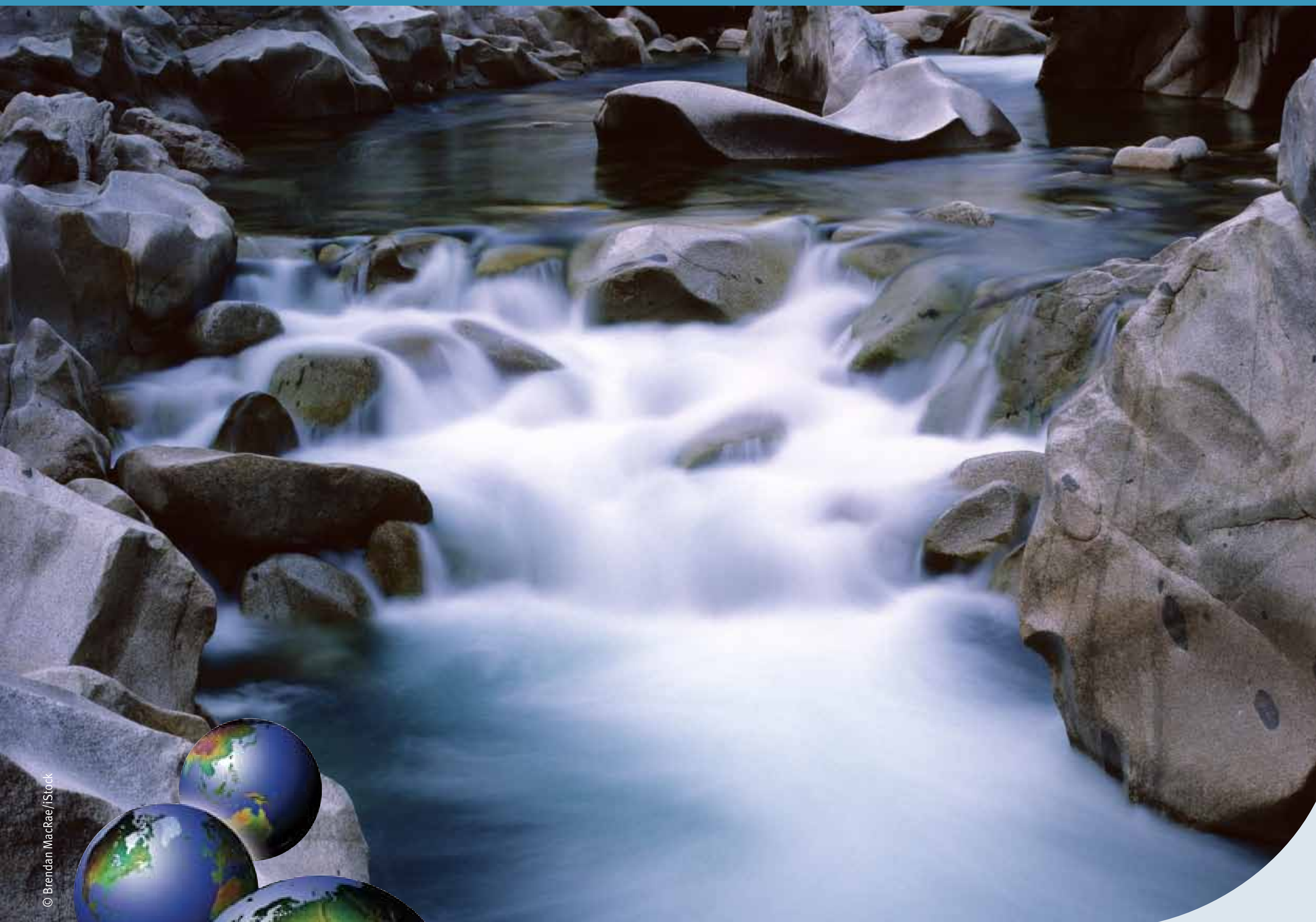
CHAPTER 4

Water



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Main Messages

Increasing water-use efficiency in all sectors is vital to ensure sustainable water resources for all uses. Human water demands, with only limited improvements in efficiency, are increasing and are already unsustainable in many regions. Nevertheless, potential exists for efficiency gains: irrigation efficiency, for example, could be increased by approximately one-third simply by implementing existing technology. At the local level, integrated demand and supply strategies are critical. At a river-basin level, more efficient and fair water allocation systems are needed. More broadly, virtual water trade can ease water demands in some locations.

Recognition of ecosystem water needs within allocation systems will help protect life-supporting ecosystem services. Freshwater and marine ecosystem services are critical to human development and integral to the transition to a green economy. Inadequately articulated objectives and lack of data, however, make it difficult to evaluate progress in meeting environmental water requirements. Better strategies and tools are needed for efficient, equitable water allocation between users, including the environment. Full implementation of international commitments and enforcement of legally binding agreements, and due consideration of customary water-use arrangements, will facilitate sustainable human and ecosystem use.

Reducing both point and non-point pollution is imperative to improve ecosystem health and provide safe water for humans. Substantial achievements in reducing some pollutants have occurred since 1992, although many water bodies are still affected, and many new contaminants have poorly understood effects. Treating municipal and industrial wastewater is achievable with existing technology, but requires better regulatory oversight, infrastructure investment and capacity building, especially in developing countries. Integrated land-water management and stakeholder participation are necessary to reduce non-point pollution of both freshwater and marine systems.

Improved water supply and sanitation is probably the single most cost-effective means of reducing water-related death and disease globally. Although the Millennium Development Goal (MDG) target on water supply was met in 2010, more than 600 million people will still lack access to safe drinking water in 2015. The MDG target on sanitation is unlikely to be met, with 2.5 billion people currently without improved sanitation facilities; poor rural populations are most affected. Meeting the water supply and sanitation MDGs would reduce the water-related global disease burden by about 10 per cent. Increased investment in infrastructure, capacity building and regulation are needed, and the participation of women is crucial for water management and the prevention of water-borne disease.

Climate-sensitive policies across all water-related sectors are essential to address extreme events and increased climatic variability. Floods and droughts still cause losses of billions of dollars annually. Climate change is altering the hydrologic cycle, threatening freshwater and marine ecosystems as well as human water security in many regions. Open oceans play a major role in regulating global climate and weather patterns, with climate change impacts manifested in warmer surface waters and rising sea levels. Ocean warming and acidification threaten tropical coral reef ecosystems, with rapid contraction predicted by 2050. Mitigation and adaptation to climate change impacts must be considered within the context of other drivers and pressures. Those related to energy production are likely to require trade-offs between human energy needs, water demands and ecosystem protection.

The pace of increasing demands on freshwater and ocean resources must be matched by improved governance. Freshwater systems integrate human activities and land management across nations and regions. The open oceans are a major global commons and require effective international cooperation and governance. Most human and environmental water problems result from inadequate governance involving policy, institutional, financial and/or stakeholder issues. Integrated management approaches for addressing these constraints require time and resources to be successful. They need enhanced integration of policies and institutions between sectors and governance levels, implementation and enforcement of relevant agreements and goals, improved monitoring and resolution of transboundary issues. Good governance, including stakeholder and private-sector participation and gender considerations, is critical to increasing societal and environmental resilience and sustainability.

INTRODUCTION

Aquatic ecosystems are major integrators of natural and anthropogenic processes. As the ultimate sink for pollutants, freshwater and marine ecosystems are among the most sensitive indicators of the environmental impacts of human activities. They support a wide diversity of life (Chapter 5), providing important goods and services that directly or indirectly support and sustain human existence and livelihoods. Adequate freshwater supplies of acceptable quality are recognized as a human right by the UN General Assembly's declaration on clean water and sanitation.

As highlighted in the *Millennium Ecosystem Assessment* (MA 2005), freshwater and marine ecosystems provide various services, including provisioning (food, water, fibre, fuel), regulating (climate, hydrological, purification), cultural (spiritual, recreational), and supporting (sediment transport, nutrient cycling). Such ecosystem services are a function of water, land, biodiversity and atmospheric links. Healthy aquatic ecosystems not only provide goods and services, but also enhance resilience against the negative impacts of environmental perturbations or disasters. Aquatic systems also drive major global bio-geochemical cycles; the open oceans play a major role in regulating global climate and weather patterns.

This chapter addresses freshwater and marine systems as distinct but linked hydrological components of the water environment. It assesses progress towards achieving water-related goals in major multilateral environmental agreements identified by the *GEO-5* High-Level Intergovernmental Advisory Panel and regional consultations. Based on the drivers-pressures-states-impacts-responses framework (DPSIR) (Stanners *et al.* 2007) used for the *GEO-5* assessment, this chapter focuses on the state, trends and impacts of the water environment, with references to drivers (Chapter 1) and responses (Parts 2 and 3), and other environmental sectors (Chapters 2, 3, 5 and 6) where appropriate.

