growth, urbanisation and trade are common to the other

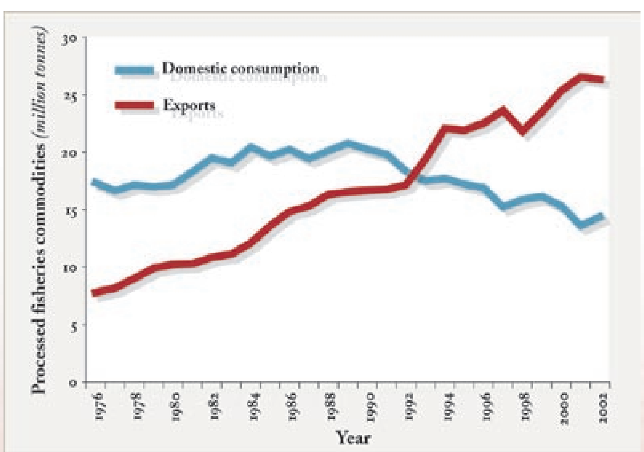


FIGURE 25. GLOBAL FISH EXPORTS AND DOMESTIC CONSUMPTION
(SOURCE: FAO 2003)

FIGURE 26. LIVE FISH FOR SALE IN A RESTAURANT IN HONG KONG
(PHOTO: C. CHEUNG)

of China, Singapore and Taiwan, fetching up to 100 USD per kg (Figure 26). The governments of the countries bordering the South China Sea/54 publicly exhort their fishermen to fish disputed waters, which has resulted in a number of conflicts, notably in the waters around the Spratly Islands. Illegal fishing, overfishing, and poaching of rare species are common in the South China Sea region.

International demand for a specific fish has led to overexploitation in several GIWA regions, such as the Indonesian Seas/57, Lake Victoria (47b), the Patagonian Shelf/38 and Sulu-Celebes Sea/56. In the South China Sea/54 region, as in many other LMEs, trawlers and driftnet operators are often foreign. The value-added component of the industry therefore benefits countries outside of the region, while the region suffers from the effects of declining resources and a deterioration in environmental quality. In order to maintain catch levels, local artisanal and small-scale commercial fishers are reverting to the use of blast fishing.

Insufficient knowledge

Insufficient scientific knowledge and a lack of awareness by fishers and consumers are major obstacles for improving policies and management, and changing the behaviour of consumers and producers.

Inadequate statistics hamper fisheries science and management, particularly in developing countries. This problem was highlighted in all GIWA regions that conducted the causal chain analysis on overfishing and other threats to aquatic living resources. Fishery management models establish allowable catch quotas based on stock biomass, size/age composition, mortalities caused by fishing and natural causes, and catch data. The status of a fishery is difficult to monitor and assess due to natural and fishing-induced fluctuations in fish populations, and the influence of pollution and climate change. Many regions lack adequate exploitation models and information on stock dynamics needed to make informed decisions. Several GEF LME projects are addressing this issue by strengthening national and regional scientific capacity in, for example, the Benguela Current/44, Guinea Current/42 and Yellow Sea/34 regions.

GIWA regional teams recognised that even when accurate data is collected and analysed, the information is often not conveyed to key stakeholders, such as fishers. As a result, fishers lack awareness of the impacts of their actions on fish stocks and their subsequent prosperity. This is a major hindrance to the adoption of sustainable fishing practices. The regional reports note that these knowledge deficiencies were caused by the following failures:

- Information is not communicated to fishers and food processors;
- Information fails to change fishing practices due to understanding difficulties, ignorance and the inability of individuals or firms to act alone;
- Traditional knowledge is often excluded from research, despite its importance to fisheries management. In some GIWA regions, however, traditional knowledge is being incorporated into management strategies.

In the Indonesian Seas/57 region, for example, many local fishermen only have a rudimentary understanding of fish and coral reef ecology. They employ destructive rather than traditional fishing methods as they yield larger catches for minimal effort and cost, despite the long-term impacts on the productivity of the fisheries.

Consumer demand determines the level of pressure on fisheries resources. In developing countries, the exhaustion of fish stocks has forced communities to find alternative sources of protein e.g. in the Benguela Current/44, Indonesian Seas/57, South China Sea/54 and Sulu-Celebes Sea/56. In developed countries, on the other hand, consumption of fish products has not been controlled by market mechanisms as prices do not reflect scarcity due to a combination of (i) fishing subsidies, (ii) access to new fishing grounds in the Indian Ocean and in African waters, and (iii) a food industry with influential power.

Inappropriate subsidies

The governments of the world grant subsidies of up to 20 billion USD annually (Milazzo 1998), thus maintaining and investing in the capacity of fishing fleets. Therefore, rather than establishing policies to control fishing, many governments are actually promoting overfishing. This was highlighted as a problem by GIWA regional teams from the Baltic Sea/17, Barents Sea/11, Oyashio Current/31, Pacific Islands/62 and Sea of Japan/33.

Governments are often reluctant to remove subsidies due to lobbying by the fishing industry and in fear of the negative socio-economic implications for fishing communities. Despite severe overfishing, the EU continues to increase fleet modernisation subsidies, although is now also initiating the decommissioning of some vessels. Russian subsidies were reduced precipitously in the 1990s, which eased fishing pressure but caused economic and social problems along the coast.

Lack of enforcement

Fishing regulations, such as property rights, quotas, protected areas and bans on destructive practices, are difficult to enforce for any government but are especially problematic for many developing countries. Insufficient enforcement was identified as a cause of overexploitation in all causal chain analyses conducted (Table 10). The inability of governments in developing countries to enforce regulations in their territorial waters is a further incentive for large-scale industrial vessels to target these waters for illegal fishing (Box 20).

In the Small Islands (Caribbean Sea/3a), the effects of overexploitation were assessed as severe, with one-third of fish species reported as overexploited. Existing regulations, which are weakly enforced, have failed to maintain populations of reef fishes and large groupers and snappers at sustainable levels, with overfishing occurring even within national parks.

Environmental management is still in its infancy in Southeast Asia, with fisheries management less developed than terrestrial environmental management. The commercial fishing industry has considerable governmental influence, and corruption is a root cause in some countries. In Lake Victoria, the near-collapse of many traditional fisheries and declines in Nile perch led to the implementation of a number of management measures, including the banning of beach seines, undersized mesh nets and trawlers. However, relevant institutions lack the capacity to enforce these fisheries regulations effectively, so they are routinely ignored by fishers.

Poverty

Poverty is a root cause and sometimes a consequence of overfishing. Fishing communities in several developing regions studied by GIWA are particularly vulnerable to the depletion of fish stocks

TABLE 10. ROOT CAUSES AND POTENTIAL POLICY INSTRUMENTS RELATED TO OVERFISHING AND OTHER THREATS TO AQUATIC LIVING RESOURCES

Contributing sector	Underlying root causes	Potential policy instruments	
		Short-term	Long-term
Overexploitation and excessive by-catch and discards			
Fisheries	Common pool resources	▪ Individually transferable quotas ▪ Total allowable catch quotas ▪ Zoning ▪ Limitation of size of vessels ▪ Line and mesh restrictions	▪ Marine protected areas ▪ Community management
	Insufficient scientific knowledge	▪ Stock assessments ▪ Catch surveys ▪ Modelling stocks and ecosystems	▪ Long-term monitoring programmes
	Insufficient knowledge by fishermen	▪ Information on gear and fishing techniques	▪ Training in better management of stocks
	Insufficient consumer knowledge	▪ Eco-labelling of fish products ▪ Eco-labelling of aquarium fishes	▪ Awareness campaigns for consumers and the public ▪ Eliminate price distortions
	Inadequate incentives leading to fleet overcapitalisation	▪ Fleet reduction programmes ▪ Reduce/redesign subsidies	▪ Progressive elimination of subsidies ▪ Promote aquaculture ▪ Job conversion stimulus packages
	Poverty and lack of alternatives	▪ Job conversion stimulus packages	▪ Education and training in alternative activities ▪ Local economic development
	Lack of regulations, compliance and enforcement	▪ Review regulations ▪ Gear verifications ▪ Ban damaging gear ▪ Support enforcement	▪ Capacity building for enforcement ▪ Promote community management
Destructive fishing practices			
Fisheries	Lack of regulations, compliance and enforcement	▪ Review regulations ▪ Gear verifications ▪ Ban damaging gear ▪ Support enforcement	▪ Capacity building/training ▪ Promote community management
	Poverty and lack of alternatives	▪ Subsidise appropriate gear	▪ Alternative livelihood programmes ▪ Local economic development

NOTE: THE TABLE PRESENTS ROOT CAUSES AND POTENTIAL POLICY INSTRUMENTS IDENTIFIED BY GIWA REGIONAL TEAMS.

BOX 20. EXAMPLES OF ILLEGAL FISHING IN THREE GIWA REGIONS

Illegal fishing is a global problem but its impacts are particularly severe in Sub-Saharan Africa, East Asia and Southeast Asia. The three examples below highlight the range and complexity of the issue.

Sulu Celebes Sea/56: The marine fisheries contribute significantly to the economies of Southeast Asia. The legal fisheries sector accounts for 2% of Indonesia's GDP but a significant proportion of the total catch is illegal. Weak enforcement makes the Sulu-Celebes Sea an easy target for illegal commercial fishers. The Indonesian Minister of Environment recently stated that illegal foreign fishing may cost the country 4 billion USD. Unfortunately, accurate data on legal, let alone illegal, fishing is generally unavailable.

Benguela Current/44: Although recreational fishing along South Africa's west coast is regulated, weak enforcement and a lack of prosecutions encourages illegal and unsustainable fishing. Enforcement agencies only have sufficient funds to inspect about 1% of fishing activities. In Namibia and Angola, anglers are not even required to purchase fishing licenses.

Caspian Sea/23: Official catches of sturgeon in the Caspian Sea dropped from a peak of 22 000 tonnes in the 1970s to only 1 800 tonnes by the late 1990s. However, illegal catches are estimated to be many times greater than legal catches. Declining living conditions and increasing unemployment in the 1990s led to small-scale poaching. The impact of which is much smaller than that of illegal commercial fishing, which is often tacitly supported by governments. Enforcement of fishing regulations is expected to remain weak due to widespread corruption and the high profit margins in the illegal fish trade.

as they are highly dependent on the fisheries for their survival and lack alternative livelihood opportunities. The lack of access to credit, alternative employment and social support leaves poverty stricken fishers little option but to unsustainably exploit dwindling stocks and employ destructive fishing practices to increase catches.

POLICY RELEVANT CONCLUSIONS

Global marine fish catches peaked in the late 1980s and have since been declining steadily. According to Pauly (2003), global catches are predicted to continue to gradually decline. If current trends persist, many GIWA regions will witness sequential depletion of fish stocks and continued destruction of habitats.

The uncertain future of the fisheries depicted by the GIWA regional assessments could be avoided if the causes of unsustainable exploitation are addressed. Damaging subsidies that encourage overfishing must be gradually curtailed and appropriate legal, regulatory and incentive frameworks need to be established and enforced. The collection and dissemination of accurate fisheries information is necessary for informed decision-making. Marine protected areas should be adequately enforced and others established. These actions, adopted within an ecosystem-based management approach, can provide substantial long-term benefits for human well-being. Aquaculture will also play a crucial role in boosting fish production to meet consumer demand but precautionary measures should be undertaken in order to avoid associated environmental impacts.

The severity and extent of overfishing has fostered the creation of a new ecosystem-based paradigm for fisheries management which aims to conserve the structure and functions of ecosystems. According to Sherman and Duda (1999), it attempts to minimise the impacts of fishing on non-target species, physical habitats, inter-species interactions and spatial processes. Ecosystem management also coordinates well with integrated water resource management, which is discussed in the chapter on freshwater shortage. The ecosystem approach is increasingly being endorsed by the UN and regional and national fishery institutions as a framework for fisheries management and as a means of achieving the fisheries goals of the World Summit on Sustainable Development (WSSD 2002). The GEF LME projects incorporate an ecosystem management approach to improve fisheries management, combat pollution and habitat degradation, and strengthen governance. Several regions assessed by GIWA have adopted ecosystem-based management as a goal. The policy instruments discussed in this section are practical ways to introduce elements of ecosystem-based management into fisheries management (Table 10).

Providing information to stakeholders

Accurate data on fish stocks and recruitment is essential for fisheries management. This information must be disseminated to stakeholders, such as fishers, the food industry, government agencies and consumers. The GIWA regional experts who prepared the South China Sea/54 assessment identified three key information and communication needs: (i) the collection and analysis of accurate fisheries data; (ii) conduct feasibility assessments prior to exploiting new fish stocks; and (iii) enhance regional communication regarding fisheries statistics, planning and management. These requirements are universal for policy-makers and producers but they are rarely met. Certification of fish is a relatively new and, as yet, uncommon approach to enable consumers to purchase fish caught by sustainable techniques.

Community management is normally based on restricting fishing methods, as well as managing the location and timing of catches. Community-based management was recommended by many GIWA teams, particularly in Sub-Saharan Africa and Southeast Asia.

Reform of subsidies and fleet reduction programmes

Until recently, governments have made relatively little effort to reform subsidies which currently encourage overfishing. The reduction of subsidies remains a contentious and complicated issue. It often involves joint involvement of national governments, regional regulatory bodies and the World Trade Organization (WTO). There needs to be controlled and gradual reductions in subsidies backed up with community support in order to minimise associated social problems. Alternative subsidies may give fishers an incentive to adopt sustainable fishing practices.

The most straightforward measure for relieving fishing pressure is to reduce the fishing fleet. However, the feasibility of such a measure is dependent on the level of influence the industry has on regulators and other governmental institutions. Decommissioning has therefore been more effective in the small-scale fisheries of developing nations rather than in reducing industrial fishing fleets of developed countries. Some EU fleet reduction programmes have effectively exported their overcapacity to developing regions. China, in response to overfishing and agreements with Japan and South Korea, announced it will reduce its fishing fleet by 12% to 220 000 vessels and the number of fishermen by 10% to 2.7 million (Sea of Japan/33). Although these reductions are encouraging, they are too insignificant to turn the tide of overfishing.

PART OF THE FISHING FLEET IN MAR DEL PLATA, ARGENTINA.
(PHOTO: IBL)

Quotas and other catch restrictions

Total Allowable Catch (TAC) quotas, based on the concept of maximum sustainable yield, can be used to reduce fishing effort. By making the quotas individually transferable (ITQs), the efficiency of TAC quotas is improved. The implementation of TAC quotas can be challenging, in terms of the initial allocation of quotas, the level of by-catch, and monitoring and enforcement issues. Precautionary quotas and the closure of fisheries for a sufficient period have allowed full recovery of severely depleted stocks in European and North American waters (e.g. herring, yellow flounder and gadoids). Fishing and processing quotas were also proposed by GIWA regional

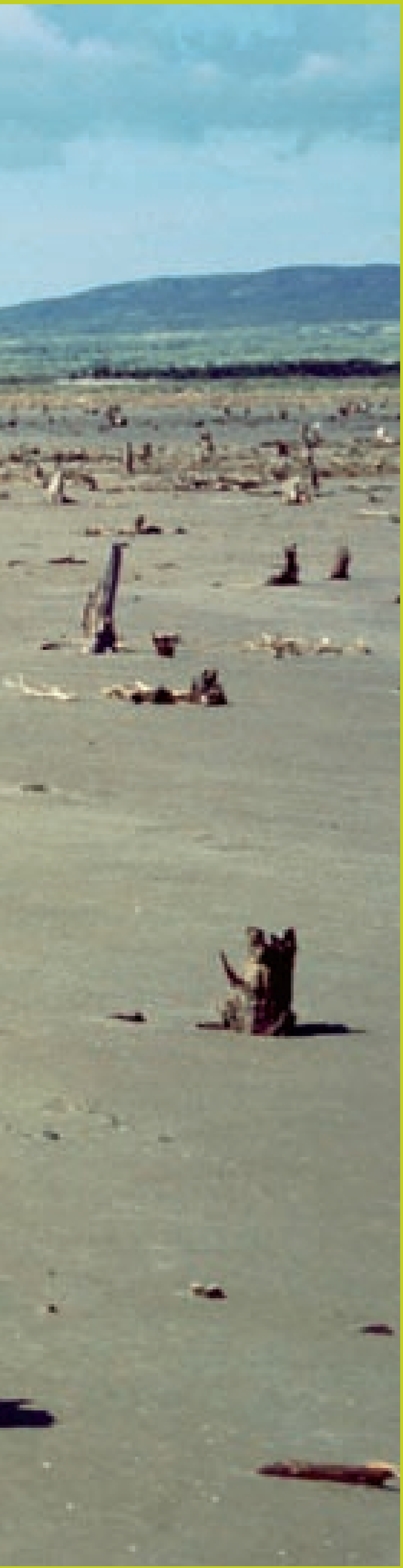
experts for freshwater systems, such as Lake Victoria. The precautionary approach is a major step towards achieving sustainable fishing but requires comprehensive monitoring, realistic stock assessments, social and economic support programmes and proper mechanisms to control implementation.

Technological advancements have made fishing more efficient and sometimes more destructive. However, gear restrictions and the promotion of selective technology are measures commonly employed in many GIWA regions and, in some cases, are effective in protecting stocks, but they increase fishing costs.

Zoning and marine parks

The establishment of protected areas or fishing areas regulated by seasonal and zonal restrictions can allow the rejuvenation of fish stocks and the protection of target species. Although zoning is generally effective for small-scale community fisheries, it can be difficult to enforce such restrictions on the industrial fishing industry. The enforcement of marine parks is expensive, but the benefits can be significant; fish catches near the Bamburi Marine Park in Kenya increased more than two-fold since its designation as a marine park (Somali Coastal Current/46b).

MANGROVE FOREST CONVERTED TO DESERT BY FARMERS IN ORDER TO PRODUCE CHARCOAL.
(PHOTO: M. EDWARDS/STILL PICTURES)



HABITAT AND COMMUNITY MODIFICATION

The GIWA assessment illustrated that the world's freshwater and marine habitats have been extensively modified by human activities. This has resulted in a loss of global biodiversity and led to the proliferation of invasive species in the coastal and freshwater systems evaluated by GIWA. Habitat modification is often the consequence of one or more of the other GIWA concerns and issues, such as pollution, invasive species, the modification of stream flow, and overfishing. The modification of stream flow following the construction of dams and other water infrastructure, particularly to supply water to irrigated agriculture, is the major cause of habitat modification in freshwater systems. In marine systems, however, the fisheries have the greatest impact on habitats and their biodiversity. The majority of regional teams predicted that habitats will deteriorate in the future due to increasing pressure from human activities. Recent mass coral bleaching events are the single most dramatic example of global climate change affecting an ecosystem on a global scale.

GIWA assessed the severity of the environmental and socio-economic impacts of this concern by evaluating two principal issues: loss of aquatic ecosystems and modification of aquatic ecosystems, including community structure and/or species composition. This chapter discusses the status of these two issues for each of five major aquatic habitats that are highlighted in the GIWA regional reports: rivers, lakes, coral reefs, mangroves and seagrasses. Although direct habitat modification is often local in extent, transboundary impacts are not uncommon (Box 21). The overall results of the GIWA assessment for habitat and community modification are summarised in the matrix in the back of this report.

