

Executive summary

The Global International Waters Assessment (GIWA) project is a holistic and globally comparable assessment of trans-boundary 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 over-arches the other four. It is clear that the five GIWA trans-boundary 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 I. 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 trans-boundary 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, over-exploitation 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 com-

ination 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 valued 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.