Although freshwater ecosystem goods and services are extensive, competition and multi-sectoral demands for water have resulted in overexploitation and contamination of resources in many regions. Competing water uses and their impacts on sustainable aquatic resources, including quantity and quality issues, are discussed, including the water needs of ecosystems. The chapter also addresses inequitable and unsustainable water demands in many countries. Pollution from land- and marine-based activities (Chapter 6) continues to degrade coastal areas and open oceans. Water quality trends are discussed. Continuing overfishing severely impacts many fish stocks, particularly marine species (Chapter 5).

Many predicted global climate change impacts will be manifested in changes to the hydrologic cycle. How they could affect the water environment is highlighted, including increased frequency, duration and severity of droughts and floods. Predicted climate change impacts and their uncertainties are discussed, including the vulnerabilities and adaptation needs of many communities.

Watersheds comprise a group of linked water systems that can include rivers, lakes, reservoirs, wetlands, underlying aquifers and downstream marine systems, although these links are often not considered in developing water management plans. This is a significant omission, since simultaneously managing for human health and social concerns – including disease and poverty, economic development and sustainable environmental integrity – within complex global connectivity often requires environmental and economic trade-offs, some very difficult. Because many water-related problems result from policy, institutional, financial or other governance inadequacies, this chapter also discusses both freshwater and marine governance elements identified in the multilateral environmental agreements. It concludes by identifying major policy and data gaps for achieving water-related goals. Policy options to address the issues raised in this chapter are addressed throughout Part 2 of *GEO-5*.

Mangroves are significant breeding grounds for marine life, and protect coastal areas from storm surges and other natural hazards. *© Jeremy Sterk*

INTERNATIONALLY AGREED GOALS

Freshwater was selected as a priority issue in all UNEP *GEO-5* regional scoping consultations, with most regions identifying Paragraph 26c of the Johannesburg Plan of Implementation (Box 4.1) as the most important freshwater goal, with water availability and marine issues also identified in several regions. Although limited by gaps in global-scale data and specific targets, the degree to which water-related multilateral environmental agreements have been addressed is a focus of the current chapter.

Goals were identified on the basis of their policy relevance and ability to illustrate intergovernmental cooperation since the United Nations Conference on Environment and Development (UNCED) in 1992 and earlier (Table 4.1).

Box 4.1 Johannesburg Plan of Implementation Paragraph 26c

Improve the efficient use of water resources and promote their allocation among competing uses in a way that gives priority to the satisfaction of basic human needs and balances the requirement of preserving or restoring ecosystems and their functions, in particular in fragile environments, with human domestic, industrial and agriculture needs, including safeguarding drinking water quality.

Source: WSSD 2002

Table 4.1 Selected internationally agreed goals and themes related to water

Major themes from internationally agreed goals		Johannesburg Plan of Implementation (JPOI) (WSSD 2002)**							Millennium Development Goals (MDGs) (UN 2000)*			UN Millennium Declaration (2000) (UN 2000)**	United Nations Convention on the Law of the Sea (UNCLOS 1982)**	London Convention on Marine Pollution (1972)*	MARPOL Convention on marine pollution (1973)	Convention on Biological Diversity (1992)		Ramsar Convention on Wetlands (1972)*	International Watercourses Convention (1997)	United Nations Framework Convention on Climate Change (UNFCCC 1992)	Ballast Water Management Convention (2004)	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) (1995)	FAO Responsible Fisheries (1995)*	UN Fish Stocks Agreement (2001)	Barbados Programme of Action for Small Island Developing States (1994)	Dublin Principles on Water and Sustainable Development (1992)	Regional seas conventions and programmes	Multilateral freshwater agreements
		7*	25*	26**	30*	31*	32	40–45	1*	4	7*	55/2				1992 targets	Aichi Targets											
Ecosystems	Protect and restore freshwater ecosystems and their services		X	X				X			X					X	X	X	X	X	X	X	X		X	X	X	X
	Protect and restore marine ecosystems and their services				X	X	X	X				X	X	X	X	X		X	X	X	X	X	X	X	X		X	
	Conserve and improve management of wetlands					X		X								X	X	X	X							X	X	X
	Ensure environmental water needs			X	X							X					X	X	X						X	X		X
Human well-being	Reduce water-related human health hazards	X	X	X			X		X	X	X	X		X	X				X		X	X			X		X	X
	Ensure equitable access to improved drinking water supply		X								X	X							X							X		X
	Secure adequate sustainable freshwater supply	X		X				X			X	X							X						X	X		X
	Develop programmes for mitigating effects of extreme water-related events			X																X					X			X
	Mitigate and adapt to adverse effects of climate change on the water environment			X													X			X					X			X
Water-use efficiency	Improve the efficient use of water resources			X				X				X							X						X	X	X	X
Water quality	Reduce and control freshwater pollution	X	X	X				X		X		X					X	X	X			X			X	X	X	X
	Reduce and control marine pollution				X		X	X					X	X	X		X	X			X	X		X	X		X	
	Improve sanitation coverage including sewage collection, treatment and disposal		X							X	X								X							X		X
Institutional and legal issues	Recognize the economic value of water																		X						X	X		X
	Develop and enforce effective legal frameworks and regulations		X	X	X							X	X	X	X	X				X		X	X	X	X		X	X
	Strengthen institutional coordination mechanisms			X	X	X	X					X		X	X	X	X		X	X	X	X	X	X	X		X	X
Water resources management	Develop and implement integrated management strategies and plans		X	X	X		X				X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
	Develop adequate monitoring systems (national, regional and global)		X	X		X		X					X	X	X	X			X	X		X		X	X		X	X
	Improve stakeholder participation and mainstream gender in water management		X					X	X																X	X	X	X
	Improve groundwater management		X	X															X						X	X	X	X

Note: Numbers at the top of the columns under JPOI, MDG and UN Millennium Declaration represent specific paragraphs, goals or articles.

* Selected by the GEO-5 High-Level Intergovernmental Advisory Panel (HLIAP). ** Selected at regional consultations.

STATE AND TRENDS

Water scarcity

Human-environment competition for scarce water resources

Water scarcity is a significant and increasing threat to the environment, human health, development, energy security and the global food supply (Pereira *et al.* 2009). Ecosystems, which provide life-supporting goods and services (Chapter 5), suffer from multiple pressures, including the need for water of adequate quantity and quality as well as appropriate timing (environmental flows). The indicator used here is blue water scarcity (Figure 4.1), the proportion of groundwater and surface water consumed relative to the sustainable water available for human use, after accounting for environmental flows (Hoekstra and Mekonnen 2011). Water scarcity is a significant factor in human water security, with a fifth of the global population living in areas with physical water scarcity (Comprehensive Assessment of Water Management in Agriculture 2007).

Falkenmark and Rockström (2004) estimated the water required to maintain ecosystem goods and services as 75 per cent of the total water use, while direct human water use represented 25 per cent of the total. These figures include both blue (groundwater and surface water) and green water (water stored in the soil). Water is overcommitted in many places, leaving insufficient resources for both human and environmental needs (Gleick and Palaniappan 2010). In a study of 424 of the world's major river basins, containing a population of 3.9 billion people, environmental flow requirements were violated in 223 basins, containing 2.67 billion people facing severe water scarcity during at least one month of the year (Figure 4.1) (Hoekstra and Mekonnen 2011). Although arid regions of Northern Africa and the Middle East are not included in this analysis, other data suggest that the proportion of renewable water withdrawn in those regions exceeds 50–75 per cent, leaving little environmental flow (FAO 2008).

Although many goals in the Johannesburg Plan of Implementation acknowledge the importance of marine and coastal ecosystems (WSSD 2002), there is less recognition of water needs to support freshwater ecosystems, which are themselves legitimate water users (Chapter 5). Although the importance of formally recognizing the environment as a legitimate water user is increasing, it remains on a relatively small scale in practice, with many aquatic ecosystems still at risk (Garrick *et al.* 2009).