Global situation and trends

- Habitat modification was the top priority issue in over one-fifth of the GIWA regions and sub-systems.
- The alteration of the world's freshwater and marine habitats has reduced global biodiversity, changed the structure of aquatic communities and led to the proliferation of invasive species on every continent and in all marine waters assessed by GIWA. Almost three-quarters of the GIWA regions/sub-systems assessed the overall impacts of habitat modification to be severe or moderate (Figure 27).
- Coral reefs have been seriously degraded by destructive fishing practices and coastal land reclamation, particularly in Southeast Asia. They are extremely vulnerable to global climate change.
- Mangrove forests are severely threatened worldwide as a result of the increased demand for timber, construction in coastal areas and aquaculture.
- Freshwater habitats, particularly wetlands, are severely modified by land-use changes, such as drainage, river levees and deforestation.

BOX 21. TRANSBOUNDARY HABITAT AND COMMUNITY MODIFICATION

Habitat modifications can have impacts on an international scale in all major aquatic ecosystems. The fragmentation of transboundary river basins by dams and other structures may cause considerable changes to ecosystem functions and services in downstream countries. In lakes and semi-enclosed seas, where water exchange is limited, land-based and upstream sources of pollution and eutrophication may alter pelagic and benthic habitats of more than one country. Wetland habitats and communities are drastically modified as a result of upstream water abstraction, changes in the flooding regime and pollution.

The degradation of coastal marine habitats often reduces the extent of important nursery and spawning grounds for migratory fish. Changes to habitats that host unique communities with high endemic species diversity will result in a loss of global diversity.

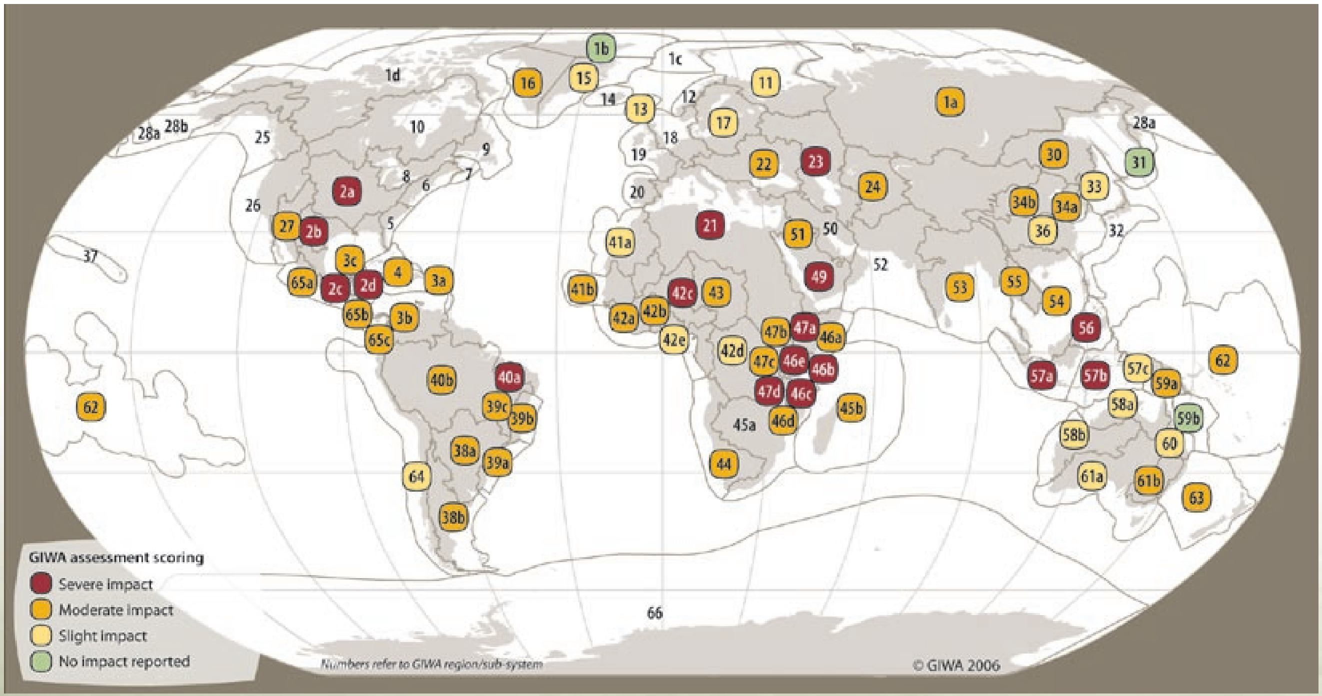


FIGURE 27. OVERALL ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF HABITAT AND COMMUNITY MODIFICATION

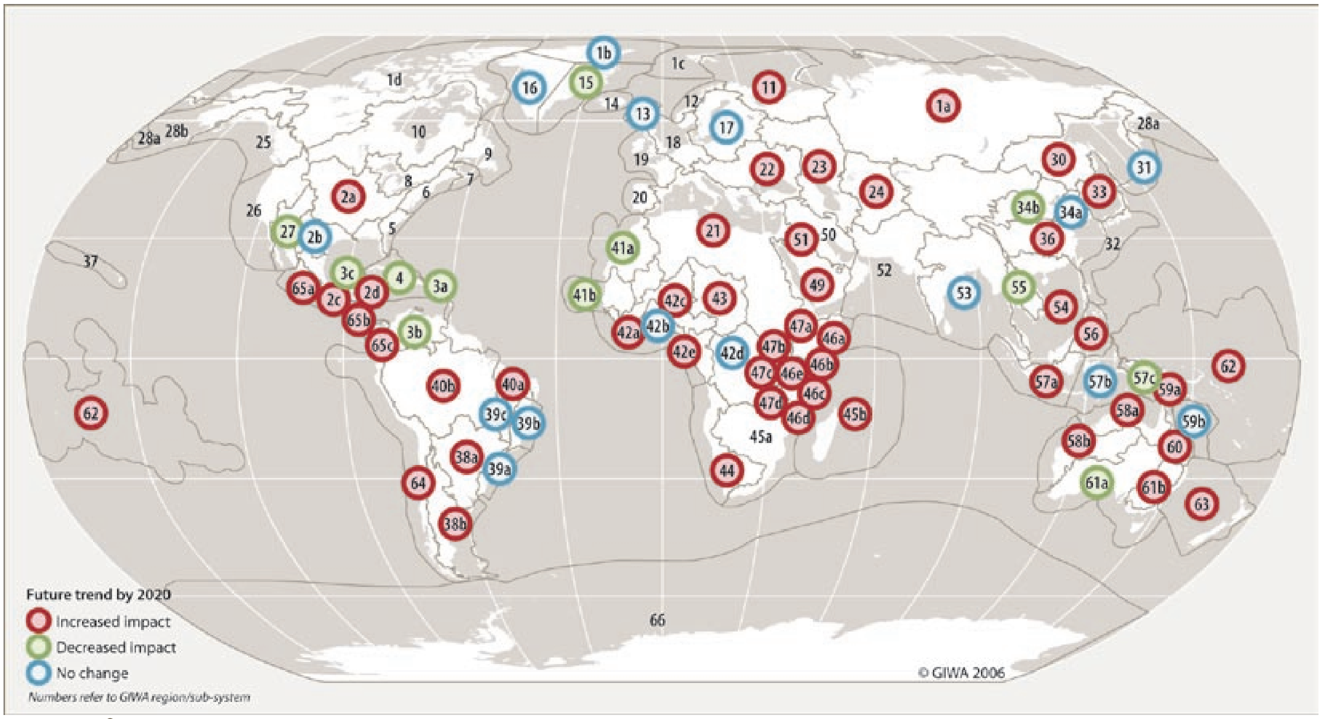


FIGURE 28. FUTURE ENVIRONMENTAL TRENDS OF HABITAT AND COMMUNITY MODIFICATION

- Regional experts forecasted that in the majority of GIWA regions, habitats will deteriorate in the future. Only a few regions are showing signs of improvement, including a cluster in the Caribbean (Figure 28).

ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS

Freshwater habitats

Freshwater habitats provide invaluable services to mankind, but growing demand for freshwater resources and services by burgeoning human populations is placing an unsustainable burden on these habitats. The modification and loss of biodiversity and/or ecosystems, and the propagation of invasive species were identified by the GIWA regional teams as the most frequent transboundary environmental impacts of freshwater habitat modification. Wetlands were recognised as severely modified ecosystems, the biodiversity of which has been impoverished by human activities. The most common socio-economic impacts are reduced fisheries revenue, loss of employment and increased costs arising from mitigation and treatment measures (Table 11, Box 22).

Rivers

There are two principal anthropogenic factors which alter the habitats of rivers: (i) inputs of pollutants, sediments and nutrients; and (ii) changes to the flow regime. The former is discussed in the chapter on pollution.

The construction of dams and other structures that control or divert the flow of water in rivers has yielded considerable economic and social benefits throughout the world, including the generation of hydropower, the provision of water for drinking and irrigation, and the mitigation of floods. However, these structures cause massive aquatic habitat and community modification in the world's river basins (Table 11 and 13). Anthropogenic activities have depreciated the value of many habitats for human well-being, including a decreased capacity to meet basic human needs, such as food and fuel.

Impacts of dams arise from either changes in the hydrological regime or the physical barriers imposed by dams (see also the chapter on freshwater shortage). Alterations to flow regimes invariably cause changes to habitats and community structures. The Colorado River Delta, for example, which once covered 780 000 ha and supported between 200 and 400 species of plant, bird and fish, has declined to less than 60 000 ha. This has been attributed primarily to the construction of the Hoover and Glen Canyon dams, and the

TABLE 11. SEVERE IMPACTS ON FRESHWATER HABITATS AND COMMUNITIES IDENTIFIED IN GIWA REGIONS

Freshwater habitats		Environmental impacts						Socio-economic impacts				
GIWA region	Freshwater habitat affected	Modification and loss of biodiversity and/or ecosystems	Changed erosion and/or sedimentation patterns	Establishment of invasive species	Loss and decline in the population of endemic fish species	Reduced fish stocks	Algal blooms	Reduced fisheries revenue and employment	Reduced revenues from tourism, higher employment and a loss of recreational values	Mitigation and treatment costs*	Loss of traditional livelihood and values	Reduced capacity to meet basic human needs (e.g. clean water)
2a Mississippi River (Gulf of Mexico)	Riparian wetlands	✓				✓		✓	✓			
2b Rio Bravo (Gulf of Mexico)	Riparian vegetation, rivers		✓	✓		✓		✓		✓		
27 Colorado River (Gulf of California)	Wetlands, riparian forests	✓		✓				✓	✓	✓	✓	
34a Yellow Sea (Yellow Sea)	Marshlands, lakes, rivers	✓		✓				✓	✓		✓	
34b Bohai Sea (Yellow Sea)	Wetlands, rivers, lakes	✓			✓			✓				
38a La Plata River Basin (Patagonian Shelf)	Rivers, riparian habitats	✓	✓				✓		✓	✓		✓
40a Paranaiba River Basin (Northeast Brazil Shelf)	Rivers, lakes	✓	✓								✓	
42c Niger Basin (Guinea Current)	Rivers, ponds, wetlands	✓	✓					✓		✓		
41b Canary Current South	Wetlands, lakes	✓		✓				✓	✓	✓	✓	
44 Orange-Vaal River Basin (Benguela Current)	Wetlands, riparian vegetation, rivers	✓		✓						✓	✓	
47b Lake Victoria (East African Rift Valley Lakes)	Wetlands, riparian vegetation, open waters	✓		✓				✓		✓		
51 Jordan	Rivers, wetlands, Dead Sea	✓			✓			✓		✓		
61b Muray Darling Basin (Great Australian Bight)	River, riparian vegetation, wetlands		✓	✓	✓					✓	✓	✓

BOX 22. TRANSBOUNDARY SOCIO-ECONOMIC IMPACTS OF HABITAT DEGRADATION: CASE OF THE YELLOW SEA CATCHMENT AREA

The GIWA assessment of the Yellow Sea region illustrates the complexity of marine and freshwater habitat modification, and the resulting socio-economic impacts. Over 30% of the freshwater wetlands, lakes, rivers and lagoons have disappeared in the last 30 years. Alien species, such as the marine cordgrass (*Spartina* sp.), have replaced endemic species, and new diseases have been introduced into both the freshwater and marine environment. The loss of wetlands in the Huai River Basin has decreased fish catches and adversely affected cultural heritage sites. The degradation of ecosystems has reduced employment in tourism and aquaculture in the basin, and overall employment has fallen by 10% over the past decade. Throughout the Yellow Sea region, the production of aquatic life used in Chinese medicine, such as seahorses, seadragons and scallops, has decreased by 40% over the same period.

(SOURCE: YELLOW SEA/34)

overuse of water by agriculture and urban areas in Arizona, California and northwestern Mexico (Gulf of California/27). In the Volta River Basin (Guinea Current/42b) more than 650 dams have impounded the Sudano-Sahelian portion of the Basin, resulting in the loss of wetlands, including marshes and floodplains.

The modification of flow regimes, in conjunction with deforestation along river banks and poor agricultural practices in surrounding catchments, has affected sediment transport, erosion rates and nutrient loads in many rivers throughout the world. In the Mekong River, this has reduced fish abundance and spawning areas, which has been a contributing factor in forcing Cambodia to shift from exporting to importing fish to meet local demand.

The construction of dams has converted many water habitats from flowing to static environments which in several GIWA regions, for example the Amazon/40b and the Patago-

FIGURE 29. ATATURK DAM ON THE EUPHRATES RIVER PROVIDES POWER TO TURKEY. (PHOTO: CORBIS)

nian Shelf/38, has caused a decline in fish species that inhabit fast-flowing, rocky-bottom habitats. Dredging for navigation has significantly modified the benthic habitats of rivers in many regions, including the Brazil Current/39. Common vegetation types, such as riparian marshes, have been displaced by aggressive invasive species, such as Water hyacinth (*Eichhornia crassipes*) and Hydrilla (*Hydrilla verticulata).*

In the Caspian Sea/23 region, international conflicts have arisen from dam-induced habitat modification affecting the commercial fish stocks of the entire region but only the countries that constructed the dams benefiting from the electricity and water for irrigation.

While habitat degradation is currently more severe in developing countries, some of the most extensive habitat modification has previously occurred in developed countries. The midwestern US states have drained the equivalent of 14.1 million ha of wetlands in the Mississippi River Basin (Gulf of Mexico/2a) over the past 200 years.

Lake habitats

Lakes are critical reservoirs that store surface water for a multitude of essential human uses and services, including consumption, agriculture and recreation. According to the GIWA regional reports, the most significant factors affecting lake habitats are: (i) dams reducing downstream flows; (ii) river diversions for irrigation and, to a lesser extent, domestic and industrial water supply; (iii) drainage basin land-use changes; (iv) the introduction of invasive species; (v) overfishing; and (vi) salinisation. Decreases in lake areas have been reported in many GIWA regions, including the Aral Sea/24, Caspian Sea/23, East African Rift Valley Lakes/47, Jordan/51 and Lake Chad/43.

The most spectacular example of lacustrine habitat modification is the retreat of the Aral Sea/24, which resulted from the diversion of water from the Amu Darya and Syr Darya rivers for irrigation. The surface area of the Aral Sea has been reduced by 50% since the 1950s and the water level has dropped 20 metres. Moreover, the increased salinity of the sea has transformed it into a biological desert and caused the total collapse of the once productive fishery. The health of the region's population has deteriorated and employment opportunities for the former shoreline communities have declined. A similar fate is currently befalling the Dead Sea (see Box 3 in the freshwater shortage chapter).

In many transboundary lakes, a reduced influx of water and increasing eutrophication have changed the community structure from open-water systems to marshy habitats, consequently altering fish assemblages. Lake Chad/43 is one of the world's most dramatic examples of rapidly shrinking open-water areas being replaced by marshy wetlands. An effect of this change is that the most important commercial fish, which were previously open-water species, have been replaced by catfish (*Clarias* sp.) and other wetland species. In addition, invasive plants now blanket half the surface of Lake Chad.

Lakes are the recipients of sediments originating from the surrounding drainage basins, which have increased in volume as a consequence of land-use changes. For example, overgrazing and deforestation has intensified sedimentation in Lake Malawi, Lake Tanganyika and Lake Turkana. Nutrients contained in these sediments have contributed to eutrophication, particularly in Lake Victoria, where anoxic conditions have reduced fish abundance and diversity, especially among endemic cichlid populations. Endemic fish populations were additionally impacted by the introduction of Nile Perch (East African Rift Valley Lakes/47).

In many international lakes, the impacts of habitat modification, particularly on fish communities, have been exacerbated by overexploitation. A combination of overfishing and the construction of the Turkwell Dam, which lowered lake levels, led to the collapse of the Tilapia (*Oreochromis* spp.) fisheries in the majority of Lake Turkana (East African Rift Valley Lakes/47a). The loss of income from the fisheries sector had a severe impact as there are virtually no other local employment opportunities.

Marine habitats

The continued health of coastal ecosystems is essential for human well-being, as well as for other ecosystem services, including shoreline protection, water quality and biodiversity reservoirs. Unregulated access to coastal ecosystems is putting these resources at risk (Table 12). The most common transboundary environmental impacts are modification and/or loss of biodiversity, and increased sedimentation or erosion. The most frequent socio-economic impacts are experienced by the fisheries and tourism sectors.

Coastal lagoons and estuaries, tidal mudflats, and sandy and rocky shores are particularly affected by pollution, such as oil spills, solid waste and eutrophication. The follow-

TABLE 12. SEVERE IMPACTS ON MARINE HABITATS AND COMMUNITIES IDENTIFIED IN GIWA REGIONS

Marine habitats		Environmental impacts						Socio-economic impacts					
GIWA region	Marine habitats affected	Modification and/or loss of biodiversity	Changes in populations and community structures	Introduction of invasive species	Loss and fragmentation of coastal habitats	Reduced productivity	Increased sedimentation or erosion	Reduced fisheries revenue and employment	Reduced tourism revenue and employment; loss of recreation values	Reduced revenue from ecosystem services	Mitigation and treatment costs (e.g. control of invasive species, coastline restoration)	Loss of traditional livelihoods	Increased user conflicts
3a Small Islands (Caribbean Sea)	Coral reefs, mangroves, seagrass beds, sandy shores	✓	✓			✓		✓	✓				✓
34a Yellow Sea (Yellow Sea)	Salt marshes, estuaries	✓	✓	✓			✓	✓				✓	
34b Bohai Sea (Yellow Sea)	Salt marshes, estuaries	✓						✓					
39a South/Southeast Atlantic Basins (Brazil Current)	Salt marshes, mangroves, coral reefs, estuaries	✓					✓	✓			✓		
39b East Atlantic Basins (Brazil Current)	Salt marshes, mangroves, coral reefs	✓		✓			✓	✓	✓		✓		
40a Northeast Brazil Shelf	Mangroves, estuaries, coral reefs	✓					✓	✓	✓		✓		
41 Canary Current	Mangroves				✓		✓	✓	✓			✓	
42c Comoe Basin (Guinea Current)	Mangroves, estuaries, lagoons	✓			✓	✓	✓	✓	✓	✓		✓	
44 Benguela Current	Estuaries, sandy foreshores	✓		✓			✓	✓	✓			✓	
53 Bay of Bengal	Mangroves, coral reefs	✓	✓			✓	✓	✓	✓	✓	✓		
54 South China Sea	Mangroves, coral reefs, wetlands, seagrass areas		✓		✓			✓	✓	✓			✓
56 Sulu-Celebes Sea	Seagrass beds, muddy and sand-gravel bottoms, coral reefs		✓					✓	✓	✓			
57a Sunda (Indonesian Seas)	Mangroves, seagrass beds, muddy and sand-gravel bottoms, coral reefs		✓							✓			
57b Wallacea (Indonesian Seas)	Mangroves, coral reefs		✓							✓			

ing section, however, will concentrate on coral reefs, mangroves and seagrass beds where human impacts are manifold.