Box 4.2 Water scarcity

Goals
Ensure environmental water needs; conserve and improve management of wetlands

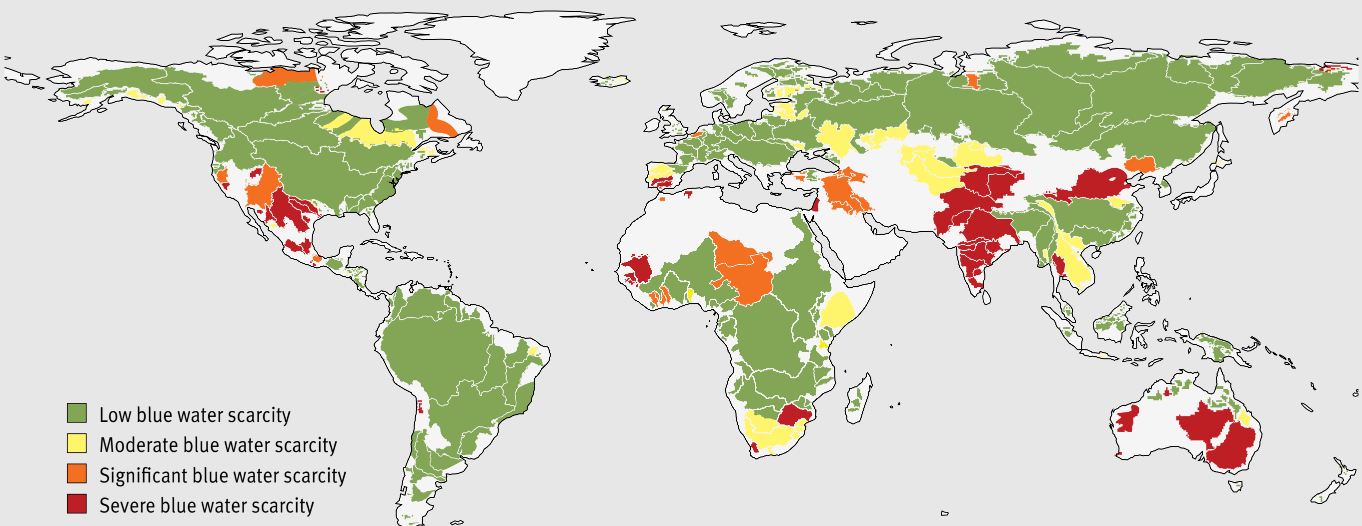
Indicators
Blue water scarcity

Global trends
Deteriorating

Most vulnerable communities
Poor communities highly dependent on ecosystem services

Regions of greatest concern
West Asia, South Asia, Mesoamerica, Australia

Figure 4.1 Annual average water scarcity in major river basins, 1996–2005



Note: The annual average is calculated from monthly values.

Source: Hoekstra and Mekonnen 2011

Water demand

Global withdrawals have tripled over the last 50 years (UNESCO 2009) to meet the demands of a growing population with increasing wealth and consumption levels. While water supply over this period has remained relatively constant, demand now exceeds sustainable supply in many places, with serious long-term implications (2030 Water Resources Group 2009). The planetary boundary for human consumptive blue water use – when used groundwater and surface water is not made available for reuse in the same basin – is estimated to be 4 000 km^3 per year, with current consumptive blue water use estimated at approximately 2 600 km^3 per year. Projected water demands may to reach planetary boundaries in the coming decades (Rockström *et al.* 2009).

Agricultural, industrial and domestic water withdrawals have steadily increased. Agriculture is by far the largest global water user (Figure 4.2), with withdrawals for this purpose being unsustainable in many places due to unbalanced long-term irrigation water budgets (MA 2005), as evidenced by the mining of aquifers and reliance on large water diversion projects. These withdrawals are projected to continue increasing, placing further pressure on aquatic ecosystems, which themselves also require water of adequate quantity, quality and timing for sustained health.

Box 4.3 Water demand

Goals
Secure adequate sustainable freshwater supply

Indicators
Water withdrawals; groundwater withdrawals; net water footprint

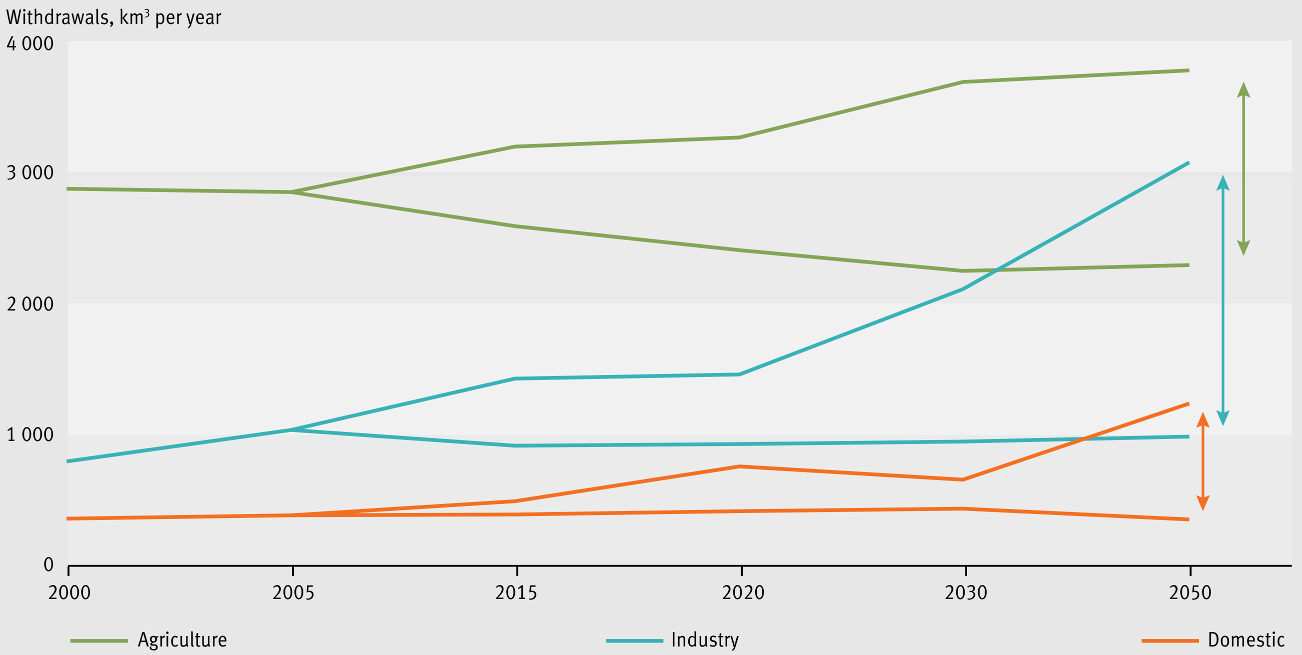
Global trends
Deteriorating

Most vulnerable communities
Developing countries with increasing water demand; communities dependent on groundwater-irrigated agriculture

Regions of greatest concern
Groundwater withdrawals: Asia and Pacific, parts of North America
Water footprint: North America, Latin America and the Caribbean, Europe

Many communities are dependent on unsustainable groundwater withdrawals (aquifer mining) to meet agricultural and domestic water demands, further threatening water security in many regions. Between 1960 and 2000, global groundwater

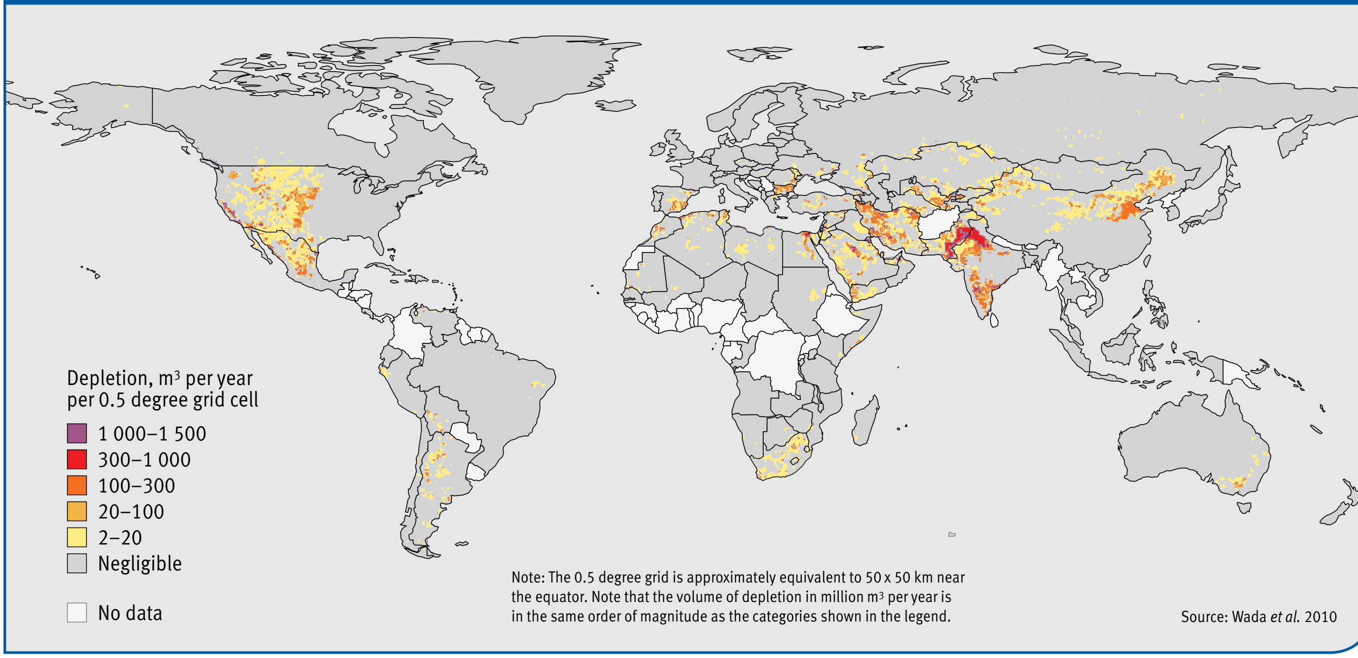
Figure 4.2 Current and projected water withdrawals by sector, 2000–2050



Note: The graph includes three different groups of scenarios (Millennium Ecosystem Assessment, *GEO-4* and OECD) and shows the range between their maximum and minimum values at each five-year interval.

Source: CESR, University of Kassel, Germany; Alcamo *et al.* 2005a, 2005b (MA scenarios); Rothman *et al.* 2007 (*GEO-4* scenarios); Bakkes *et al.* 2008 and OECD 2008 (OECD scenarios)

Figure 4.3 Global annual groundwater depletion, 2000



withdrawal increased from 312 km^3 to 734 km^3 per year, resulting in groundwater depletion increasing from 126 km^3 to 283 km^3 per year (Wada *et al.* 2010). Many globally important agricultural centres are particularly dependent on groundwater, including northwest India, northeastern China, northeast Pakistan, California's Central Valley, and the western United States (Figure 4.3) (Wada *et al.* 2010).

Sprinkler irrigation systems are usually more efficient than flood systems. *© Pgiam/iStock*

Not all water withdrawals result in consumptive water use, since much withdrawn water is returned in the form of wastewater or irrigation return flows. Rain-fed agriculture also represents significant human water use without direct water withdrawals. Global water consumption per person, as measured by the water footprint, averages 1 387 m^3 per year. North America has the highest water footprint at 2 798 m^3 per person per year, while Asia and the Pacific have the lowest at 1 156 m^3 per person per year (Figure 4.4). Of the total global water footprint, 74 per cent represents rainwater stored in soil (green water), 11 per cent represents the consumptive use of surface and groundwater (blue water), and 15 per cent represents the freshwater required to assimilate pollution from all sources (referred to in the water footprint terminology as grey water). Agriculture accounts for 92 per cent of the total global water footprint; livestock and related products alone account for 27 per cent (Chapter 1) (Mekonnen and Hoekstra 2011).

Water use efficiency and the virtual water trade

Since the renewable supply of water is relatively constant, addressing water scarcity relies in large part on reducing water demand by improving efficiency and reducing consumptive water use. All user demands must be considered together, including environmental water requirements.

Although improved methods and technologies have produced efficiency gains in all sectors in some regions, the need, and potential, exists for further improvements to ensure the well-being of a growing world population while minimizing the impacts on ecosystems and their goods and services.

The need and potential for improvement is greatest in the agricultural sector (Figure 4.5), since approximately 70 per

Box 4.4 Water-use efficiency

Goals
Improve the efficient use of water resources

Indicators
Irrigation efficiency; net virtual water trade

Global trends
Some progress

Most vulnerable communities
Those dependent on irrigated agriculture in arid areas; poor communities in net virtual-water exporting countries

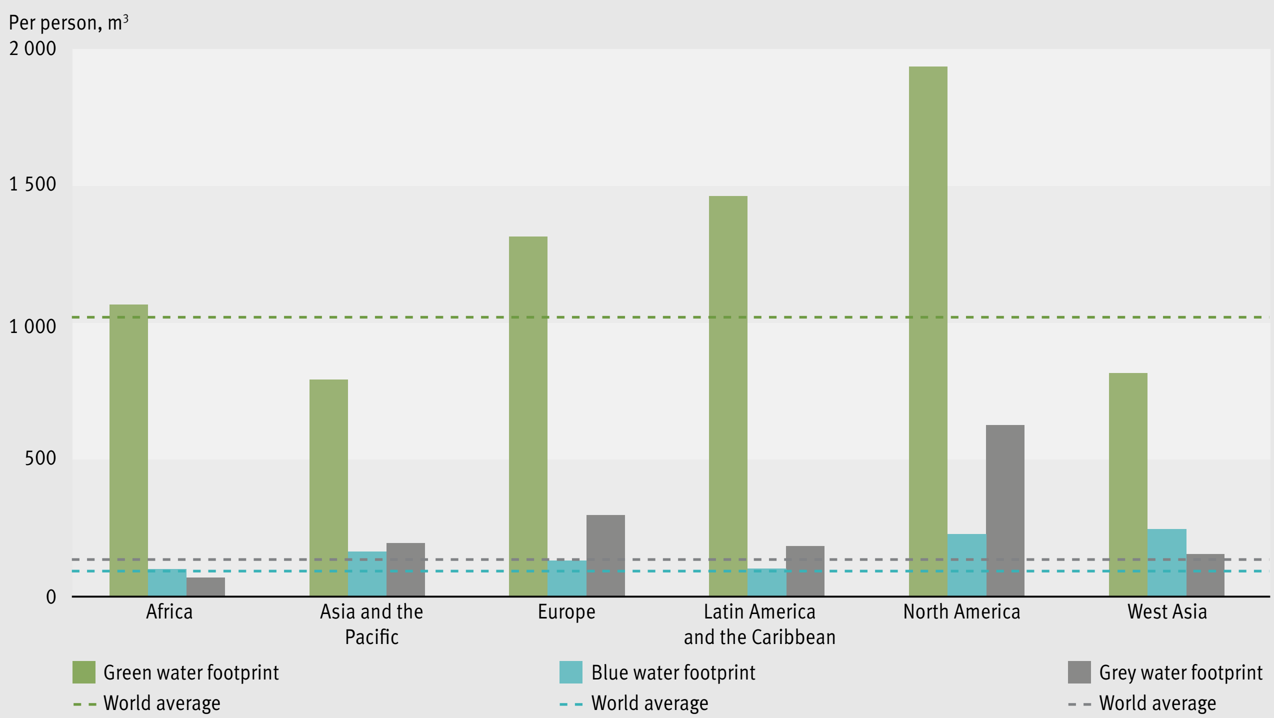
Regions of greatest concern
West Asia, Asia and the Pacific, parts of Africa and Central America

cent more food will be needed by 2050 to cope with a growing population and dietary changes (Chapter 1) (Boelee 2011). Improvements in the application, conveyance, distribution and management of irrigation can raise the overall efficiency of the water getting to the crops from approximately 35 per cent to 75 per cent or more (Rohwer *et al.* 2007). Broader agricultural water-use efficiency strategies include land-water management and reuse (Ali 2010), while food supply chains beyond the farm can also be more water efficient.

There is inadequate global data to evaluate the overall state and trends of industrial and domestic water-use efficiency. Nonetheless, opportunities do exist for significant improvement in these sectors, particularly where there are major withdrawals and/or rapid urbanization is occurring (Chapter 1). Water allocation efficiency is also required at the river-basin level to ensure sustainable, equitable and economic water use.