Coral reefs

The condition of coral reefs varies regionally depending on the level of human pressure placed on them. Coral reefs in more sparsely populated regions of the world, such as the Coral Sea/59, Great Barrier Reef/60 and Pacific Islands/62, are generally in good condition. However, in densely populated regions and in locations where reefs are easily accessible, coral reef ecosystems are degraded by overfishing and destructive fishing methods, sedimentation, inappropriate coastal development and tourism. The reefs of Indonesia provide annual economic benefits of 1.6 billion USD, based on their value for food security, employment, tourism, pharmaceutical research and production, and shoreline protection. However, over the next 20 years, anthropogenic degradation of reefs could cost Indonesia around 2.6 billion USD (Indonesian Seas/57).

Burgeoning coastal populations with few alternative sources of food or income have led to the widespread overexploitation and degradation of coral reef ecosystems in many developing regions. In the Pacific Islands/62 region, the breakdown of traditional community controls on fishing has led to overfishing near populated areas. Here, as well as in most other tropical shallow water systems, overexploitation has greatly affected fish populations and changed the community dynamics of the reefs. Reefs and their dependent species are also altered by the use of dynamite and narrow meshed nets.

Coastal development is a major source of coral reef degradation. In the Indonesian Seas/57 region, development and expansion of ports has destroyed reefs and associated islands. In addition, the construction of hotels along the foreshore adjacent to coral reefs increases the number of people in coastal areas resulting in the accumulation of solid waste, eutrophication from the discharge of untreated effluents and physical damage from anchoring and other tourist activities (Caribbean Sea/3, Caribbean Islands/4) (Box 23).

The addition of nutrients within untreated or inadequately treated effluents from coastal cities has caused dramatic changes to many coral reefs worldwide. Reefs near urban centres in Brazil exhibit 77% macroalgal cover, compared with 41% in less populated areas (Northeast Brazil Shelf/40a). Poor agricultural practices and deforestation have also decreased the extent of coral reefs, especially near river mouths where sediments, pesticides and fertilizers smother the corals and impede their growth.

Up until 1998, the global agenda to conserve coral reefs had concentrated on preventing direct anthropogenic impacts. However, during the last decade, mass coral bleaching events provide tangible evidence of the effect of climate change on aquatic habitats, emerging as potentially the greatest threat to coral reefs (Box 24).

Box 23. Tourism and habitat modification: case of the Caribbean

Tourism is a vital industry for the economies of many Caribbean nations, accounting for one-quarter of GDP and one in every five jobs. The Wider Caribbean region attracts 57% of international scuba diving tours; generating nearly 900 million USD in 2005. The cruise industry also represents a significant proportion of tourism, with 14.5 million cruise passengers received by the Caribbean Islands/4 region in 2000. Employment has subsequently shifted from fishing to tourism.

Since the success of the tourism industry is dependent on the beauty and services of coastal ecosystems, it is vulnerable to environmental degradation. Reef dive tourism is inadequately managed in the Caribbean Islands/4, as in many parts of the world, causing significant anchor and diver damage in intensely visited locations. In the Central America/Mexico sub-system (Carribean Sea/3c), hotel construction is of particular concern due to the resultant habitat fragmentation. Land-based sources and ship-borne pollution, including waste discharged by cruise liners and tourist facilities, enters coastal waters, further reducing the environmental quality of the Caribbean.

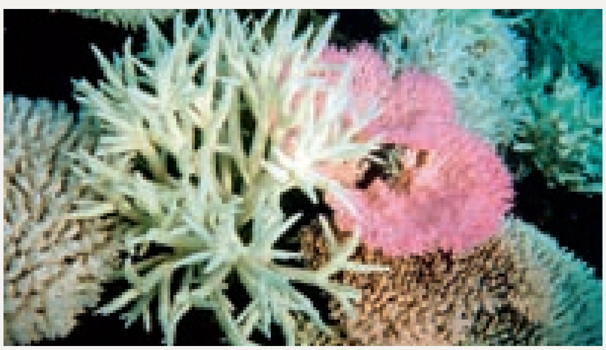
Diving boat, Divi Flamingo, Antilles. (Photo: J. Oliver, ReefBase)

Habitat modification reduces income opportunities in the tourism sector as fishing, snorkelling and diving become less appealing to tourists. The costs can be considerable; 12 million USD of tourism revenue are lost annually in the Nicoya Gulf of Costa Rica.

(Source: Small Islands (Caribbean Sea/3a), Central America/Mexico (Caribbean Sea/3c), Caribbean Islands/4)

BOX 24. CORAL BLEACHING AND THE INFLUENCE OF EL NIÑO AND GLOBAL CLIMATE CHANGE

Bleaching in corals is a stress response caused by the loss of the symbiotic dinoflagellates that reside within coral tissue. Although many factors can cause bleaching in certain localities, only abnormal increases in sea temperature over a period of months can cause coral bleaching on a regional and even global scale. In the 1997/1998 El Niño event, bleaching caused coral mortality, effectively destroying around 50% of the world's shallow water coral reefs. The Indian Ocean was particularly affected but extensive bleaching was also reported in the South China Sea, Sulu-Celebes Seas, the Pacific Islands and throughout the Caribbean. Prior to coral bleaching in the 1990s, the phenomenon was thought to be local in extent. Since then, six mass bleaching events have occurred, always coinciding with an El Niño event. At present, mass bleaching of corals only occurs if an El Niño of sufficient strength prevails for long enough to cause significant increases in sea temperature. However, if global sea temperatures continue to rise as predicted and approach the thermal tolerance limit of corals, El Niños of smaller magnitude would be capable of causing mass bleaching. The increasing frequency and severity of mass coral bleaching events are considered the most significant threat caused by global climate change to an ecosystem on a global scale.



BLEACHED CORALS IN THE GREAT BARRIER REEF, KEPPEL ISLANDS.
(PHOTO: G. LOTTON, REEFBASE)

Mangroves

Mangroves are highly productive forest habitats found along sheltered tropical coastlines. They are essential sources of wood for firewood and construction, as well as invaluable nursery areas for juvenile fish and crustaceans. They also provide coastal protection and filtration functions.

The area of the world's coastline occupied by mangroves is rapidly declining. More than a dozen GIWA regions reported that unsustainable timber harvesting has degraded mangrove ecosystems. In Africa's Volta River Delta, the degradation of mangrove habitats has changed the species composition of 70% of the fish communities since 1969, and has led to the collapse of the shrimp and Jack mackerel fishery and a downturn in the freshwater clam industry (Volta Basin (Guinea Current/42b)). The economic costs can be substantial. For example, in the Indian Ocean Islands/45b, direct monetary costs from loss of mangrove habitats are 600 USD per ha, or 204 million USD per year. Similarly, in many regions, rice paddies, and sugar cane and palm plantations have replaced large areas of mangrove forest.

FIGURE 30. COASTAL DEVELOPMENT NEAR A MANGROVE ESTUARY, SINGAPORE.
(PHOTO: J. OLIVER, REEFBASE)

The growth of coastal towns and cities has destroyed many mangrove forests (Figure 30). In the Guinea Current/42 region, the expansion of Accra in Ghana has cleared 55% of the mangroves and significant areas of marshland in the surrounding area. The expansion of population centres also requires infrastructure development, such as roads, ports and waste disposal sites. In the Philippines, 60-80% of the mangrove forests have been cleared for port developments. The reclamation of land for infrastructure development is often most visible in densely populated islands and atolls, where both space and natural resources are limited. This is demonstrated in the Pacific Islands/62, where more than 50% of the region's mangroves have been removed or severely degraded. In the Brazil Current/39 region and Caribbean/3&4, the construction of tourist hotels and associated facilities, such as marinas, golf courses and airports, has resulted in the destruction of mangrove habitats.

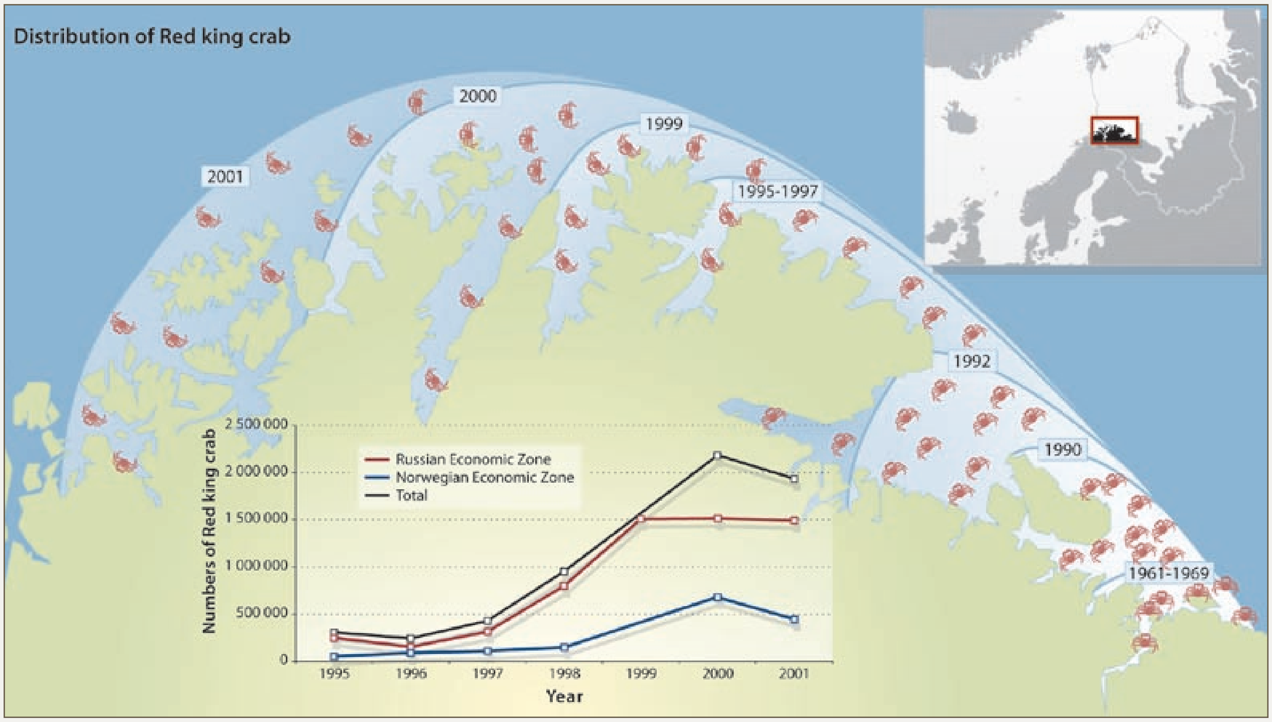
BOX 25. TRANBOUNDARY IMPACTS OF INVASIVE SPECIES

In addition to the increase in global maritime traffic and aquaculture, invasive species, which can be intentionally or accidentally introduced, are now widely acknowledged as a critical transboundary problem in both freshwater and marine habitats. Invasive species have caused environmental impacts in almost half of the GIWA regions. A number of initiatives aimed at limiting the introduction and extent of invasive species have been developed, including the GEF/IMO/UNDP Global Ballast Water Management Programme (GLOBALLAST) and regional activities, such as the GEF-supported UNDP Caspian Environment Programme.

In freshwater systems, the widespread introduction of Tilapia (*Oreochromis* spp.), Carp (*Cyprinus carpio*), Nile perch (*Lates niloticus*) and Water hyacinth (*Eichhorizia crassipes*) has significantly impacted riverine and lake habitats, and has led to the extinction of endemic species in several GIWA regions, including the Gulf of California/27, Benguela Current/44, East African Rift Valley Lakes/47b,c, South China Sea/54 and Indonesian Seas/57a,b. The accidental introduction of the Asian mussel (*Limnoperna fortunei)* into the La Plata River costs nearly 1 million USD every day that the Itaipú Dam has to shutdown power in order to remove the mussels (Patagonian Shelf/38a).

In marine habitats, there are a greater number of introduced species but many remain undetected. The GIWA regional teams that highlighted marine invasive species as a concern include the Barents Sea/11, Baltic Sea/17, Black Sea/22, Caspian Sea/23, Brazil Current/39, Yellow Sea/34, and Benguela Current/44. The impact of invasive species on the ecology of the Black Sea is discussed in Box 19 in the chapter on overfishing and other threats to aquatic living resources.

The Red king crab (*Paralithodes camtschaticus*) of the Pacific was deliberately introduced by Russian scientists into the Barents Sea/11. Since its introduction, the population of Red king crab has increased and spread westwards into Norwegian waters where it has significantly altered benthic communities. In 2002, commercial fishing of the Red king crab began in Norway, which has increased employment in the fish processing sector but at the cost of jobs in factories processing traditional fish catches. Several other invasive species in the Barents Sea have caused economic losses. In Russia, the introduction of the Humpback salmon (*Oncorhynchus gorbuscha*), which is less prized than the Atlantic salmon (*Salmo salar*) for sport and commercial fisheries, has reduced the economic and recreational value of many rivers. Parasites and pathogens caused at least 500 million USD of damage to the Norwegian farmed and wild salmon fishery between 1985 and 2000.



INCREASED EXTENT OF RED KING CRAB IN THE BARENTS SEA.
(SOURCE: MATISHOV & DENISOV 2000)

Aquaculture is probably the greatest single factor behind mangrove deforestation, particularly in South America and Southeast Asia (see Box 18). In the Philippines, prawn aquaculture occupies an area of 500 000 ha and has reduced intact mangrove forests by 50%. In the 1990s, governments of the Indonesian Seas/57 region allocated up to 1 million ha of land, mostly mangrove forests, to the shrimp industry. However, about 70% of the shrimp farms were abandoned by 2001 because they had become unproductive as a result of aquaculture pollution and the creation of acid sulfate soils. Mangrove conversion throughout Southeast Asia has led to conflict between local inhabitants and migrants. The introduction of aquaculture in Brazil has created similar conflicts between prawn farmers and artisanal fishermen. Brazilian prawn farmers buy or appropriate land, which is usually public, and close its access to fishermen, many of whom have fished these areas for many years (Brazil Current/39).

Seagrasses

Seagrass communities are highly productive habitats commonly found in shallow coastal and estuarine waters in many regions of the world. In addition to providing valuable nursery areas for juvenile fish and crustaceans, seagrass beds are important filters and stabilisers of sediments, particularly in regions prone to storms, such as the Pacific Islands/62 and the Caribbean region/3 & 4. These services provide considerable economic benefits; in the South China Sea/54 region the value of seagrass beds and coastal swamps is estimated to be 190 million USD annually.

Seagrass beds are primarily degraded as a result of increasing concentrations of nutrients and particulate matter in coastal waters. Physical disturbance resulting from the increasing use of the coastal zone for transportation, reclamation and fishing also causes extensive damage.

In the Caribbean, land reclamation, and coastal and port construction associated with tourism have caused considerable degradation to seagrass communities and reduced water clarity as a result of dredging and landfill activities. The increase in coastal activity, particularly tourism, recreation and urban development, has resulted in significant impacts on seagrass communities due to increased sedimentation and nutrient loads emanating from sewage discharges, and from physical damage caused by boating, anchoring and other activities. Eutrophication, stimulated by elevated nutrient loads, has increased the turbidity of coastal waters, which subsequently harms seagrass communities and reduces biodiversity. In Southeast Asia, trawling in coastal waters also damages seagrass beds (Indonesian Seas/57, Sulu-Celebes Seas/56).

Box 25 discusses the transboundary impacts of invasive species in marine and freshwater habitats.

ROOT CAUSES

Habitat and community modification was targeted for causal chain analysis in 16 GIWA regions/sub-systems (Table 13 and 14). The most common immediate causes identified by the GIWA regional teams were: (i) pollution; (ii) invasive species; (iii) modification of stream flow; and (iv) overfishing. The principal sectors causing environmental impacts were agriculture and the fisheries. Many of the GIWA causal chain analyses discussed the extent to which the three other GIWA concerns drive habitat modification. The following section examines the root causes of habitat degradation.

Population and economic growth

Demographic change, such as population growth, was identified as one of the main root causes in almost every GIWA regional report that focused on habitat modification in the causal chain analysis. Increasing populations exacerbate the transboundary impacts and causes of habitat modification. In the East China Sea/36 region, for example, thousands of hectares of shoals have been reclaimed in the Yangtze (Changjiang) estuary for the expansion of agriculture and urban areas in order to accommodate an increasing population.

In the neighbouring South China Sea/54, as in many other regions, most of the transboundary habitat impacts and their immediate causes are exacerbated by population growth and migration, as well as economic and industrial growth. These impacts threaten the coastal and marine habitats on which the population depends.

Increased pressure on ecosystems and the consequent modification of habitats are not only a matter of population growth. Economic growth and increasing demand for products are also root causes of habitat modification. The economies of many countries in Southeast Asia, especially China, are growing rapidly. In the Yellow Sea/34 region, as in other parts of Asia, higher living standards have increased demand for cultured fish, which has encouraged aquaculture devel-

TABLE 13. IMMEDIATE CAUSES OF HABITAT AND COMMUNITY MODIFICATION

	Targeted issues																
	Modification and loss of ecosystems																
	Immediate causes								Main sectors involved								
GIWA region	Modification of stream flow	Land use practices	Coastal erosion	Sedimentation	Pollution	Introduction of invasive species	Overexploitation of fish	Increased urban development/expansion	Agriculture	Domestic	Forestry	Fisheries	Maritime traffic	Coastal development	Mining	Industry	Energy
2a Mississippi River (Gulf of Mexico)	✓	✓	✓						✓	✓							
3a Small Islands (Caribbean Sea)			✓	✓	✓	✓	✓		✓			✓	✓	✓			
3b Magdalena Basin (Caribbean Sea)					✓				✓						✓		
3c Central America/Mexico (Caribbean Sea)					✓				✓		✓						
11 Barents Sea						✓						✓					
23 Caspian Sea	✓				✓	✓	✓		✓	✓		✓				✓	✓
34 Yellow Sea	✓				✓	✓			✓	✓		✓				✓	✓
36 East China Sea			✓	✓	✓			✓	✓	✓				✓		✓	
38b Buenos Aires Coastal Ecosystem (Patagonian Shelf)	✓				✓	✓	✓	✓		✓		✓			✓	✓	
40a Paranaiba River Basin (Northeast Brazil Shelf)	✓			✓		✓			✓		✓				✓		
40b Amazon	✓				✓				✓		✓				✓		✓
42c Niger River Basin (Guinea Current)	✓				✓				✓								
54 South China Sea		✓			✓		✓	✓		✓	✓	✓			✓	✓	
56 Sulu-Celebes Sea					✓		✓		✓		✓	✓		✓		✓	

NOTE: THE TABLE PRESENTS A SELECTION OF GIWA REGIONS WHERE THE REGIONAL TEAM HAS CONDUCTED A CAUSAL CHAIN ANALYSIS ON THE GIWA CONCERN HABITAT AND COMMUNITY MODIFICATION.

opment. Fish and seafood consumption has become more fashionable among health-conscious consumers in developed countries, further fuelling aquaculture expansion. Aquaculture has increased pollution, introduced invasive species and converted vast areas of wetland and mangrove forest.