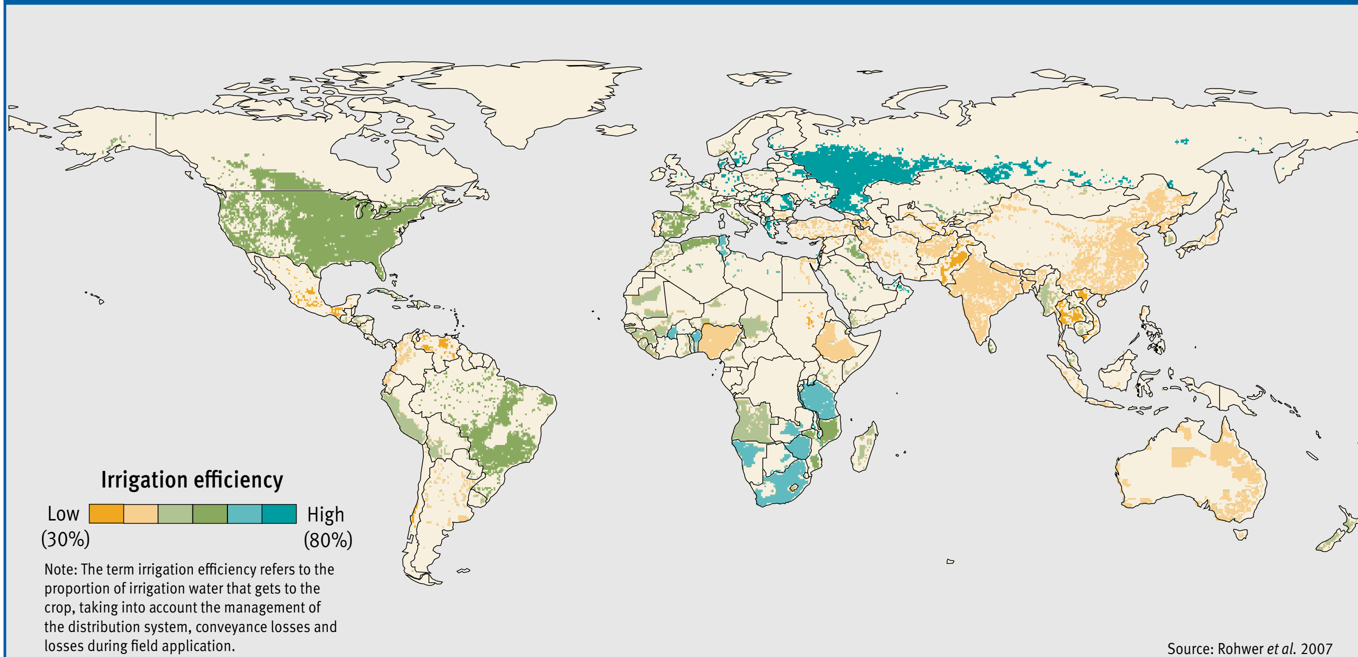
At national, regional and global scales, the virtual water trade – the water embedded in traded products ranging from crops to manufactured goods – can be a tool for improving overall efficiency by capitalizing on the comparative advantages of certain water uses in particular regions. About one-fifth of the global water footprint is related to production for export (Figure 4.6). The global virtual water trade for agricultural and industrial products totalled 2 320 km^3 per year between 1996 and 2005, with crops contributing 76 per cent and animal and industrial products each contributing 12 per cent (Mekonnen and Hoekstra 2011). The virtual water trade can efficiently redistribute water and partially help to address the disconnection between consumption and the impacts of production (Chapter 3). Water-scarce basins, countries or

Figure 4.4 Annual global and regional water footprint, 1996–2005



Source: Mekonnen and Hoekstra 2011

Figure 4.5 Global irrigation efficiencies, 2000

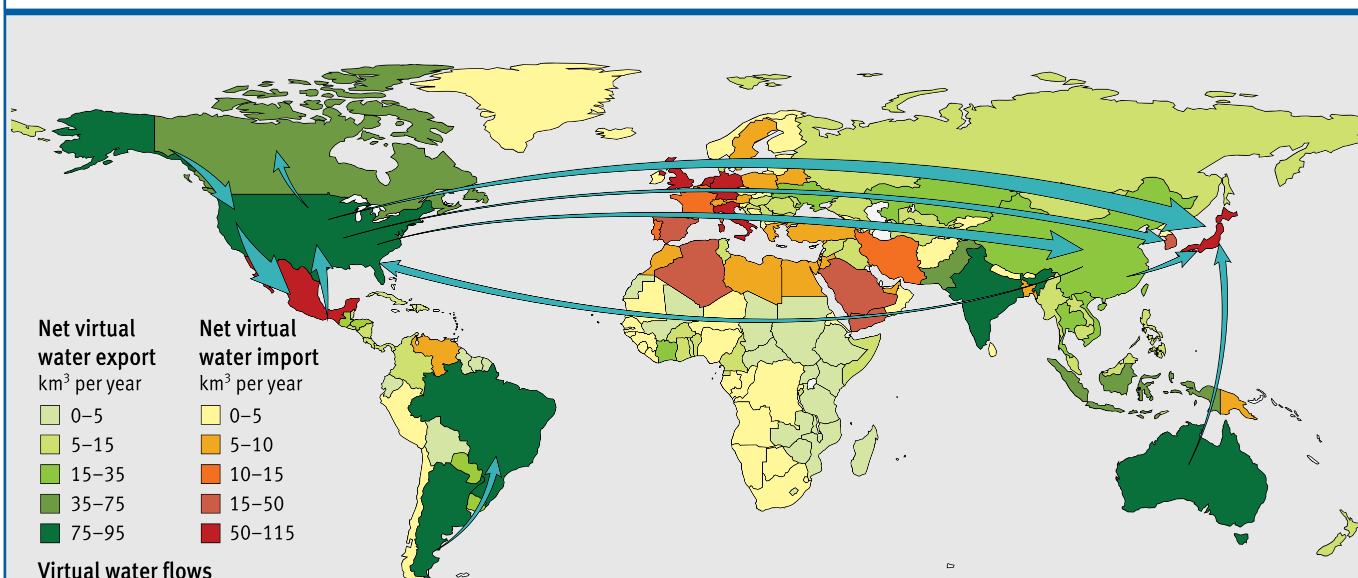


Note: The term irrigation efficiency refers to the proportion of irrigation water that gets to the crop, taking into account the management of the distribution system, conveyance losses and losses during field application.

Source: Rohwer *et al.* 2007

regions, for example, can import water-intensive products through trade, preserving scarce water resources for more valuable purposes. However, it can also lead to overexploitation of water resources in net exporter countries, prioritizing commodity water needs over basic local needs, especially where strong economic drivers promote commodity exports (Chapter 1). Another characteristic is that some net virtual water exporters, such as Australia or South Asia, are also water scarce, while some net importers may have abundant supplies, as is the case for Central Europe.

Figure 4.6 Virtual water imports, exports and flows around the world, 1996–2005



Note: Only net flows related to trade in agricultural and industrial products and greater than 15 km^3 per year are shown. The larger the arrow, the greater the flow.

Source: Adapted from Mekonnen and Hoekstra 2011

Changes to the hydrologic regime

Extreme events: floods and droughts

The number of flood and drought events classified as disasters – when ten or more people are killed, 100 are affected, a state of emergency is declared or international assistance is requested (EM-DAT 2011) – has risen since the 1980s, as have the total area and number of people affected and the level of damages (EM-DAT 2011; Rosenfeld *et al.* 2008; Kleinen and Petschel-Held 2007). River channelization, floodplain loss, urbanization, particularly in coastal areas, and changing land use are major reasons for the increasing impacts of floods and droughts as well as growing vulnerability to those impacts (Chapter 1). The number of people affected and total damages vary significantly, making it hard to identify trends with confidence (Lugeri 2010). Vulnerability depends on the preparedness and capacity to anticipate and react to extreme events. There are varying preparedness levels on a regional basis for dealing with sudden-onset (floods) and gradual-onset (droughts) disasters (IOM 2010).

Floods cause loss of life and billions of dollars of damage annually (Figure 4.7), with the economic losses higher in developed countries due to the financial valuation and insuring of assets. Between the 1980s and the 2000s, a 230 per cent rise in the number of flood disasters was accompanied by increasing levels of damages (Figure 4.7) (EM-DAT 2011). In addition, the number of people exposed to floods increased by 114 per cent (UNISDR 2011). Over 95 per cent of deaths related to natural disasters between 1970 and 2008 occurred in developing countries (IPCC 2011) and although governments in South and East Asia, for example, increased their disaster preparedness levels, the capacity of communities to cope with such extreme events is weakening because of inadequate social capacity and greater flood severity (Osti *et al.* 2011). Looking to the future, higher precipitation intensity is forecast for the northern

Box 4.5 Extreme events

Goals
Develop programmes for mitigating the effects of extreme water-related events

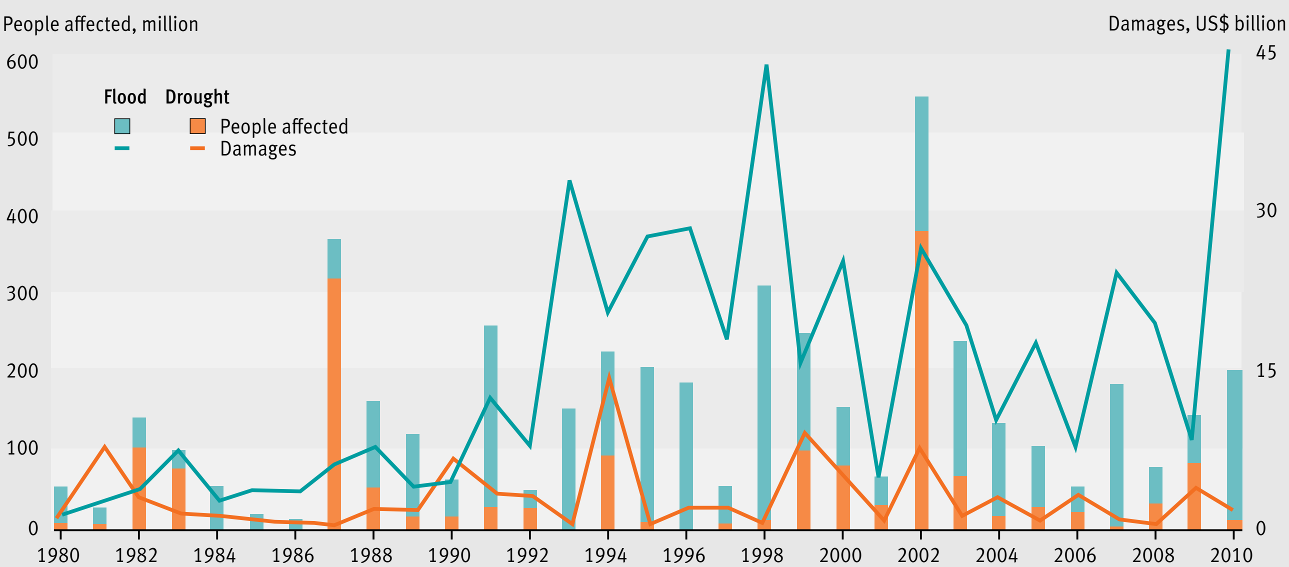
Indicators
Number of people affected by floods and droughts; total damages from floods and droughts

Global trends
Modest progress in some years or regions and a deteriorating situation in others

Most vulnerable communities
Deltas, low-lying areas, development in river floodplains, islands, and urban areas with inadequate drainage infrastructure are vulnerable to floods; communities directly dependent on rain-fed agriculture are vulnerable to droughts

Regions of greatest concern
South East Asia, North America (Mississippi Basin) and Latin America (Amazon Basin) for floods; small island developing states (SIDS), West Asia, Northern and Western Africa, Australia and South and Central Asia for droughts

Figure 4.7 People affected by and damages associated with floods and droughts, 1980–2010



Note: The costs of the large floods in Thailand and Pakistan in 2011 are not included here.

Source: EM-DAT 2011

hemisphere and equatorial areas, with many already arid and semi-arid areas expected to get drier (IPCC 2007a).

The number of drought disasters rose by 38 per cent between the 1980s and the 2000s, the number of people affected increased and related damages also increased (EM-DAT 2011). Droughts disrupt sustainable social and economic development, hindering achievement of the Millennium Development Goals (MDGs), and place additional stresses on ecosystems. Communities dependent on rain-fed crops, which represent approximately 70 per cent of global crop production, often have few alternative food sources beyond international aid (Portmann *et al.* 2010). This is evidenced by the severe ongoing drought in Eastern Africa and the reduction of net primary production in Latin America, Africa and South East Asia (Zhao and Running 2010). Droughts also affect irrigation and can exacerbate water resource conflicts, with arid and semi-arid areas being particularly vulnerable, especially in the context of climate change.

Dams and river fragmentation

Dam building and river control significantly benefit humans, providing flood protection, reliable water supplies and hydroelectric power. But dams can also have detrimental impacts on ecosystems, including channel fragmentation and flow modification, altering ecosystem processes and affecting aquatic organisms, particularly migratory species. Improved management of existing dams to ensure environmental flows and retain or create fish passes is important to mitigate conflicts, although such measures often fall short as a full remedy (Gleick 2003). Careful trade-off analyses are necessary to ensure that the design, location and operation of new dams minimize environmental impacts (Matthews *et al.* 2011).

Box 4.6 Dams and river fragmentation

Goals
Secure an adequate and sustainable freshwater supply; reduce water-related human health hazards (flood protection); protect and restore freshwater ecosystems and their services (often conflicting)

Indicators
Dam density

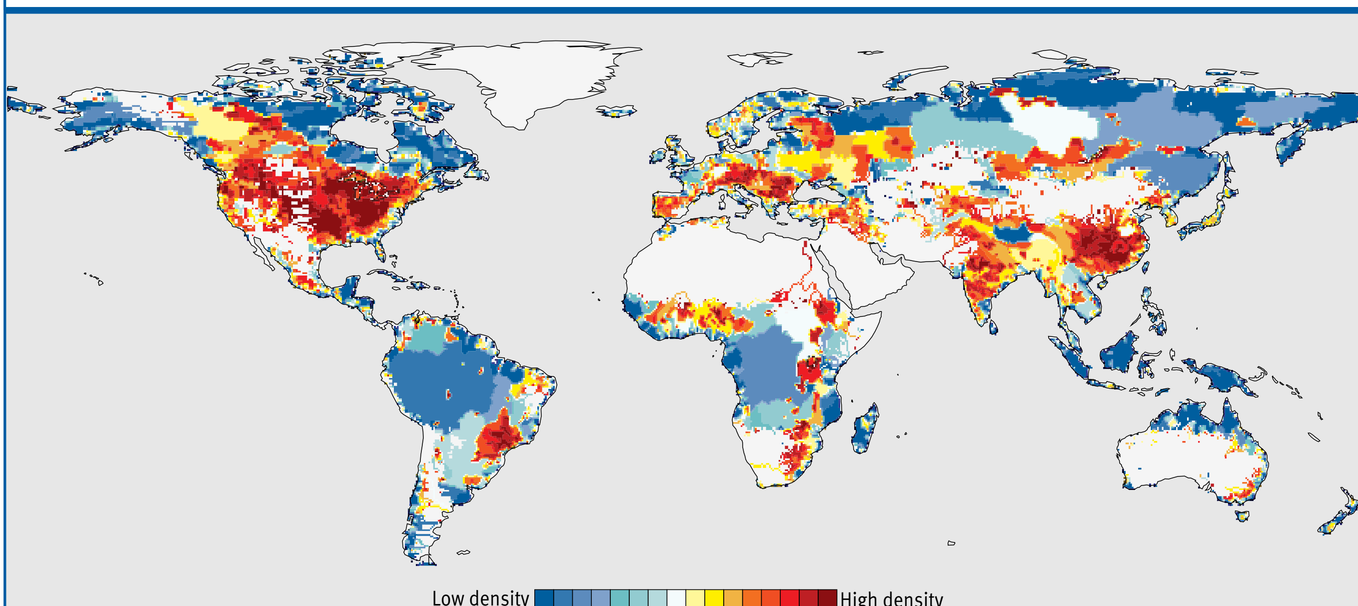
Global trends
Dam density is increasing; there is some progress on adequate supply of sustainable freshwater; freshwater ecosystems and their services are deteriorating

Most vulnerable communities
Populations displaced by dam construction; populations dependent on dams for water supply

Regions of greatest concern
Developing countries, Asia, Southern Africa

Dam density is highest in industrialized countries (Figure 4.8), although construction in developed regions has slowed because most suitable locations have already been used, and because recent legislation and public pressure do not support dam construction. However, dam building is being actively pursued in many developing countries to secure water and electricity

Figure 4.8 Global density of medium to large dams



Source: Vörösmarty *et al.* 2010

supplies. As this trend is likely to continue (Chapter 1), dam planning should consider any predicted increase in flow variability associated with climate change.

Freshwater and marine water quality

Groundwater contamination

Groundwater around the world is threatened by pollution from agricultural and urban areas, solid waste, on-site wastewater treatment, oil and gas extraction and refining, mining,

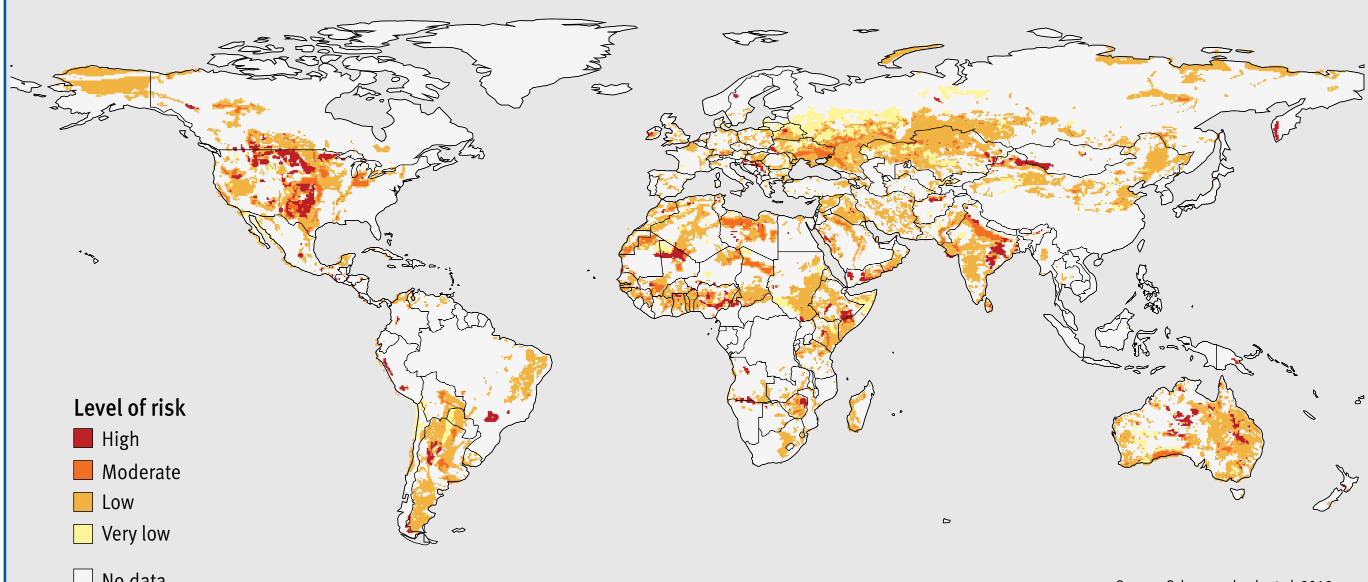
> ### Box 4.7 Groundwater contamination
>
> **Goals**
> Mitigate effects of groundwater contamination
>
> **Indicators**
> Arsenic, nitrate and salinization
>
> **Global trends**
> Very little progress in some areas; deterioration in others
>
> **Most vulnerable communities**
> Populations in rapidly urbanizing areas with inadequate sanitation
>
> **Regions of greatest concern**
> Arsenic is of particular concern in Bangladesh, India, highly populated river deltas in South East Asia, North America and Eastern Europe