Market failures

Market prices are often not representative of the true value of goods and services provided by ecosystems. While the short-term gains from blast fishing may be impressive, consumer prices do not incorporate the cost of the long-term damage to coral reefs. If fish prices accounted for environmental and social costs, the use of destructive practices would be discouraged.

In the Caspian Sea/23 region, high unemployment rates have led to increased small-scale farming along the coast. The new farms, which are located on infertile soils, are dependent on environmentally harmful pesticides that are both readily available and cheap. The prices of pesticides do not account for the negative externalities from the run-off of these pollutants into the Caspian river basins and adjacent coastal waters. Consequently, farmers have little economic incentive to switch to modern and less damaging substitutes.

Policy failures

In the Niger Basin (Guinea Current/42c) there is little understanding of the complex human-environment interactions, which provides an inadequate basis for sound policy-making. In the Buenos Aires coastal ecosystem (Patagonian Shelf/38b), statistics for fisheries and other ecosystem-based activities are lacking. Furthermore, the datasets of the Argentinean provincial and national governments, as well as the Uruguayan jurisdictions, are incompatible. Scientific experts in the Caspian Sea/23 region lack the financial and/or technical resources to conduct a thorough assessment of living resources. Governments and the fishing industry of the region also pressurise scientists into adjusting scientific recommendations. Political expediency may help the governments of the Caspian Sea/23 region to reach agreements, but they are not founded on sound information nor enforced, which has resulted in a legacy of policy failures. Given the weak information base and lack of coordination between executive and

TABLE 14. POTENTIAL POLICY INSTRUMENTS RELATED TO HABITAT AND COMMUNITY MODIFICATION

Contributing sector	Underlying root causes	Potential policy instruments	
		Short-term	Long-term
Modification and loss of ecosystems			
Agriculture	▪ Lack of monitoring and enforcement capacity ▪ Lack of public awareness ▪ Weak long-term cross-sectoral planning ▪ Fragmented land use management	▪ Improved land use management ▪ Promotion of appropriate technologies ▪ Market-based fees and charges ▪ Education ▪ Capacity building ▪ Stakeholder dialogue	▪ Implement land use planning and management systems ▪ Increase enforcement ▪ Low-impact rain-fed agriculture ▪ Encourage the production of appropriate crop varieties
Energy production	▪ Weak regulations ▪ Inadequate institutional capacity	▪ Improve regulations on dam construction ▪ Environmentally friendly farming	▪ Construct fish migration paths ▪ Stakeholder dialogue
Industry	▪ Inadequate implementation of new technology and infrastructure ▪ Lack of habitat protection ▪ Low enforcement capacity	▪ Promotion of appropriate technologies ▪ Improved stakeholder participation ▪ Strengthen local control	▪ Improved natural resource management ▪ Pollution taxes and fines ▪ Integrated, multilateral conservation
Fisheries	▪ Insufficient enforcement capacity ▪ Lack of research for making sound policies ▪ Inadequate implementation of appropriate fishing gear	▪ Capacity building ▪ Improved regulation and enforcement ▪ Expanded community education programmes ▪ Follow recommendations of scientific organisations	▪ Improved management of protected areas ▪ Adoption of regulations at international level ▪ Partnerships
Urban development	▪ Urbanisation ▪ Inadequate knowledge of sewage treatment ▪ Inadequate financial capacity to promote compliance ▪ Poverty	▪ Strengthen institutions ▪ Increase knowledge	▪ Improve legal framework ▪ Clear and transparent decision-making
Coastal development	▪ Lack of enforcement ▪ Rapid population growth ▪ Poverty ▪ Institutional weakness	▪ Promotion of alternative energy technologies to replace wood fuels ▪ Improved the governance framework ▪ Capacity building in policy formulation	▪ Improved control of population growth ▪ Coastal management planning

scientific organisations, it is not surprising that Argentina and Uruguay (Patagonian Shelf/38) disagree on crucial aspects of administering shared coastal resources and postpone difficult management decisions.

Even when information is available to make sustainable policy decisions, organisations responsible for formulating policies may not include environmental considerations or broad stakeholder involvement in the decision-making process. Political structures in some Southeast Asian countries are still dominated by hierarchy and patronage, with democratic decision-making yet to be common practice. This governance model has resulted in bureaucratic inaction, the misallocation of financial resources and a mistrust of government officials. Consequently, it is difficult to obtain local support for many governmental management policies and even for collecting accurate statistics.

POLICY RELEVANT CONCLUSIONS

Both freshwater and coastal marine ecosystems are confronted and continually degraded by a wide range of powerful stressors. In freshwater ecosystems, increasing human populations will continue to demand additional freshwater for drinking, irrigation, hydropower and waste disposal. The introduction of invasive species will also exert greater influences on freshwater ecosystems in the future. The adoption of integrated management and increased public awareness of the plight of freshwater ecosystems will only partially reduce the rate of habitat degradation.

The pressures exerted by widespread poverty and population growth are also placing a burden on coastal and marine ecosystems and the resources they provide. Overfishing, coastal development, sedimentation, pollution and the expansion of aquaculture are some of the factors that will continue to degrade transboundary coastal ecosystems.

While appropriate legislation is in place in many countries, a lack of capacity to implement or enforce such legislation, particularly in many GEF-eligible regions, will allow negative habitat and community modification to continue in both types of aquatic system.

GIWA regional teams selected specific policy options that address habitat modification and promote an ecosystem-based approach (Table 14). Their suggested interventions are divided into four groups: (i) building a knowledge base; (ii) integrating ecosystem issues into policies; (iii) supporting marine protected areas; and (iv) strengthening institutional capacity. Most successful interventions use multiple instruments to address different root causes and take into account regional environmental and socio-economic particularities.

Knowledge base and assessments

Policy makers require information to evaluate the trade-offs between policies and to set priorities. Despite having made major progress, we are yet to understand important aspects of the interaction between habitats, their organisms and human actions. Furthermore, economic valuation of the goods and services provided by ecosystems is still struggling to gain acceptance as a regular policy tool in most parts of the world. Given the complexity of transboundary issues, these assessments require cooperation between scientists from a range of disciplines. By evaluating impacts and trade-offs, assessments like GIWA can improve the compatibility of different sectoral, national and regional policies.

Policy integration

The management of aquatic habitats and resources, as well as addressing the multitude of causes behind the problems they face, has proven difficult. This has led to the development of an ecosystem-based approach to the management of freshwater and marine transboundary waters. One ecosystem-based approach that is becoming widely accepted is Integrated Coastal Zone Management (ICZM). It is analogous to the integrated water resource management approach discussed in the chapter on freshwater shortage. Many GIWA regional teams throughout the tropics recommend pursuing, or are already implementing, ICZM.

Actions to preserve habitats have traditionally segregated ecosystems from economic activities by establishing protected areas, bans and zoning. However, some of the richest aquatic habitats are located in areas where human activities take place (e.g. fishing in coastal waters). Consequently, policy measures that aim for sustainability have become essential elements of natural resources management strategies. One particularly important aspect of policy integration is to ensure sectoral government agencies, such as ministries of forestry, energy and roads, incorporate environmental and social concerns in their decision-making. Most GIWA regional teams recommended a wider use of economic incentives, such as those included in Table 15. They also stressed the importance of enforcing existing regulations.

TABLE 15. POTENTIAL ECONOMIC INCENTIVES TO ADDRESS TRANSBOUNDARY HABITAT AND COMMUNITY MODIFICATION

Instruments	Incentives	Disincentives	Examples of GIWA regions
Property rights	▪ Ownership, management, access and use rights over biodiversity ▪ Joint, collaborative and co-management of biodiversity ▪ Leases, concessions, licenses, permits and franchises for the management, use, harvesting and prospecting of biological resources	▪ Exclusion from land and biodiversity ▪ Enforcement and penalties for unsustainable or illegal biodiversity use	38b South Atlantic Drainage System (Patagonian Shelf) 11 Barents Sea 34 Yellow Sea 36 East China Sea 42c Niger Basin (Guinea Current)
Market and charge systems	▪ Improvement of existing biodiversity markets and prices, and development of new biodiversity markets and charges, including tourist levies, entrance fees, user fees, prospecting fees and royalties ▪ Tradable quotas, permits, rights and licenses ▪ Develop alternative biodiversity markets and products ▪ Eco-labelling and accreditation of sustainable biodiversity products	▪ Ban on biodiversity impacting products or markets ▪ Biodiversity impacting product quotas or limits	38b South Atlantic Drainage System (Patagonian Shelf) 42c Niger Basin (Guinea Current)
Fiscal instruments	▪ Subsidies for biodiversity conserving activities, technologies and products ▪ Tax relief or differential taxes on land uses, technologies and products ▪ Credits and offsets for biodiversity conserving activities	▪ Taxes or surcharges for products which impact biodiversity ▪ Differential land use, technology and product taxes	23 Caspian Sea
Livelihood support	▪ Improving efficiency, scope and sustainability of biodiversity utilisation	▪ Rural development and livelihood diversification and improvement	56 Sulu-Celebes Sea 54 South China Sea 42c Niger Basin (Guinea Current)

(SOURCE: GIWA AND IUCN 2000)

CORAL REEF, AUSTRALIA
(PHOTO: EYEQNET)

Marine Protected areas

Even when economic incentives are used to promote conservation, some valuable but fragile habitats may be degraded if economic activities are not restricted. Marine Protected Areas (MPAs) can play a major role in conserving marine ecosystems and maintaining their associated value for human well-being. MPAs can range from small, highly protected reserves prohibiting all resource extraction, to large reserves zoned for multiple uses and sustainable development.

Unfortunately, many existing MPAs are only "paper parks" that fail to meet their objectives. On the other hand, there are highly successful MPAs, including: the Apo Island Marine Sanctuary and the Danjugan Island Marine Reserve in the Philippines; the Kiunga Marine Reserve in Kenya; the Chumbe Island Marine Park in Tanzania; and the Great Barrier Reef Marine Park in Australia.

Capacity strengthening

Designing and implementing sustainable use and conservation policies requires the integration of academic disciplines and cooperation among specialists and policy-makers. Institutions responsible for managing habitats frequently lack essential skills necessary for ecological and economic assessments, management, financial reporting and control, monitoring and enforcement.

A lack of financial resources is a constraint for the conservation of aquatic habitats in many regions. Effective actions necessary for the management of protected areas and the enforcement of exclusive economic zones can only be implemented if financial resources are provided.

Social instruments, many based on stakeholder participation, were also frequently recommended by GIWA regional teams. Participation goes beyond consultation; it should empower people to make the decisions and manage the resources on which their livelihoods depend.

STAKEHOLDER DISCUSSION IN KIUNGA NATIONAL MARINE RESERVE:
JUNIOR WWF OFFICER IN DIALOUGE WITH SPOKESMAN OF FISHERS.
(PHOTO: G. HEMPEL)

Conclusions

Globally, the unsustainable use of freshwater and overfishing are the two most severe concerns in transboundary waters worldwide. Together with global climate change and pollution, they modify habitats and result in a loss of biodiversity. These water-related problems are amongst the most serious and immediate threats to humanity.

Although freshwater and marine issues differ greatly, they have mostly the same root causes like poverty and population growth. The pressure on aquatic resources is increased further by poor governance, and market and policy failures. More dams, deeper wells and larger fishing fleets are not the answer; instead, the world's limited aquatic resources need to be shared and used wisely. Broad cooperation by a variety of stakeholders is an essential component of ecosystem-oriented management.

GIWA has focused on the transboundary nature and causes of the major aquatic concerns affecting Large Marine Ecosystems and international river basins, and developed potential options to address these concerns.

A number of globally relevant conclusions can be drawn from the giwa regional assessments. giwa has confirmed that transboundary pressures from human activity have weakened the ability of aquatic ecosystems to perform essential functions. The continued neglect of ecosystems and the inability to protect water resources are compromising human well-being and sustainable development. In general, the concerns are expected to increase in severity over the forthcoming decades, particularly freshwater shortage, pollution, and habitat modification in developing regions. Furthermore, global climate change will exacerbate the situation in many parts of the world.

Marine and freshwater systems are inextricably linked within the global hydrosphere. The transboundary consequences of human activities in freshwater systems are also felt in the coastal and marine environment, including changes in salinity and currents, sedimentation, eutrophication and toxic pollution. Although human marine activities affect freshwater systems less commonly, ocean processes impact coastal and even inland environments, and human well-being in various ways, e.g. by saline intrusion, storm surges and climate induced impacts.

giwa confirmed that overfishing has the most adverse transboundary effects on marine ecosystems, while human-induced changes in water flow were considered to have the most severe transboundary impacts on freshwater ecosystems.

Challenges to international marine systems

The giwa regional teams assessed three basic types of fisheries. In the shelf and enclosed seas of polar and temperate zones, a limited variety of demersal and pelagic fish species are harvested, most with a lifespan of several years. These stocks are extensively overfished, but could be restored by limiting catches and fishing effort (preferably as a precautionary measure). Climate driven regime shifts often conceal fishery-induced changes to stocks. The side-effects of the fisheries could be minimised by restricting destructive bottom trawling and through the introduction of regulations and selective technologies to reduce by-catch and discards. In many giwa regions, international agreements and organisations have been established to improve fisheries management. However, the effectiveness of those measures is often hindered by weak enforcement and a lack of political will in the face of lobbying by the fisheries industry.

Upwelling regions, particularly the four large western boundary systems (the Benguela/44, California/26, Canary/41 and Humboldt/64 currents), are amongst the most productive fishing regions in the world. Local and international fishing fleets catch mainly small, short-lived pelagic fish. Fishing management must adapt precautionary regulations in response to massive climate driven fluctuations in fish stocks in these regions, for example, during enso events. The pelagic fisheries of upwelling regions have limited side-effects.

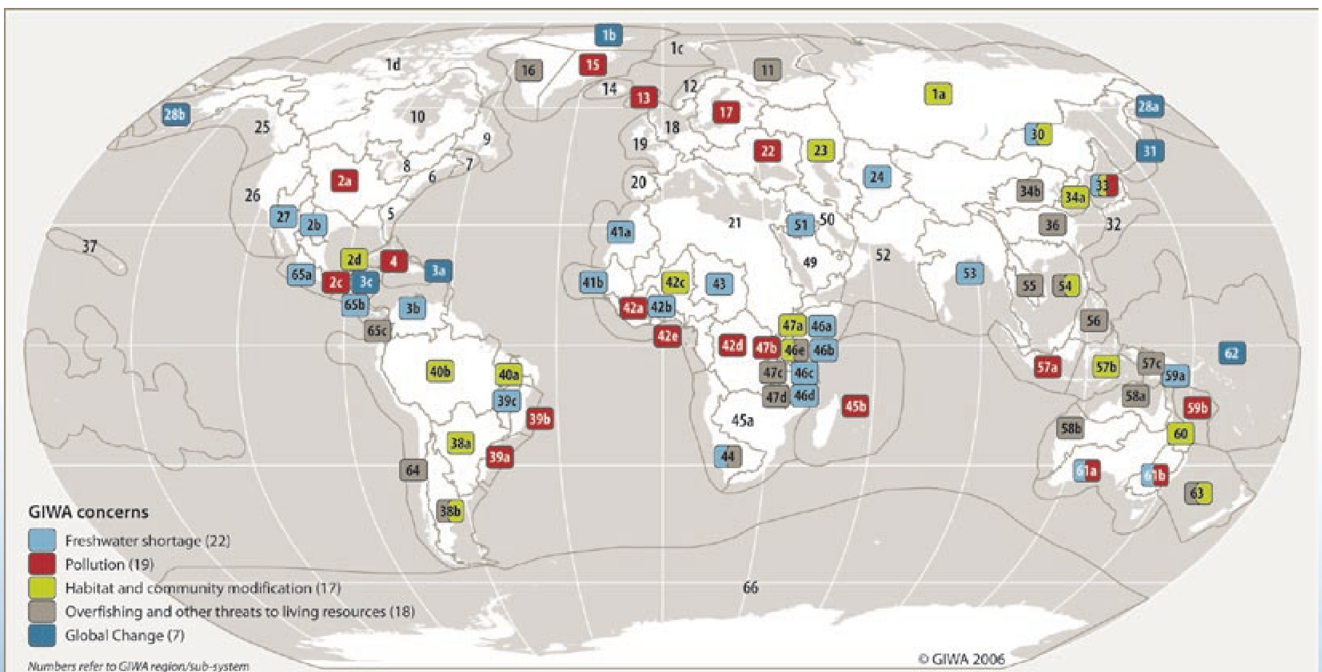


figure 31. top priority concerns by giwa region and sub-system
note: several regions and sub-systems identified more than one top priority concern.

In tropical and subtropical LMEs, small-scale, mostly artisanal fisheries exploit nearshore stocks, while industrialised fleets, often from overseas, operate offshore. They harvest a great variety of fish and other living resources using a broad range of fishing methods. In many GIWA regions these fisheries have severely depleted stocks which has led to 'fishing down the food web', where overfishing causes a trophic shift towards small, short-lived organisms lower in the food chain.

Ecosystem-based management can be achieved in many GIWA regions through the adoption of a variety of management instruments, including fleet reduction programmes, subsidy reforms, improved definition of rights, gear control, and closed seasons and areas. These measures, based on broad stakeholder involvement, aim to promote sustainability in the fisheries and to protect marine ecosystems.

Coastal habitats are not only degraded by the fisheries. Hypoxic (oxygen-depleted) zones in the marine environment were previously restricted to enclosed seas but are now observed in many coastal areas. Increased quantities of suspended sediment discharged by rivers or originating from coastal activities, such as construction and dredging, are degrading marine habitats, particularly coral reefs. In addition, nearshore habitats are modified by mariculture, oil and gas activities, wind parks and coastal development, including the construction of ports and tourist facilities. Mass coral bleaching, caused by water temperature increases, is considered the greatest threat to coral reefs on a global scale.

The creation of marine protected areas, zoning and bans can conserve sensitive habitats, such as coral reefs, mangroves and seagrass beds. In areas where human interference is unavoidable, policy measures which promote the adoption of sustainable practices were recommended by GIWA regional teams.

Although the transboundary impacts on marine ecosystems could be mitigated and controlled by present management instruments, political will and institutional capacity needs strengthening in most GIWA regions.

Challenges to international freshwater systems

The modification of stream flow by water infrastructure was the most severe and widespread transboundary impact affecting freshwater ecosystems. Dams fragment rivers and create a series of lakes and large reservoirs used for a variety of human uses, including drinking water, irrigation and the generation of hydroelectricity. Stream flow is also altered by the canalisation of meandering rivers to improve navigation.

Land-use change, including forest colonisation, urbanisation, draining of wetlands and irrigation of dry lands, modifies the drainage patterns and groundwater recharge rates of international river basins. In many GIWA regions, changes in the hydrological regime, resulting from both water impoundment and land-use change, have altered evaporation rates, the seasonal periodicity of flooding, erosion-accretion dynamics and the water table. These changes have adversely affected downstream habitats, particularly wetlands, and have subsequently reduced biodiversity and modified community structures.

Extensive soil and groundwater salinisation resulting from reduced freshwater availability, inappropriate irrigation practices and overabstraction of groundwater was reported in many GIWA regions. Toxic and microbial pollution are additional threats to freshwater systems.

On a global scale, freshwater shortage is the most severe aquatic concern. On all continents, the inhabitants of desert and semi-arid zones have strayed from their traditional path of sustainable water use and now overexploit their scarce surface and upper groundwater supplies. Inappropriate land-use management, inefficient use of freshwater by irrigation, evaporation from reservoirs, and greater water demand fuelled by the expansion of agriculture, as well as population and economic growth, have resulted in greater water scarcity and an increase in the frequency and duration of droughts. The overabstraction of fossil water from deep aquifers is increasingly common.

In the majority of arid and semi-arid regions, attempts to halt or reverse current degradation trends are constrained by: poverty and slow economic development; deficiencies in the technical, administrative and managerial capacity of institutions responsible for water management; weak national and regional legal frameworks; and a lack of international cooperation. In most GIWA regions, there is a need to increase the knowledge base regarding surface and ground water budgets and for a change in water policy from building new dams and deepening wells to conserving water through demand and efficiency management.

In the past, freshwater shortage has not been a concern in the humid zones of the higher latitudes and near the equator. Today, water is used unsustainably by large urban agglomerates and irrigated agriculture, resulting in water scarcity even in areas with substantial rainfall.

GIWA mega-regional trends

Considerable political and cultural differences exist between and within the GIWA mega-regions which affect the characteristics and relevance of the root causes for policy makers. The international waters of Sub-Saharan Africa are among the most degraded, particularly as a result of freshwater shortage. Incessant poverty and weak national legal frameworks and institutional capacity cause unsustainable development and constrain environmental management. In Southeast Asia, pollution and habitat modification have the most severe impacts. Increasing pressure on natural resources resulting from rapid economic growth is insufficiently controlled by the reform of relevant policies. In the former Soviet Union, water bodies were considered inexhaustible and to be infinite receptors of waste; a perception that will take a long time to change. Deficiencies in policy development and widespread corruption are impediments to habitat restoration, cleaner water and sustainable fisheries. In South and Central America, the overall environmental status of international waters seems of a higher quality than in other mega-regions. Nevertheless, pollution and habitat modification are relatively widespread but can be addressed through long-term natural resource planning, stronger political will and the strengthening of institutions responsible for environmental management and enforcement.

Cross-cutting root causes and management responses

Despite the above noted regional disparities, this global synthesis of the regional reports illustrates that the majority of the GIWA concerns have the same root causes: global climate change, population growth, migration to coastal areas, urbanisation, industrialisation, increasing economic pressures on resources, globalisation of trade and markets, and greater demand for water-intensive goods and services. These cross-cutting root causes are intrinsic elements of human societies. They cannot be resolved by simple policy interventions in the water sector alone but require concerted actions at all levels of national and international governance. The failure of global policy measures aimed at reducing the rate of global climate change demonstrates the difficulties in addressing these root causes.

Further root causes, such as market failures, institutional weaknesses, knowledge deficiencies, inappropriate subsidies and other unsustainable policy instruments, can be resolved by concerted action by all stakeholders in a given region. Even beyond regional boundaries. In the present era of globalisation, many policy responses need to be initiated by the international community.

Pollution and the exploitation of water and aquatic living resources are often sufficiently regulated. However, enforcement and implementation can be weak due to a lack of awareness at all levels, weak institutions, inadequate technical and financial resources, negligence, bureaucracy and corruption. There is insufficient environmental monitoring in both developing and developed regions. Cooperative efforts for training and other forms of capacity building are needed on a regional basis, as well as through North-South partnerships.

The GIWA regional assessments, in accordance with other recent assessments, found that the complexity and diversity of transboundary systems require the integration of management across countries, sectors and ecosystems. Ecosystem-based management, including Integrated Coastal Zone Management (ICZM) and Integrated Water Resource Management (IWRM), offers the best path for advancing sustainable development. An ecosystem-based approach was called for at the World Summit on Sustainable Development (WSSD).

In contrast to traditional approaches that ignore issues which transcend limited sectoral interests, ecosystem-based management offers a framework for changing the practices of economic activities. The fishing industry, for example, has largely disregarded environmental warnings, opting instead for the blind hope that natural population recruitment will maintain the viability of the fisheries. Ecosystem-based management needs to be flexible and adaptive to the dynamic interactions of ecosystems and societies. The success of GEF LME projects has proven that an ecosystem-based approach can be implemented in widely differing regions.

GIWA, lessons learnt

Lessons can be learnt from the successes and weaknesses of GIWA. It has been the largest global assessment of a broad array of ecosystem-wide water issues from a transboundary perspective, holistically assessing international river basins and their adjacent LMEs. GIWA has prioritised and provided information on transboundary aquatic concerns so that regional and international policy makers and managers can better manage international waters.

GIWA's bottom-up approach was the project's greatest strength. Regional teams conducted the assessment based on existing regional data and information, and adapted the methodology to the local conditions. In many GIWA regions, the assessment process has strengthened communication between social and natural scientists, as well as managers, providing the basis for long-term collaboration. It has also fostered transboundary cooperation and new partnerships within the regions and between neighbouring regions. GIWA not only assessed the available policy critical information, but also identified key knowledge gaps. GIWA's bottom-up approach resulted in strong local ownership of the GIWA regional reports.

In many regional teams, however, social scientists and policy specialists were underrepresented and stakeholder involvement was limited in several policy option analyses. Information availability varied regionally and nationally, especially between developed and developing regions, which affected the accuracy and comparability of the results.

In future, the methodology should further incorporate the multitude of interactions between the various concerns and issues. Greater involvement of governments and various stakeholder groups would strengthen the causal chain and policy options analyses. It is essential to maintain close links with other assessment projects in order to avoid conflicting approaches and duplication of efforts, particularly in regions where scientific and technical expertise are limited.


(PHOTO: G. HEMPEL)

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Acronyms

ACOPS	Advisory Committee on Protection of the Sea
ANA	Brazilian National Agency of Waters
CAS	Chinese Academy of Sciences
CCA	Causal Chain Analysis
DDT	Dichloro Diphenyl Trichloroethane
DEWA	Division of Early Warning and Assessment
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
EU	European Union
FAO	United Nations Food and Agriculture Organization
GEF	Global Environment Facility
GEMS	Global Environmental Monitoring System
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIWA	Global International Waters Assessment
GLOBALLAST	Global Ballast Water Management Programme
GPA	Global Programme of Action
GWP	Global Water Partnership
HAB	Harmful Algal Bloom
IAH	International Association of Hydrogeologists
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISARM	International Shared Aquifer Resource Management
ISO	International Organization for Standardization
ITQ	Individually Transferable Quota
IWRM	Integrated Water Resources Management
LME	Large Marine Ecosystem
MARPOL	International Convention for the Prevention of Marine Pollution from Ships
MDG	Millennium Development Goal
MPA	Marine Protected Area
MSC	Marine Stewardship Council
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
PCB	Polychlorinated Bifenyls
POA	Policy Options Analysis
POP	Persistent Organic Pollutant
SAP	Strategic Action Programme
SCOPE	Scientific Committee on Problems of the Environment
SEI	Stockholm Environment Institute
Sida	Swedish International Development Cooperation Agency
SIDS	Small Island Developing States
STAP	Scientific Technical Advisory Panel
TAC	Total Allowable Catch
TDA	Transboundary Diagnostic Analysis
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
UNSCD	United Nations Commission on Sustainable Development
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
WCD	World Commission on Dams
WHO	World Health Organization
WMO	World Maritime Organization
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization
WWC	World Water Council

ANNEXES

Annex I: Global International Waters Assessment

Origin, objectives, workplan, teams and products

THE NEED FOR A GLOBAL INTERNATIONAL WATERS ASSESSMENT

Water is a vital life supporting resource, necessary for agriculture and other economic purposes, and for generating hydropower. Marine and freshwater ecosystems provide valuable resources in terms of fish and other aquatic living resources.

Globally, anthropogenic activities are degrading the world's water bodies. Aquatic ecosystems and human well-being are negatively impacted by dramatic changes in the flow regime of river basins, increasingly severe natural disasters, such as floods and droughts, greater pollution loads, and the overexploitation of virtually every commercial fishery. Furthermore, freshwater and marine habitats are directly modified by urban and infrastructure development. There is a growing public awareness and concern regarding the declining quality and quantity of the world's aquatic resources, resulting in mounting pressure on governments and decision makers to initiate new and innovative approaches to managing these resources in a sustainable manner to ensure their availability for future generations.

The management of the world's aquatic resources for the mutual benefit of all societies and the environment is an extremely complex task. Without the construction of reservoirs, dams and canals, water 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 areas a

THE GLOBAL ENVIRONMENT FACILITY (GEF)

The Global Environment Facility forges international cooperation 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:

- Assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them;
- Building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns;
- Implementing measures that address the priority transboundary environmental concerns.

The goal is to assist countries in using 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

The University of Kalmar hosts the GIWA Coordination Office and provides scientific advice and administrative and technical assistance to GIWA. The 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 that gives Kalmar a unique educational and research profile compared with other small universities in Sweden. Of particular relevance for GIWA is an established research programme in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the university's Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Coordination 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 this cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

considerable distance away from the source. In the case of transboundary river basins, such as the Amazon, Nile and Niger, the impacts are transported across national borders, thus affecting more than one riparian country. In the case of large oceanic currents, the impacts can even be propagated between continents. The inextricable linkages within, and between, freshwater and marine environments requires a drainage basin approach to managing aquatic resources.

In addition, there is a growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective, nationally focused approaches to managing these 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, a shift in focus towards international cooperation and intergovernmental agreements is required. 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 these resources. As a consequence, cross-sectoral, multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Many assessments of aquatic resources are conducted by local, national, regional and international bodies. They often concentrate on specific themes, such as biodiversity or persistent toxic substances, or focus on marine or freshwater systems separately. A globally coherent assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, had never previously been undertaken but was clearly needed.

INTERNATIONAL CALL FOR ACTION

The need for a holistic assessment of transboundary waters was acknowledged by several international environmental organisations. The Global Environment Facility (GEF) recognised that its international waters component suffered due to the lack of a global assessment that could provide a clear understanding of the nature and root causes of international water problems, and that could indicate priorities for project intervention. The urgent need for an assessment of the causes of environmental degradation was also highlighted at

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, in addition to those created through transboundary movement of water. Single-country policies and actions inadequately cope with these transboundary problems.

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 further the complexity. These initiatives provide a new opportunity for cooperating nations to integrate many different programmes and instruments into comprehensive regional approaches in order to address the challenges to international waters.

the UN General Assembly Special Session on the Environment in 1997, and demonstrated through commitments by the UN Commission on Sustainable Development on freshwater in 1998, and seas in 1999. 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,' also emphasised the need for an investigation of the root causes of the degradation of the transboundary aquatic environment and options for addressing them.

These interests finally led to the development of the Global International Waters Assessment (GIWA) and its inauguration in 1999. The importance of GIWA was further underscored by the United Nations Millennium Declaration adopted by the UN General Assembly in 2000, and particularly the Plan of Implementation of the World Summit on Sustainable Development (WSSD) in 2002. The Plan calls for inter alia: integrated river basin management and increased understanding of the long-term sustainability of freshwater, coastal and marine environments; integrated assessment at the global and regional levels for the conservation and management of living and non-living marine resources; and the use of environmental impact assessments in decision making processes. The GIWA project was intended to provide information to support the implementation of such plans.

CONCEPTUAL FRAMEWORK AND OBJECTIVES

The primary objectives of GIWA are:

- To provide a prioritising mechanism that allows GEF to focus its 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.

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

UNEP WATER POLICY AND STRATEGY

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

- Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;
- Raising awareness of the importance and consequences of unsustainable water use;
- Supporting the efforts of governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;
- Providing support for the preparation of integrated management plans and programmes for aquatic environmental hotspots, based on the assessment results;
- Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

- A broad transboundary approach that provides a truly regional perspective by incorporating expertise and existing information from all nations in the region, and by assessing the major 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 provides globally comparable results.

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. 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, and the Volga River in Russia, which is principally responsible for changes to the Caspian Sea. Furthermore, GIWA is a regional assessment that has incorporated data from a wide range of sources and includes expert knowledge and information from a variety of sectors in each country of a region. The transboundary concept adopted by GIWA includes impacts caused by globalisation, international trade, demographic changes and technological advances, and recognises the need for international cooperation to successfully address these issues.

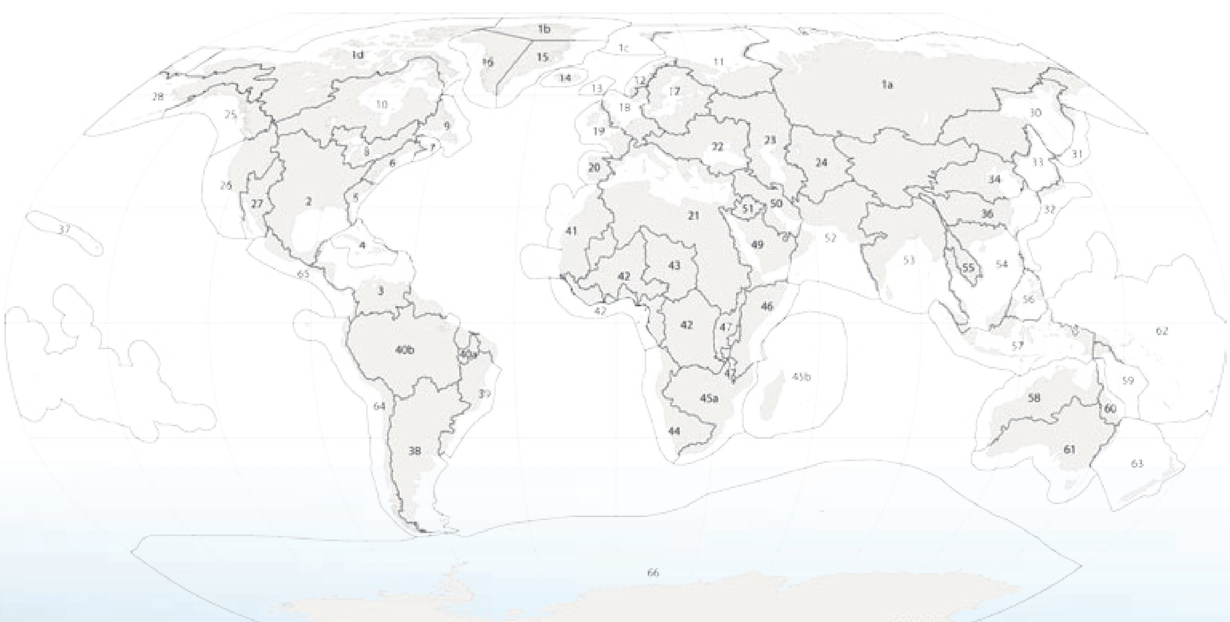
SCALE AND METHODOLOGY OF THE ASSESSMENT

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of GIWA, the geographical units being assessed have been designed according to the drainage basins of discrete hydrographic systems rather than political borders. The geographic units 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 that drain into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs). Some of the regions were later reconfigured and divided into sub-systems which were assessed individually by separate teams. Not all of the 66 regions were assessed by GIWA. Priority was given to GEF-eligible regions, i.e. developing regions and regions with transitional economies.

LARGE MARINE ECOCSYSTEMS

Large Marine Ecosystems (LMEs) are ocean regions 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: (i) bathymetry; (ii) hydrography; (iii) productivity; and (iv) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It was 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 cooperated in an action programme to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management unit for coastal ocean resources. The LME concept has also been adopted by GEF, which recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating sectoral economic activities.



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 I. THE TRANSBOUNDARY REGIONS ASSESSED BY THE GIWA PROJECT

In consideration of the objectives of GIWA and the elements incorporated into its design, a innovative methodology for the implementation of the assessment was developed during the initial phase of the project.

A holistic, region-by-region assessment of the world's transboundary aquatic resources had never been undertaken before and therefore a new methodology was required. A multidisciplinary, multi-sectoral, multinational approach was developed. The methodology is now available as a platform for future international assessments of aquatic resources.

The methodology focuses on five major environmental concerns; freshwater shortage, pollution, overfishing and other threats to aquatic living resources, habitat and community modification, and global change. The root causes, including global trends, policy, legislation, governance, institutional capacity and knowledge, are also analysed. Wherever possible, the causal chain analysis was followed by policy option analysis which outlined potential courses of action that aim to mitigate or resolve environmental and socio-economic problems in the region.

For a detailed description of the GIWA methodology, see Annex II.

GIWA REGIONAL ASSESSMENTS

The regional reports

The results of the GIWA assessment for each region are presented in the regional reports. These reports provide a brief physical and socio-economic description of the most important features of the region. The remaining sections of the report present the results of each stage of the assessment. Each regional report is reviewed by at least two external reviewers in order to ensure scientific validity and applicability.

The project has published 23 regional and thematic assessments in printed form (or in preparation for print) and on the web, and a further 12 are available online at www.giwa.net (see list below and the fold-out map inside of the front cover).

Regional reports printed or in preparation for print

Region 1a. Russian Arctic
Region 3a. Caribbean Sea/Small Islands
Region 3b/c. Caribbean Sea/Orinoco, Magdalena, Catatumbo/Central America, Mexico
Region 4. Caribbean Islands
Region 11. Barents Sea
Region 17. Baltic Sea
Region 23. Caspian Sea
Region 24. Aral Sea
Region 30. Sea of Okhotsk
Region 31. Oyashio Current
Region 38. Patagonian Shelf
Region 39. Brazil Current
Region 40b. Amazon
Region 43. Lake Chad
Region 45b. Indian Ocean Islands
Region 47. East African Rift Valley Lakes
Region 54. South China Sea
Region 55. Mekong River
Region 62. Pacific Islands
Region 64. Humboldt Current
Region 65. Eastern Equatorial Pacific

Printed thematic reports

Region 22. Black Sea. Transboundary waters in the Black Sea – Danube region; legal and financial implications.
Region 22. Black Sea. Eutrophication in the Black Sea region – impact assessment and causal chain analysis.