Mining and mineral extraction can significantly reduce river or groundwater levels. *© BanksPhotos/iStock*

manufacturing and other industrial sources. The primary causes are inadequate control of these activities and exceedance of the natural attenuation capacity of underlying soils and strata (Foster *et al.* 2006). Salinization of overexploited aquifers, especially in coastal areas, is another serious concern, particularly for communities dependent on groundwater for drinking.

Groundwater nitrate concentrations are increasing, especially in areas of rapid urbanization, inadequate sanitation and/or heavy agricultural fertilizer use. Nitrate in groundwater contributes

Figure 4.9 Estimated risk of arsenic in drinking water, based on hydrogeological conditions



Source: Schwarzenbach *et al.* 2010

to eutrophication and has direct human health impacts. Both naturally occurring arsenic and that mobilized by human activities threaten drinking water quality in many countries (Figure 4.9). Groundwater contaminated with arsenic from natural geologic sources affects 35–75 million people. Surface water pollution in some regions has led to the development of groundwater as a source of drinking water, resulting in inadvertently exposing people to these natural sources of arsenic (Schwarzenbach *et al.* 2010; Brunt *et al.* 2004).

Pathogenic contamination

Pathogenic contamination of surface and groundwater is a critical threat to human health in many areas and contributes to water treatment costs in many communities. Using domestic sewage collection and treatment as a proxy, microbial contamination has decreased over past decades in most developed countries. In contrast, microbial pathogens are often the most pressing water quality issue in many developing countries (Figure 4.10).

Box 4.8 Pathogenic contamination

Goals
Improve sanitation coverage including sewage collection, treatment and disposal; reduce and control freshwater and marine pollution

Indicator
Faecal coliform concentration; population without access to improved sanitation

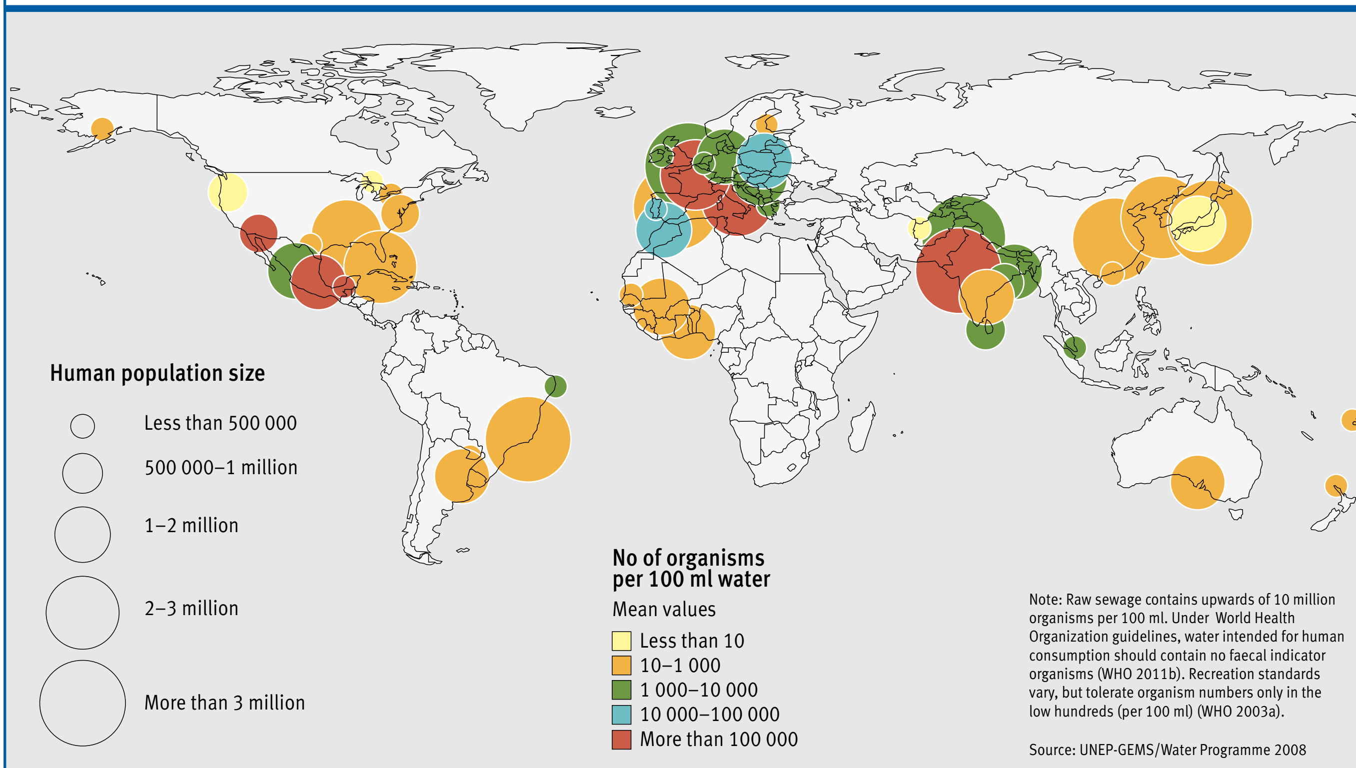
Global trends
Some progress

Most vulnerable communities
Poorest and most rural communities

Regions of greatest concern
Africa, South Asia, South Pacific

Because human and animal faeces are the primary pathogenic sources of water contamination, achieving MDG Goal 7c of halving the population without basic sanitation by 2015 will help reduce such pollution. Nevertheless, although some regions have made significant progress, the world is currently not on track to attain this goal (Figure 4.11). Improved sanitation continues to bypass the poorest communities and individuals, especially in Africa and South Asia (WHO 2012). Unless achieving the MDG sanitation goal in the future includes the provision of wastewater collection and treatment facilities, increasing access to improved sanitation could have

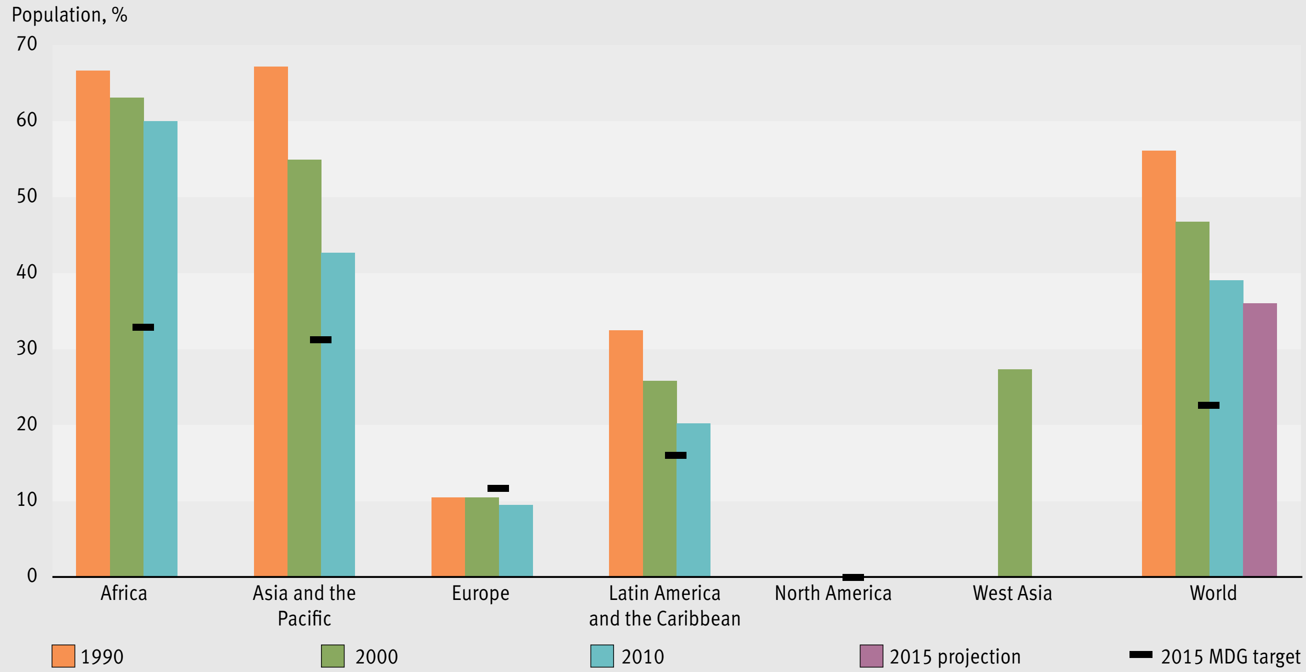
Figure 4.10 Faecal coliform concentrations in rivers near major cities – an indicator of waterborne pathogens, 1990–2011