Published on web

Region 1b. Arctic Greenland
Region 13. Faroe Plateau
Region 15. East Greenland Shelf
Region 16. West Greenland Shelf
Region 27. Gulf of California
Region 36. East China Sea
Region 34. Yellow Sea
Region 41. Canary Current
Region 42. Guinea Current
Region 44. Benguela Current
Region 56. Sulu-Celebes Sea
Region 57. Indonesian Seas

To obtain copies of the printed reports, please contact:
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United Nations Environment Programme,
PO Box 30552, Nairobi 00100, Kenya,
Tel: +254 20 762-4299, Fax: +254 20 762-4269,
Email: dewainfo@unep.org.

The global network

In each of the GIWA regions, the assessment was conducted by a team of local experts led 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 in 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. The selection of the team members is one of the most critical elements for the success of GIWA. In order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a variety of institutions, such as universities, research institutes, government agencies and the private sector. The teams included representatives from each country in the region.

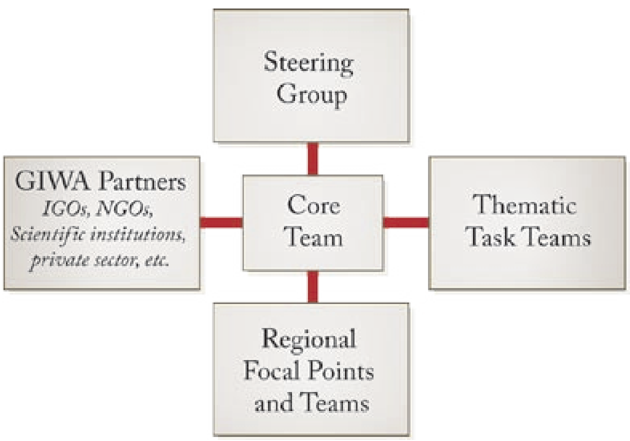


FIGURE 2. THE ORGANISATION OF THE GIWA PROJECT

In total, almost 1 500 experts contributed to the GIWA project, building strong local ownership for the reports and creating a global network of experts and institutions that can facilitate the exchange of experiences and expertise.

The regional assessments would have been impossible without the remarkable efforts of all regional task teams. UNEP appreciates the work and contributions of the teams to GIWA, particularly the focal points:

Russian Arctic	Alla Tsyban
Arctic Greenland	Mogens Dyhr-Nielsen
Gulf of Mexico	Alejandro Yáñez-Arancibia
Caribbean Sea	Francisco A. Arias-Isaza
Caribbean Islands	Antonio Villasol Nunez
Barents Sea	Natalia Golubeva
East Greenland Shelf	Mogens Dyhr-Nielsen
West Greenland Shelf	Mogens Dyhr-Nielsen
Baltic Sea	Ain Lääne
Black Sea	Felix Stolberg, Olena Borysova, Valery Michailov
Caspian Sea	Felix Stolberg, Olena Borysova, Rovshan Mahmudov
Aral Sea	Felix Stolberg, Olena Borysova, Igor Severskiy
Gulf of California	Edgar Arias Patron, Omar Vidal
Bering Sea	Suzanne Marcy
Sea of Okhotsk	Arkady V. Alekseev
Oyashio Current	Arkady V. Alekseev
Kuroshio Current	Roger Juliano
Sea of Japan	Arkady V. Alekseev
Yellow Sea	Teng Seng-Keh
East China Sea	Jing Zhang
Patagonian Shelf	Ana Mugetti
Brazil Current	Marcia Marques
Northeast Brazil Shelf	Maria Irles de Oliveira Mayorga
Amazon	Ronaldo Borges Barthem
Canary Current	Mhammed Tayaa
Guinea Current	Jean Folack, Julius Wellens-Mensah
Lake Chad	Johnson A. Oguntola
Benguela Current	Kim Prochazka
Agulhas Current	Chris Magadza
Indian Oceans Islands	Rolph Antoine Payet
Somali Coastal Current	Renison K. Ruwa
East African Rift Valley Lakes	Eric Odada
Red Sea & Gulf of Aden	Habib N. El-Habr, Najah T. Mistafa
Euphrates and Tigris River Basin	Habib N. El-Habr, Najah T. Mistafa
Jordan	Habib N. El-Habr
Bay of Bengal	Jayampathy Samarakoon
South China Sea	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Mekong River	Anond Snidvongs
Sulu-Celebes Sea	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Indonesian Seas	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
North Australian Shelf	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Coral Sea Basin	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Great Barrier Reef	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Great Australian Bight	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Pacific Islands	Fabián Eguiguren Valdivieso
Tasman Sea	Clive Wilkinson, Lyndon DeVantier, Russell Reichelt
Humboldt Current	Ulises Munaylla Alarcón
Eastern Equatorial Pacific	Ulises Munaylla Alarcón

MANAGEMENT OF GIWA

The project was implemented by the United Nations Environment Programme (UNEP), in collaboration with the University of Kalmar, Sweden, with financial support from GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), the Ministry for Foreign Affairs of Finland (10%), the Norwegian government, the Municipality of Kalmar, the University of Kalmar and UNEP. The funds were mainly used to support assessments of GEF-eligible regions. Assessments of GEF non-eligible regions were conducted by various international and national organisations as in-kind contributions to GIWA.

The GIWA project, managed by the UNEP/GIWA Core team, was comprised of the following staff:
Scientific Director: Dag Daler (2000-2005), Per Wramner (1999-2000).
Coordinator for the Northern Hemisphere: Elina Rautalahti-Miettinen (2000-2005).
Coordinator for the Southern Hemisphere: Juan Carlos Belausteguigoitia (2002-2005), Nick Mandeville (1999-2000).
Coordinator for Sub-Saharan Africa: Edith Mussukuya (2001-2004).

Officers from the UNEP Headquarters who liaised with the GIWA core team included Salif Diop, Ahmed Djoghlaf, Vladimir Mamaev, John Pernetta, Takehiro Nakamura, Pinya Sarasas, Dik Tromp, Isabelle Vanderbeck.

The GIWA project was guided by a Steering Group consisting of representatives from the following agencies and scientific bodies:
UNEP/DEWA as chair of the Steering Group: Dan Claasen, Timothy Foresman, Steve Lonergan.
UNEP/DGEF: John Pernetta, Vladimir Mamaev.
GEF Secretariat: Alfred M. Duda.
GEF/STAP: Angela Wagener, Alexei Maximov.
ACOPS: Jubomir Jeftic, Viktor Sebek.
ANA: Jerson Kelman.
CAS: Jing Zhang.
Ministry for Foreign Affairs of Finland: Eero Kontula.
GESAMP: Stjepan Keckes, Michael E. Huber.
GWP: Kahlid Mohtadullah, Emilio Gabrielli, Erik Skoglund, Björn Guterstam.
Municipality of Kalmar: Anders Engström, Lars Malmborg.
Ministry of the Environment, Norway: Per W. Schive, Hanne-Grethe Nilsen.
NOAA: Kenneth Sherman.
SCOPE: Gotthilf Hempel who also served as the GIWA Ambassador.
SEI: Arno Rosemarin.
Sida: Kent Blom, Mats Segnestam, Bengt Johansson, Mats Eriksson.
University of Kalmar: Åke Hagström.
UNDP: Andrew Hudson.
The World Bank: Inesis Kiskis, Stephen F. Lintner.
WWC: Vanessa Lemaire-Drinkwater.

During the development of GIWA, a number of experts made significant contributions, especially in the development of its unique methodology. UNEP would like to acknowledge the following:

Olena Borysova, John Dixon, William Hogland, Norman Lee, Olof Lindén, Marcia Marques, Laurence Mee, Anond Snidvongs, Felix Stolberg, Galina Titova.

A special acknowledgement is extended to the University of Kalmar, which served as the executing agency, for its outstanding team of hardworking and devoted staff comprising of the following individuals:

Scientific team for the regional reports:
Scientific Advisor: Erik Arrhenius (1999-2001), Olof Lindén, who also served as Acting Coordinator for the Southern Hemisphere (2000-2001, 2005), Ulla Li Zweifel (2002-2003, 2005).

Supporting scientific team
Petre Badulescu (1999-2000), Ye Chun, (2001-2002), Sara Gräslund (2001), Bertil Hägerhäll also served as acting Coordinator for the Northern Hemisphere (1999-2000), Linda Holm (2001), Marcia Marques (2000-2004), Göran Rudbäck, Liaison Officer (1999-2001), Susanna Stymne Airey (2001), Bo Wiman (1999-2000).

Editorial team for the regional reports:
Scientific Editor: Ulla Li Zweifel (2002-2004).
Supporting editors: Kristin Bertilius (2003-2005), Pierre Blime (2004), Johanna Egerup (2003-2005), Giovanna Fistarol Salomon (2004), Matthew Fortnam (2003-2005), Rasmus Göransson (2005), Niklas Holmgren (2003-2005), Malin Karlsson (2002-2005), Marianne Lindström (2003-

2005), Eva Lövbrand (2002-2003), Najah Mistafa (2002-2005), Sanna Mels (2004-2005), Joakim Palmqvist (2001-2005), George Roman (2004), David Souter (2001-2004), Monique Stolte (2003, 2005).

Information & web team
Åse Allberg (2001-2002), Peter Dietrich (2000-2001), Britt Hägerhäll (1999-2000), Elisabet Idermark (2002-2005).

Administration team
Elisabeth Andersson (2003-2004), Maria Carlson (2002), Niklas Carlsson (2004), Lena Månsson (2000-2005), Caisa Oskarsson (1999-2005).

University of Kalmar administration & scientific support:
Björn Lange (2002-2005), Ulf Lidman (2002-2005), Bengt Sedvall (1999-2001).

Between 2002 and 2005, 10 interns from various parts of the world participated in the GIWA project to learn and gain experience in the field of international waters.

Special thanks are also given to: the UNEP Collaborating Centre on Water and Environment for its in-kind contribution to a number of regional assessments and for its staff, in particular Per Bögelund-Hansen, Mogens Dyhr-Nielsen and Niels Ipsen; UNEP Grid Arendal, in particular Hugo Ahlenius, Lars Kullerud, Philippe Rekacewicz and Svein Tveitdahl; and to David Aubrey, Mike Bewer, Johan Holmberg, Jeff Thornton.

Annex II: GIWA methodology

The specific objective of GIWA was to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources. To achieve this, the assessment incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments. GIWA enables GEF to focus its resources and provide guidance to governments and decision-makers. The combination of all these elements into a single coherent methodology had not previously been attempted and therefore posed a significant challenge.

The GIWA methodology was achieved through an interactive process, guided by a Methods Task team comprised of experts with water, environmental assessment and socio-economic backgrounds. The preliminary versions of the methodology underwent extensive external peer reviews and preliminary testing in selected regions, the results of which were incorporated into the final GIWA methodology.

TABLE 1. PRE-DEFINED GIWA CONCERNS AND THEIR CONSTITUENT ISSUES ADDRESSED WITHIN THE ASSESSMENT

GIWA concerns	Environmental issues
Freshwater shortage	Modification of stream flow Pollution of existing supplies Changes in the water table
Pollution	Microbiological Eutrophication Chemical Suspended solids Solid wastes Thermal Radionuclide Spills
Overfishing and other threats to aquatic living resources	Overexploitation Excessive by-catch and discards Destructive fishing practices Decreased viability of stock through pollution and disease Impact on biological and genetic diversity
Habitat and community modification	Loss of ecosystems Modification of ecosystems
Global change	Changes in hydrological cycle Sea level change Increased UV-B radiation as a result of ozone depletion Changes in ocean CO_2 source/sink function

Considering the significant regional disparities in terms of the quality, quantity and availability of data, and socio-economic and environmental conditions, an innovative approach was required to achieve global comparability. The assessment focuses on the impacts of five pre-defined concerns in transboundary waters: freshwater shortage, pollution, habitat and community modification, overfishing and other threats to aquatic living resources, and global change. These encompass a diversity of issues which were grouped under the five concerns. In total, the impacts of 22 issues were evaluated (see Table 1).

The assessment integrated 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. The assessment was implemented by conducting 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 their collective knowledge and experience. The results were substantiated with the best available information, which is presented in the regional reports.

The GIWA methodology can be divided into four logical steps: i) Scaling defines the geographic extent of the region; ii) Scoping identifies and prioritises problems based on the magnitude of their impacts on the environment and human societies in the region; iii) Causal chain analysis (CCA) determines the root causes of those problems; and iv) Policy options analysis (POA) assesses various policy options that address those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps are summarised below and are fully described in two documents: 'GIWA Methodology Stage 1: Scaling and Scoping' and 'GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis' (Figure 1).

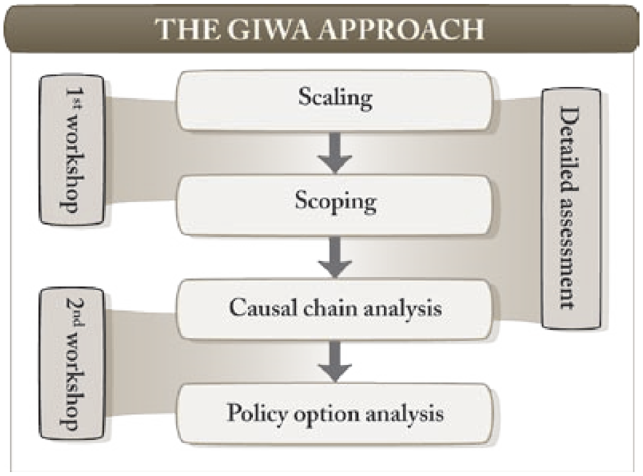


FIGURE I. THE GIWA ASSESSMENT APPROACH

Scaling – Defining the geographic extent of the region

Scaling defines the geographic scale of the assessment. The world was divided into 66 contiguous regions that are generally defined by a large but discrete drainage basin and its adjacent coastal waters, rather than political boundaries. In many cases, the boundaries of the marine areas coincided with those of Large Marine Ecosystems (LMEs) as defined by the US National Oceanic and Atmospheric and Administration (NOAA). During scaling, the regional teams inspected the boundaries proposed for the region during the preparatory phase of GIWA. If necessary, they revised the boundaries to remove important overlaps or gaps with neighbouring regions. The regional teams identified all the transboundary elements of the region's aquatic environment and determined whether they could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately. Other regional teams decided to merge their region with an adjacent region. The following changes were made:

- The Arctic/1 was divided into the Russian Arctic/1a, Arctic Greenland/1b, Arctic European/Atlantic/1c and Arctic North America/1d.
- The Amazon/40 was divided into the Northeast Brazil Shelf/40a and Amazon/40b.
- The Agulhas Current/45 was divided into Agulhas Current/45a and Indian Ocean Islands/45b.
- The East Bering Sea/28 and West Bering Sea/29 were merged into the Bering Sea/28.
- The Yellow Sea/34 and Bohai Sea/35 became the Yellow Sea (Yellow Sea/34a) and Yellow Sea (Bohai Sea/34b).
- The Gulf of Aden/48 and Red Sea/49 were merged into the Red Sea and Gulf of Aden/49.

Some regional teams decided to undertake separate assessments for transboundary water systems identified within their region. Often this included assessing the LME separately from the transboundary river basin. The Guinea Current/42 regional team, for example, assessed five sub-systems: Comoe Basin/42a; Volta Basin/42b; Niger Basin/42c; Congo Basin/42d; and Guinea Current LME/42e. Altogether, assessments were undertaken in 74 regions and sub-systems.

When analysing the results of the GIWA assessments in this global synthesis, the regions were grouped into the following mega-regions: Arctic Rim; Europe & Central Asia; North America; Central America; South America; Sub-Saharan Africa; North Africa & the Middle East; Northeast Asia; Southeast Asia; Australia & Pacific Islands; and the Antarctic.

Scoping – Assessing the GIWA concerns

Scoping assessed the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues. It is not designed to provide an exhaustive review of water-related problems that exist within each region, but instead identified the most urgent transboundary problems in the region and prioritised the most important issues for remedial actions. The priorities determined by Scoping are one of the main outputs of the GIWA project.

Focusing on pre-defined concerns and issues ensures comparability between the assessment results of the different regions. The magnitude of the environmental and socio-economic impacts caused by each issue was assessed for the entire region using the best available information obtained from a wide range of sources and the knowledge and experience of the regional experts. In order to increase the global comparability of the results, to remove bias caused by different perceptions of the severity of the impacts, and to encourage consensus amongst the team, the issues were evaluated using a standardised scoring system involving a four-point scale:

0 = no impact reported
1 = slight impact
2 = moderate impact
3 = severe impact

Each issue was scored according to a detailed set of pre-defined criteria that are used to guide experts in the assessment. For example, the criteria for assigning a score of 3 to the issue ‘loss of ecosystems or ecotones’ is: permanent destruction of at least one habitat, reducing its surface area by >30% over the last 2-3 decades. The full list of criteria for environmental and socio-economic impacts is presented in Tables 7-16 at the end of this Annex.

A trade-off associated with assessing the impacts of each concern and their constituent issues for an 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 for an entire region, it does not mean that the entire region suffers from 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 the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected are of sufficient overall severity to meet the criteria defining a severe problem and that regional actions should be initiated in order to mitigate the impacts of this problem.

Once each issue has been scored, it is weighted according to the relative contribution it makes to the overall environmental impacts of the concern and a weighted average score for each of the five concerns is calculated (Table 2).

The socio-economic impacts are assessed for each concern, not each issue. The socio-economic impacts are grouped into three categories; economic impacts, health impacts and other social and community impacts (Table 3-5). For each category, the size, degree and frequency of the impact is evaluated and a weighted average score is calculated for the overall socio-economic impacts of each concern.

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 ECONOMIC IMPACT ASSESSMENT OF FRESHWATER SHORTAGE

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	50
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasional/Short – Continuous 0 1 2 3	2	20
Weight average score for Economic impacts		2	

TABLE 4. EXAMPLE OF HEALTH IMPACT ASSESSMENT OF FRESHWATER SHORTAGE

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	Occasional/Short – Continuous 0 1 2 3	2	20
Weight average score for Health impacts		2	

TABLE 5. EXAMPLE OF OTHER SOCIAL AND COMMUNITY IMPACT ASSESSMENT OF FRESHWATER SHORTAGE

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	50
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasional/Short – Continuous 0 1 2 3	2	20
Weight average score for Other social and community impacts		2	

In addition, to ensure the long-term applicability of the options that were developed to mitigate these aquatic concerns, Scoping not only assessed the current impacts of these concerns and issues but also predicted the future impacts according to the “most likely scenario”, which considers demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment in the region by 2020.

In order to identify which concern is the top priority for the region, a final overall score is calculated based on the present and future scores of the environmental and socio-economic impacts of each concern. The prioritised concern is then analysed further in the CCA and POA. In the example presented in Table 6, the scoping assessment indicated that habitat and community modification was the priority concern in this region. The top priority concern(s) identified by the numerical outcome should correspond with the knowledge of the experts in the team and should be substantiated with supporting information.

However, in cases where the numerical results did not yield consensus among the regional experts in terms of

TABLE 6. EXAMPLE OF THE COMPARATIVE ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF EACH MAJOR CONCERN, AT PRESENT AND BY 2020

Type of impact									
Concern	Environmental score		Economic score		Human health score		Social and community score		Overall 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
Overfishing and other threats to aquatic living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	2.1
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	2.6
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	1.2

the ranking of priorities, the team continued by assigning weights to the relative importance of present and potential future impacts. Similarly, the team assigned weights indicating the relative contribution of environmental and socio-economic factors. The team should then recalculate the weighted average score for each concern taking into account both present and future impacts and environmental and socio-economic factors. The outcomes of these additional analyses are then subjected to further discussion to identify the overall priorities of the region.

The assessment recognises that the five GIWA concerns interact with each other. For example, pollution can destroy aquatic habitats that are essential for fish reproduction, which in turn can cause a decline in fish stocks and subsequent overexploitation. Once the priority concern for the region is agreed, the team should highlight the links between the concerns in order to identify where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

The causal chain analysis (CCA) traces the cause-effect pathways of the prioritised transboundary issues; from the socio-economic and environmental impacts back to their root causes. The CCA aims to identify the most important drivers of the aquatic concerns, so that they can be targeted by policy measures in order to prevent further degradation of the region's aquatic environment.

Root causes are not always easily identifiable because they are often separated, spatially or temporally, 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 varying local circumstances, the GIWA CCA is not a rigidly structured analysis but rather a guiding framework. Ideally, the CCA would be conducted 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. It was therefore necessary to develop a relatively simple and practical analytical CCA model.

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 difficulties in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and the issues that have been prioritised during the scoping assessment. The prioritised issue and its related environmental and socio-economic impacts are the starting point for the CCA. The next element in the 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 include:

- Increased nutrient inputs and concentrations
- Trapping of nutrients in stagnant water
- River and stream alterations
- Run-off and storm water

The sectors of human activity that contribute most significantly to the immediate cause are then determined. Assuming that the most important immediate cause in the example is increased nutrient concentrations, the most likely source of those nutrients would be from the agricultural, urban or industrial sectors. After identifying the sectors that are primarily responsible for the immediate causes, the root causes acting on these sectors are established. For example, if agriculture is found to be primarily responsible for the increased nutrient concentrations, the root causes may be:

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

Policy options

Despite considerable efforts by many governments and other organisations to address transboundary water problems, there is still much to be done. An important characteristic of GIWA's policy option analysis is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overfishing, and habitat modification are complex phenomena. The policy options analysis (POA) consists of two tasks:

Construct policy options

Policy options are different courses of action that aim to solve or mitigate environmental and socio-economic problems in the region. Although a variety of policy options could be constructed to address each root cause identified in the CCA, only those with the greatest likelihood of success were analysed by GIWA.

Select and apply the criteria against 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 GIWA are envisioned as contributions to a larger policy process. As such, the GIWA methodology, which was developed to test the performance of various options under various circumstances, was kept simple and broadly applicable.

GIWA ASSESSMENT CRITERIA FOR SOCIO-ECONOMIC IMPACTS

Socio-economic impact categories:

- **Economic impacts:** The key economic and public service sectors that are affected by the degradation of the aquatic environment should be identified and their relative importance to the regional economy assessed. The degree to which the quantity and quality of their output has been reduced and their costs of operation increased should be similarly assessed. Finally, the frequency and duration of the impacts should be determined.
- **Human health impacts:** The approximate number and types of people affected should be identified, the nature and degree of severity of the health impacts should be assessed and the frequency and duration of the impacts should be determined.
- **Other social and community impacts:** The number, size and principal characteristics (e.g. presence of vulnerable groups) of the affected communities should be determined, as well as the aspects of community life affected. The extent to which community life is affected and the frequency of these impacts should also be assessed.

Three broad criteria are considered when scoring the degree of severity (0-3) of the impacts:

- Size of the population or economic and public sectors affected (categorised as: very small; small; medium; and large).
- Degree of severity of the socio-economic impacts experienced (minimum; small; moderate; severe).
- Likely duration of the impacts (ranging from very occasional/very short-term to continuous/long-term).

TABLE 7. SCORING CRITERIA FOR THE 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 an 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 the 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 changes 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 water supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and groundwaters.	■ 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 do 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 .	■ Rivers 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 groundwater; 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 8. SCORING CRITERIA FOR SOCIO-ECONOMIC IMPACTS OF FRESHWATER SHORTAGE

Loss of agricultural uses (crops, livestock, aquaculture)	Reduced availability of fish as food	Increased damage to water-related equipment
Loss of human drinking water supplies	Loss of waste assimilative capacity	Damage to infrastructure
Loss of recreational use or aesthetic values	Increased costs of alternative water supplies	Increased costs of deepening wells and pumping
Loss of hydroelectric power production	Reduction in future use options	Population migration
Loss of coastal harbours and inland transport	Human health impacts	Transboundary implications
Loss of industrial uses	Reduced agriculture productivity (crops, livestock, aquaculture)	Increased vulnerability to sea level rise
Increased potential for upstream/downstream conflicts	Increased intake treatment costs	

TABLE 9. 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 products for consumers and no fisheries closures or advisories.	■ There is a minor increase in incidence of bacterial related gastroenteric disorders in fisheries products for consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries products for 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 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 10. SCORING CRITERIA FOR SOCIO-ECONOMIC IMPACTS OF POLLUTION

Increased risks to human health
Increased costs of human health protection
Loss of water supplies (e.g. potable water)
Increased costs of water treatment
Costs of preventive medicine
Costs of medical treatment
Costs of clean-up
Loss of tourism or recreational values
Loss of aesthetic values
Loss in fisheries
Costs of increased fisheries product processing
Change in fisheries value
Reduced options for aquaculture development
Risk to aquaculture
Loss of property values

Costs of weed control
Loss of wildlife sanctuaries
Costs of increased navigational clearance, navigational surveys or dredging activities
Increased costs of fish surveillance in the case of toxin incidence
Costs of reduced fish marketability due to aesthetic perceptions
Loss of protected areas
Reduction in options for other uses of freshwater
Potential for international conflicts
Loss of reservoir storage capacity
Damage to equipment (e.g. particle impacts)
Increased costs of coastal protection from waves/ storm surges/erosion
Costs of cleaning intakes
Endangerment of species

Increased costs of animal protection (esp. endangered species)
Displacement of valued species
Avoidance of amenities and products due to perceptions of effects of contamination
Costs of public reassurance
Maintenance of monitoring and radiological protection activities for public reassurance purposes
Costs of preventive measures (e.g. tanker design/ construction)
Costs of contingency measures
Costs of litigation
Costs of insurance
Costs of disruption to shipping, marine reserves and marine scientific activities during survey and clean-up of spills

TABLE 11. SCORING CRITERIA FOR ENVIRONMENTAL IMPACTS OF OVERFISHING AND OTHER THREATS TO AQUATIC 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 of fish with commercial gear for sale or subsistence.	■ Commercial harvesting exists but there is no evidence of overexploitation.	■ 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 occurs 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 occurs 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 occurs 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 12. SCORING CRITERIA FOR SOCIO-ECONOMIC IMPACTS OF OVERFISHING AND OTHER THREATS TO AQUATIC LIVING RESOURCES

Reduced economic returns	Loss of food sources (e.g. sources of protein) for human or animal consumption	Increased risks of predation, competition and/or disease for commercially valuable species
Loss of employment / livelihood	Reduced earnings in one area by destruction of juveniles in other areas (migrating populations)	Inter-generational equity issues (access to resources)
Potential new employment possibilities	Loss of protected species	Possible human health impacts
Improved catch/earnings	Reduced commercial value resulting from tainting	
Conflict between user groups for shared resources including space		

TABLE 13. 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 the 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 the 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 changes 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 changes 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[1].

[1] Constanza et al. (1997).

TABLE 14. SCORING CRITERIA FOR SOCIO-ECONOMIC IMPACTS OF HABITAT AND COMMUNITY MODIFICATION

Reduced capacity to meet basic human needs (food, fuel) for local populations	Loss of opportunity for investment income and foreign exchange from former ecosystem (e.g. loss of materials for potential pharmaceutical products)	Costs of responding to risks
Changes in employment opportunities for local populations and associated changes in social structures	Human conflicts, national and international	Intergenerational inequity
Loss of aesthetic values / recreational values for local populations	Loss of educational and scientific values	Modification or loss of cultural heritage
Loss of existing income and foreign exchange from fisheries, tourism, etc.	Increased risks to human population and capital investment	Costs of controlling invasive species
	Loss of land due to loss of physical protection	Costs of restoration of modified ecosystems

TABLE 15. 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 (in 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 ■ Changes 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 of 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 behaviour 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 evidence 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%.	■ Evidence 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.

TABLE 16. SCORING CRITERIA FOR SOCIO-ECONOMIC IMPACTS OF GLOBAL CHANGE

Freshwater availability	Human migration	Loss of income and employment
Food security	Damage to human life and property	Loss of property & capital assets
Employment security	Response costs for extreme events	Loss of incomes and foreign exchange from fisheries
Changes in productivity of agriculture, fisheries and forestry	Costs for avoiding navigational hazards	Loss of opportunity for investments (both domestic and foreign)
Changes in resources distribution and political jurisdiction over them	Increased costs of coast protection and emergency response/forecast	Increased costs of human health care

Annex III: GIWA's key: Causal chain and policy options analysis in a theoretical perspective

GIWA was created "to develop a comprehensive, strategic framework for the identification of priorities for remedial and mitigatory actions in international waters". Establishing priorities for actions implies not only an assessment of the severity of the problems but also an analysis of what can be done to solve or mitigate these problems. One of the salient characteristics of the GIWA assessment is that its recommendations are based on understanding the root causes of the problems. Freshwater scarcity, water pollution, unsustainable exploitation of living resources and habitat destruction are complex phenomena. Policy options that are grounded in a better understanding of these problems will contribute to the creation of more effective responses to the extremely complex water-related transboundary problems.

ROOT CAUSES

In order to identify root causes, GIWA regional teams conducted causal chain analyses. A causal chain is a series of hypotheses that link a problem with its effects and causes. The GIWA causal chain methodology includes immediate and root causes. Immediate causes are physical, biological or chemical factors that directly influence the system under analysis. Two examples of immediate causes are increased nutrients (in the case of eutrophication) and water diversions (in the case of freshwater shortage). A root cause operates in an indirect way by forcing immediate causes to exert a greater pressure on the system. Root causes may be divided into three groups. The first group contains the factors that explain policy failures. The second group encompasses factors that shape the behaviour of those who consume water and water-related resources. The last group includes general trends and conditions that affect the demand for and supply of water and water-related resources. Figure 1 illustrates the links among immediate causes, root causes, environmental problems and human welfare.

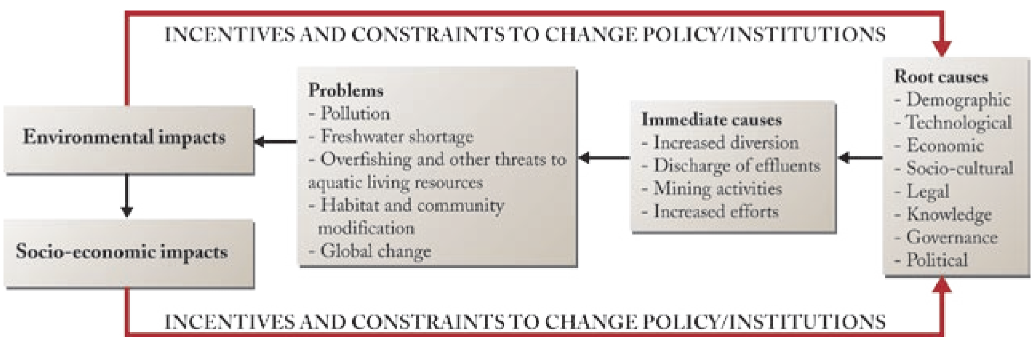


FIGURE 1. THE GIWA CAUSAL CHAIN ANALYSIS

Policy-related root causes

Policy-related root causes refer to the reasons why government actions (or the lack of them) contribute to increased pressures on aquatic ecosystems. Policy-related root causes attempt to explain two forms of policy failure. The first one refers to policy interventions that create or aggravate an environmental problem. A public project of low but inflated economic return and high (but underestimated or neglected) environmental impacts, and an energy or fuel subsidy to extract groundwater are two examples of this form of policy failure. The second form of policy failure refers to the lack of interventions when they are needed and could be realised in an efficient, effective and equitable way. What are the causes of these two forms of policy failure?

The GIWA regional reports look at failures of government policies to perform three essential functions: (i) detecting signals and distributing information; (ii) reaching agreements that balance stakeholder interests; and (iii) implementing, as well as enforcing, these agreements (World Bank 2003). In order to perform these essential functions, governments require enabling legal and organisational frameworks, as well as the ability to mobilise the required financial resources.

Detecting changes

The first vital institutional function is the ability to detect signals of changes and trends that affect the status of human activities and their impact on aquatic ecosystems. Signals take various forms. In the Volta Basin (Guinea Current 42/b), in Sub-Saharan Africa, the combination of climatic changes and increased damming led to a reduction of 30% of the region's headwaters, with an associated reduction of up to 50% of the stream flow in some catchments, while the water demand increased by 600%. The governments of Burkina Faso and Ghana failed to take into account this drastic change. In just a few years, water scarcity and misuse of the remaining supplies had translated into a negative trade balance for agricultural products, farmland loss, as well as the resettlement and migration of a large percentage of the population. Monitoring the balance of ecosystems between their status and the human demand for their services, as well as detecting signals of such changes and predicting their potential impact, could have triggered the right policy response at the right time (World Bank 2003).

Providing information

In addition to the collection and monitoring of key aquatic ecosystem data, such as stocks, flows and quality, as well as information on all the human-environment mechanisms affecting them, the proper and timely distribution of information to the right stakeholders is essential. This is why local assessments are so important. Local assessments allow institutional organisations not only to gather knowledge, but also to distribute it to key stakeholders, allowing them in turn to make well-informed decisions. In a transboundary water context, 'providing information' also means that governments need to share data and decisions that will affect their common aquatic resources.

Balancing interests

The failure to balance interests in international waters is a frequent cause of environmental and socio-economic problems. The balancing of interests has several dimensions. The most obvious is the international dimension, but balancing the interests of different sectoral users (e.g. agriculture, energy, industry, fisheries, households, etc.) is also a clear dimension. Perhaps the most difficult balance is between direct use to meet human needs and environmental preservation. Human uses need to be allocated in a way that ensures the sustainability of ecological and hydrological systems.

This balancing of interests should be conducted at different levels. At a project planning level, water infrastructure projects should contain a complete evaluation of social, economic and environmental costs and benefits. During the allocation decision making process, the interests of the different users and the environment should be voiced. In the course of court processes or private negotiations, information should be used to establish an understanding of the sufferers of a transboundary pollution problem and the contributors to that problem.

Executing decisions and inducing compliance

The execution of policy decisions is essential in order to have their intended impact; decision making alone is clearly not enough. Even if a more efficient and equitable legal and organisational framework for water allocation is adopted, if there are no incentives for users, or the authorities lack the commitment to penalise or reverse transgressions, the implementation of that decision will probably fail. How are policy decisions implemented and enforced? Much environmental regulation has been 'command and control', where governments require or prohibit specific actions or technologies, with potential fines or jail terms for those who do not follow the rules. If sufficient resources are made available for monitoring and enforcement, command and control approaches are effective. But when governments lack the will or resources to guard 'protected areas', when major environmental damage comes from hard-to-detect sources, and when there is a need to encourage innovation in behaviours or technologies rather than to require or prohibit familiar ones, command and control approaches are less effective. Other approaches may be more effective. Voluntary approaches and those based on information disclosure have only begun to receive the attention they deserve as supplements to other tools. Success appears to depend on the existence of incentives that benefit leaders in volunteering over laggards and on the simultaneous use of other strategies, particularly ones that create incentives for compliance. The difficulties created by sanctioning pose major problems for international agreements.

Behavioural root causes

Environmental problems in international waters (freshwater shortage, pollution, overfishing and habitat modification) are, to a great extent, the result of human activities that use natural resources and produce pollution. Environmental problems in international waters are not the result of a conspiracy of any specific group, nor are they attributable simply to negligence, ineptitude or malevolence. They are the result of ordinary people doing ordinary things; farmers irrigating their lands, fishermen catching fish, and households and industry using water. Problems are aggravated by faulty social coordination mechanisms. Users do not take into account the impact that their actions impose on other people. Water is particularly difficult to manage because all life and all sectors of the economy depend on water and, because of this, all users are interdependent. This basic fact gives rise to two questions: (i) what are the factors that determine/influence the ways in which people use water and water-related resources?; and (ii) how can user behaviour that threatens social welfare and environmental sustainability be discouraged, and behaviour that enhances social welfare and environmental sustainability be encouraged? This section answers the first question and provides the foundations for the policy options section to answer the second.

Culture and sense of community

Culture and sense of community affect the way people relate to aquatic ecosystems. There are at least three ways in which culture impacts this relationship. Firstly, culture can have a major impact on economic behaviour through its effect on work ethics, motivation, and attitudes towards risk, among other factors. Secondly, culture influences political participation. The culture of participation can be essential to the management of aquatic ecosystems. Finally, culture moulds social solidarity and association. Apart from economic and political interactions, the preservation and guardianship of common assets (like community-managed fisheries) is largely influenced by what members of a social group may voluntarily do for each other.

Laws

The way in which people use natural resources depends on a number of issues, but one critical aspect is the property rights that govern the use of those resources. In this context, property rights refer to a bundle of entitlements that define the owner's privileges and limitations on the use of the resource. Property rights can be vested with different agents, for example, individuals, the state and in groups of people. Each of these has numerous subtypes, and a myriad of hybrids exists as well. Regulations affect people's behaviour by proscribing certain conduct (as in the case of a mandatory technology) or performance (as in the cases of limits on fish catches or pollution effluents). Both laws and regulations are enforced by the threats of administrative penalties (fines, loss of licenses, etc.) or, in some cases, imprisonment.

Education and training

Education and training can alter attitudes and beliefs about environmental problems. They shape the behaviour of individuals by increasing their knowledge of a problem, by convincing them that the severity of the problem calls for their personal involvement, and by preparing the person to be able to take specific actions to help mitigate the problem.

Economic considerations

Economic considerations (especially prices and wealth) affect people's production and consumption decisions. Prices play three critical roles in market economies: (i) they match supply and demand of goods and services (as a commodity becomes dearer, consumers reduce consumption and producers increase supply); (ii) they allocate goods and services; and (iii) they prevent wasteful use of resources (input prices can have a considerable effect on their usage). Unfortunately, in the case of environmental services, the price system often fails to perform these functions.

Economic possibilities

People's behaviour depends on their economic situation. The role of poverty deserves special attention. Establishing causal links between poverty and environmental degradation is complex and debatable. There are many examples of poor communities that have managed their resources in a sustainable way. The impact of poverty on the environment ultimately depends on the alternatives that poor people have to generate income, invest in conservation and procure food, water and energy. These alternatives in turn depend on institutional factors like the definition of property rights (uncertainties of property rights are common among poor farmers and poor fishermen) and access to markets (access to credit seems particularly important in this context).

Technology
Finally, with regard to technology, GIWA case studies have focused on the reasons why environmentally friendly technologies are not used. Lack of enforcement of environmental regulations is the first, and most obvious, explanation. Insufficient information is another natural explanation. Information is a public good and, as such, markets will in general fail to provide it. The way in which sectors are organised may also pose a problem for the efficient diffusion of environmentally friendly technologies (e.g. fishermen may get their gear from processing firms or from traders). Uncertainty is another potential reason for the slow adoption of environmentally friendly technologies. Producers and consumers may wonder whether new technologies will perform as expected. Lack of access to credit to finance the acquisition of innovative technologies may also play a part, especially in the case of the poor. Finally, cultural conformity and inertia may also be part of the explanation for the slow (or non) adoption of innovative environmentally friendly technologies.

General conditions
General conditions include population dynamics (growth, geographical distribution and migration), economic growth and natural phenomena (e.g. El Niño). A larger population requires more goods and services, which in turn requires more water for food, energy and industrial production. Half of the Earth's population lives in coastal areas, and that proportion is expected to grow. This trend, coupled with urbanisation, will exert additional pressure on fragile aquatic ecosystems. Economic growth also affects the demand for goods and services provided by aquatic ecosystems. Trade, one of the engines of economic growth, poses special challenges and opportunities for resource management.

POLICY OPTIONS ANALYSIS

The last step in identifying "priorities for remedial and mitigatory actions in international waters" consists of analysing policy options to address the priority problems. The GIWA policy analysis is preliminary; it is designed to screen options that deserve a more detailed assessment which will be transferred to stakeholders so that the options can be further analysed in the decision-making processes. The analysis summarises the views of regional experts in different disciplines and is meant to provide policy makers with a practical and systematic way to evaluate the pros and cons of different policy instruments. Policy analysis must be tailor-made to suit the particular conditions (environmental, economic, social, political and administrative) of the problem. The GIWA methodology is based on a list of tasks and choices designed to make the methods and conclusions transparent. Accordingly, each regional team followed this approach.

The task list contains the following items:
- Problem definition;
- Assembling evidence and information;
- Identifying instruments;
- Selecting evaluation criteria and evaluating outcomes; and
- Selection of actions.

The definition of the problem is the link between the policy options analysis and the rest of the GIWA methodology. The scoping phase identifies the priority problem and the causal chain analysis establishes the immediate and root causes. The problem definition combines the priority problem and its most important immediate causes. For example, in the case where pollution results from eutrophication, and run-off from fertilizers is the only immediate cause, the problem definition might be: "there is too much nutrient run-off from fertilizers".

The second task is to assemble evidence and information about the environmental and the socio-economic context of the problem. The information gathered should help answer the following questions:
- Who are the stakeholders and what are their interests?
- What is the institutional background for the situation (laws, regulations, norms, traditions, authorities, etc.)?
- What are the roles, responsibilities and capabilities of different authorities (e.g. sub-national and national governments)?
- What is the status of the ecosystem and what are the important ecosystem processes for the area of concern?

The third task is to identify policy instruments. It is useful to divide policy instruments into two groups, depending on whether or not they are aimed at changing human behaviour. The policy instruments aimed at changing human behaviour can in turn be divided into the following categories (World Bank 1997):

- Using markets;
- Creating markets;
- Using environmental regulations;
- Engaging the public; and
- Developing international environmental agreements.

Using existing markets to provide economic incentives to change people's behaviour may be very effective. Unfortunately, prices often do not promote sustainable use of natural resources, for two reasons. Firstly, certain subsidies lower the financial cost of overexploiting a natural resource or polluting the environment. The other reason is that usually when it comes to goods and services linked to natural resources and the environment, market prices only reflect private costs and benefits, disregarding the effects on other people or on the environment. The prices of pesticides and fertilizers that pollute watercourses do not reflect the social and environmental costs that their use imposes on others. The main categories of instruments that rely on existing markets and some examples of their use are shown in Table 1.

TABLE 1. INSTRUMENTS FOR USING EXISTING MARKETS

Instrument	Example
Subsidies reduction	Energy to pump groundwater Pesticides
Targeted subsidies	Payment for non-marketable ecological services
Taxes	Pesticides Effluent taxes
User charges	Irrigation water
Deposit refund systems	Plastic bottles
Performance bonds	Tourism development of coastal areas Hazardous pollutants management

Policy instruments based on existing markets have two positive characteristics: Firstly, they are, frequently, easy to implement and they may have positive fiscal impacts (as in the case of reducing subsidies or levying taxes on goods or services that have a negative environmental impact). The main disadvantage of this family of instruments is that most of them are politically difficult to implement because they impose an additional financial burden on users of water and water-related resources. An additional disadvantage is that existing markets sometimes only target the real problem in an indirect way (e.g. using the markets of agro-chemicals to address pollution).

Creating markets can also provide positive incentives for people to alter their behaviour in a socially and environmentally positive way. Many environmental goods (or problems like pollution) and services do not have their own markets. This lack of markets discourages the production of environmental services and encourages the creation of environmental problems. If the owners of wetlands were paid for the environmental services that their properties offer, land use changes would diminish. Similarly, if polluters had to pay for the amount of pollution they generate, pollution would decrease. The main categories of instruments that rely on creating markets and some examples of their use are shown in Table 2.

TABLE 2. INSTRUMENTS FOR CREATING NEW MARKETS

Instrument	Example
Establishing property rights	Water markets
Tradable permits and rights	Tradable fishing quotas Tradable effluent rights

The main advantage of these types of instruments is that they target the actual problem in a direct way, getting the incentives right and encouraging cost-effective solutions for environmental problems. Their main disadvantages are that they require solid institutions for their implementation and that they may be costly to implement.

Regulations are the most common type of instrument to address environmental and natural resource problems. The reasons for this are mainly due to their intuitive simplicity and to the fact that they frequently match the interests of both the authorities and the regulated community. The main categories of instruments that rely on regulations and some examples of their use are shown in Table 3.

TABLE 3. INSTRUMENTS FOR REGULATIONS

Instrument	Example
Action (technology) standards	Boat and mesh sizes Zoning Bans
Performance standards	Effluent standards Total allowable catch quotas

Conditions that favour the use of regulations include:

- Unacceptably high costs of even minor quantities of a pollutant (or any undesired effect);

- A minimal number of polluters;
- Monitoring results is expensive while monitoring technologies is simple; and
- There is one clearly superior technology.

Perhaps the most important disadvantage of regulations is that authorities misuse them easily (because of their intuitive appeal) when regulators do not consider all the direct and indirect costs that regulations impose. An additional problem is the risk that regulators may identify themselves with the interests of the regulated community rather than with the interests of society as a whole (including the regulated community).

Engaging the public means providing people with more information and giving stakeholders the opportunity to participate in the decision-making process. Lack of information can be an obstacle to more environmentally friendly behaviour because the links between individual behaviours and their environmental impacts may be difficult to understand from personal experiences. Providing more information allows the public to act in the economic and political arenas to demand better environmental quality. In the economic arena, consumers can affect production processes by demanding environmentally friendly products. In the political arena, information can trigger political demands for a better environment. Information can also help producers improve their environmental performance, as in the case of best practices and information on the environmentally correct application of certain inputs, like pesticides.

Public participation in decision-making processes is the other major way to engage the public to solve or mitigate environmental problems. One of the main features of environmental problems is that some decision-making processes may not always consider the interests of all stakeholders. Increased participation to improve environmental quality may be achieved at different levels (project planning, monitoring and evaluation of large infrastructure; operation of irrigation infrastructure; management of small scale natural resources; court processes etc.). The main categories of instruments that rely on engaging the public and some examples of their use are shown in Table 4.

Providing information is not enough to guarantee a change in people's behaviour. Furthermore, better information is only likely to induce behavioural changes that are not very expensive to the people and that are compatible with their deeper values. Information-based instruments work best when they are coupled with other instruments. Similarly, a call for increased participation is on its own not likely to be effective. Instruments based on participation require solid institutions to balance the interests of the different stakeholders.

TABLE 4. INSTRUMENTS FOR ENGAGING THE PUBLIC

Instruments	Examples
Information for consumers	Eco-labelling Information disclosure
Information for producers	Best practices dissemination Compliance promotion
Participation	River basin councils Irrigation management Community management

Economic, social and demographic dynamics are increasing the interdependency of nations. The use of water, its pollution, the destruction of aquatic ecosystems and the unsustainable exploitation of fisheries have local, national and frequently regional and even global effects. Addressing regional environmental problems requires cooperation. International environmental agreements offer a framework for cooperative management of aquatic ecosystems. However, effective international environmental agreements are neither easy to craft nor implement. There is no problem in discussing an agreement but the combination of self-interest and sovereignty may keep important countries out of the agreement. Moreover, it may happen that signatories to such an agreement may not uphold their responsibilities.

Non-behavioural interventions

Direct government involvement, including different forms of government investment, plays an important role in both actual and potential interventions. Funding protected natural areas, financing improved understanding of natural phenomena, investing in infrastructure and financing research are some of the major categories of direct government intervention. Economies of scale and the public-good nature of many environmental and natural resource services are the main reasons to include instruments based on government investment on a list of effective actions to solve or mitigate problems in international waters. Public goods provide services that communities enjoy in common, such as unpolluted water. Government intervention is required to produce public goods because most people would not voluntarily pay for a service that they can get for free. The funds raised by voluntary contributions to finance large infrastructure projects (e.g. water treatment plants) would not be enough to finance the required project at its optimal scale. The scale of these projects may require the taxing and borrowing capacities of governments to raise the necessary funds. The main categories of instruments that rely on direct government involvement and some examples of their use are shown in Table 5.

TABLE 5. INSTRUMENTS FOR DIRECT GOVERNMENT INVOLVEMENT

Instruments	Examples
Understanding, describing and predicting	Meteorological systems
Infrastructure	Municipal water treatment plants
Protection	Protected areas
Research	

The main drawback of policy instruments based on government investment is the lack of funding due to the fiscal situation of governments (especially in developing countries) and their inability (again, mainly in developing countries) to charge beneficiaries for the positive outcomes that these interventions generate.

The next task is selecting evaluation criteria and evaluation outcomes to assess the expected results of the selected options. The methods used to test the performance of options under the different criteria are practical and simple because the GIWA policy option analysis is only meant to provide options for further analysis and discussion.

There are several criteria that can be used to evaluate the outcomes of policy interventions. A combination of the following criteria is frequently used:

- Effectiveness (certainty of result);
- Efficiency (maximisation of net benefits) or cost effectiveness (achieving a set policy goal at minimum cost);
- Equity (fairness in the division of costs and benefits); and
- Practical criteria (political acceptability, implementation feasibility).

To evaluate the effectiveness of an instrument, it is useful to think about situations that could hinder its successful implementation, as well as the likelihood that these situations will occur. The list of adverse situations is unfortunately long: bureaucratic resistance, lack of political will, "capture" of policy benefits by an undeserving group; excessive administrative costs; lack of enforcement; waste; abuse that undermines political support; etc. Robustness is a useful criterion to apply when some of these situations are likely to occur.

Efficiency refers to the maximisation of net benefits. A full evaluation of efficiency is beyond the mandate (and resources) of the GIWA. However, most regional GIWA teams did include lists of the costs and benefits of the options they analysed. Even in this limited and unquantified form, a list of costs and benefits serves a useful purpose: it reminds policy makers of the potential impacts (both positive and negative) of a policy decision.

Equity is not usually the main objective of environmental and natural resource policy. However, we should question the justification of any measures designed to improve environmental conditions in international waters whose costs are disproportionately paid by the poor. Furthermore, unfair patterns of incidence may erode the political support necessary for policy interventions. The GIWA methodology instructs regional teams to evaluate the fairness in the distribution of costs and benefits of the analysed options. It also advises regional teams to suggest compensating measures in certain cases.

A policy option may have great theoretical appeal, but its eventual impact will be determined by what happens to the option as it goes through the decision-making and policy implementation processes. Practical criteria are meant to assess the prospect of a successful transit through these processes. The most widely used practical criteria are political acceptability and administrative feasibility.

A quick (and preliminary) way to assess the political acceptability of an intervention is to look at who gains and who looses from it, and to estimate the expected actions and impacts of the opposing and supporting groups. Administrative feasibility includes considerations about the legality of an intervention, as well as the capacity (technological, financial and operative) of the implementing organisation.

The last task is to choose actions from the list of analysed options. In most circumstances, instruments are complementary and a combination of incentives, regulations, information and direct government involvement is the best way to address a problem. Consider the case of pollution. A good programme to improve water quality would probably include regulations (e.g. banning certain pollutants in water effluents and setting acceptable ranges for others), incentives to induce the required reductions in pollution discharges, information on best practices, and the provision of collective infrastructure (e.g. treatment facilities).

Options have to be prioritised when they are substitutes or when restrictions (budgetary or otherwise) do not allow the implementation of all the interventions that would have a positive impact on the problem. If one of the policy options under consideration is expected to produce a better result than any of the other options with regard to every evaluative criterion, the choice is obvious. However, this is not always the case. It may also happen that under a specific criterion one instrument outperforms another but the relation is reversed if another criterion to evaluate performance is used. In these cases, what option(s) is (are) chosen depends on the relative weights of the different criteria and on the differences in performance under each criterion.

The relative weights of the criteria may depend on the conditions of each particular problem. Equity considerations will probably not be influential if the problem affects a society with an even distribution of wealth and modest implementation costs. In contrast, if the problem takes place in a context of a skewed distribution of wealth, and the implementation of an option would entail net losses for the poor, equity should be strongly weighted. Regardless, effectiveness should be weighted heavily.

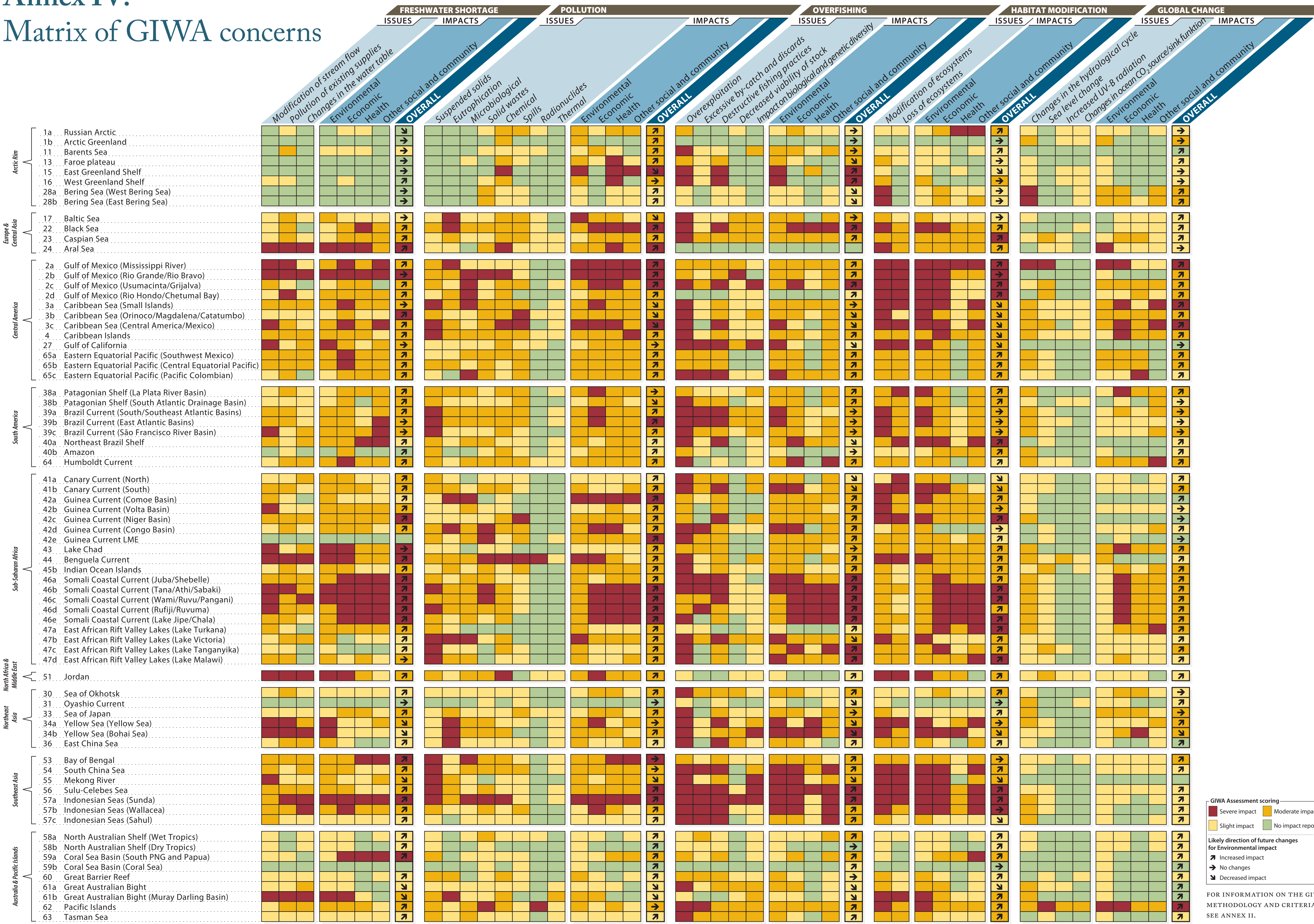
THE GIWA LME MATRIX

Some of the GIWA regions include one or more LMEs within their boundaries. However, the numbering system used by GIWA is different to that used for LMEs. Where the GIWA considered several sub-systems within an LME, an adjusted score of the sub-systems was applied at the LME scale. Therefore the scores presented in this matrix do not always correspond with the GIWA regional scores.

The GIWA findings for the concerns of Overfishing and other threats to aquatic living resources, Pollution and Habitat and community modification as well as information from other sources, were arranged into the five LME modules.

Annex IV: Matrix of GIWA concerns

THE GIWA SCORING MATRIX BY MEGA REGION



FOR INFORMATION ON THE GIWA METHODOLOGY AND CRITERIA SEE ANNEX II.

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

BROAD TRANSBOUNDARY APPROACH

GIWA recognises that many water bodies and resources, and the human impacts on them are not confined to a single country.

REGIONAL ASSESSMENT – GLOBAL PERSPECTIVE

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

GLOBAL COMPARABILITY

In each region, the assessment focuses on five major concerns that are comprised of 22 specific water-related issues.

INTEGRATION OF INFORMATION AND ECOSYSTEMS

GIWA recognises the inextricable links between the freshwater and the coastal marine environment and assesses them together as one integrated unit.
GIWA recognises that the integration of socio-economic and environmental information and expertise is essential in order to obtain a holistic understanding of the interactions between the environmental and societal aspects of transboundary waters.

PRIORITIES, ROOT CAUSES AND OPTIONS FOR THE FUTURE

GIWA identifies the priority concerns of each region, determines their societal root causes and discusses options to mitigate the impact of those concerns in the future.

THIS REPORT

The GIWA Final Report provides a comprehensive review of the most important findings from the GIWA regional reports. It summarises the major transboundary concerns and their environmental and socio-economic impacts. To better understand these concerns and develop solutions to address them, the Report identifies the root causes and draws policy relevant conclusions. It also outlines knowledge gaps which impede the sustainable management of international waters.

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