Note: Raw sewage contains upwards of 10 million organisms per 100 ml. Under World Health Organization guidelines, water intended for human consumption should contain no faecal indicator organisms (WHO 2011b). Recreation standards vary, but tolerate organism numbers only in the low hundreds (per 100 ml) (WHO 2003a).

Source: UNEP-GEMS/Water Programme 2008

Figure 4.11 Population without access to improved sanitation compared to MDG target, 1990–2015



Note: For MDG monitoring, WHO/UNICEF defines an improved sanitation facility as one that hygienically separates human excreta from human contact (WHO 2012).

Source: WHO 2012

the unintended negative impact of delivering more untreated wastewater to water bodies, further degrading downstream water quality (Biswas and Tortajada 2011).

Nutrient pollution and eutrophication

Eutrophication, resulting from excessive nutrient pollution from human sewage, livestock wastes, fertilizers, atmospheric deposition and erosion (Chapter 3), is a continuing, pervasive water quality problem. Although there has been increased sewage treatment in many areas, much less progress has been made in reducing nutrient loads from non-point sources, including agricultural and urban run-off and atmospheric deposition to freshwater and marine systems. Interference with global nutrient cycles may be reaching planetary boundaries, beyond which marine and freshwater ecosystems might not recover, although specific thresholds for these processes remain uncertain (Rockström *et al.* 2009).

Box 4.9 Nutrient pollution and eutrophication

Goals
Reduce and control freshwater and marine pollution

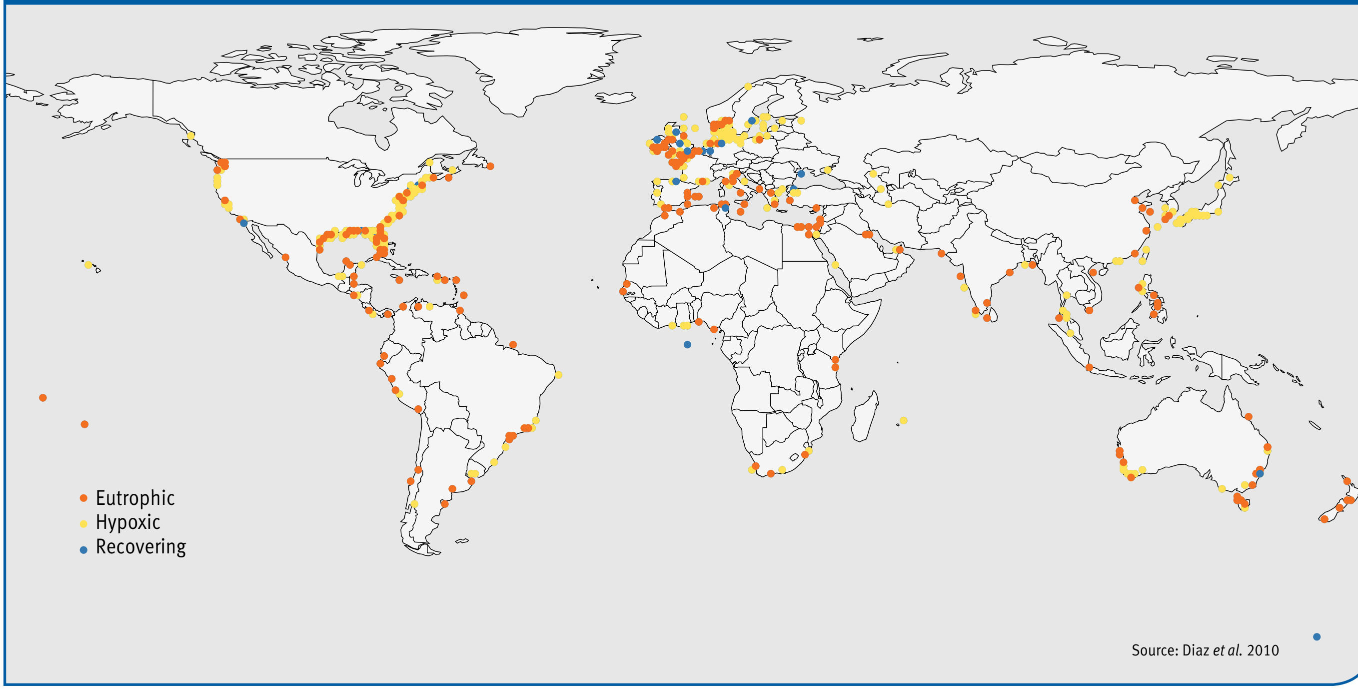
Indicators
Marine: prevalence of coastal dead zones; frequency and intensity of harmful algal blooms
Freshwater: global river exports of nitrogen and phosphorous

Global trends
Very little progress or deteriorating

Regions of greatest concern
South East Asia, Europe, eastern North America

Global river nutrient export has increased nutrient export has increased by approximately 15 per cent since 1970, by approximately 15 per cent, since 1970, with South Asia accounting for at least half of the increase (Seitzinger *et al.* 2010). There has been a 74 per cent increase in algal and macrophyte gross productivity in lakes since 1970 (Lewis 2011), and a dramatic increase in the number of eutrophic coastal areas since 1990. Under severe eutrophic conditions, algal blooms can produce hypoxic conditions, causing fish kills in lakes, and dead zones in coastal areas. Hypoxia has become a significant and increasing problem in lakes and rivers, estuaries and coastal areas around the world (Diaz *et al.* 2010; Rabalais *et al.* 2010; Diaz and Rosenberg 2008). At least 169 coastal areas are considered hypoxic, with dead zones especially prevalent in the seas around South East Asia, Europe and eastern North America (Figure 4.12). Only 13 coastal areas appear to be recovering (Diaz *et al.* 2010; Rabalais *et al.* 2010), most in North America and northern Europe. Whereas phosphorus loads are projected to level off, global river nitrogen loads are likely to

Figure 4.12 World hypoxic and eutrophic coastal areas, 2010



increase by an additional 5 per cent by 2030, mostly in South Asia (Seitzinger *et al.* 2010).

Nutrients can also cause harmful algal blooms in freshwaters and coastal areas, some releasing algal toxins that directly affect human health (WHO 2003a), aquatic organisms and livestock. The number of reported outbreaks of paralytic shellfish poison, a harmful algal toxin found in eutrophic waters, increased from fewer than 20 in 1970, to more than 100 in 2009 (Anderson *et al.* 2010).

Box 4.10 Marine litter

Goals
Reduce marine pollution

Indicator
Levels of litter at the shoreline; levels on the sea bottom and in marine gyres

Global trends
Little to no progress

Most vulnerable communities
Coastal populations

Regions of greatest concern
Unknown

Marine litter

Litter is found in all the world's oceans because of poor solid waste management and the increased use of plastic (UNEP 2009). It damages wildlife, fisheries and boats, contaminates coastal areas, and presents safety and human health risks. Marine litter accumulates on coastal beaches, on the sea bottom (Galgani *et al.* 2000) and large marine gyres in both the Atlantic and Pacific Oceans (Law et al. 2010; Martinez et al. 2009).

Of the 12 seas surveyed between 2005 and 2007, the South East Pacific, North Pacific, East Asian Sea and Wider Caribbean coasts contained the most marine litter (UNEP 2009), and the Caspian, Mediterranean and Red Seas the least. Regional studies of the Baltic Sea (HELCOM 2009), Northeast Atlantic (OSPAR 2009), US coastline (Sheavly 2007) and North Atlantic Subtropical Gyre indicated no statistically significant changes in litter quantity between 1986 and 2008, while data from the Mid-Atlantic indicated an increase in land-based and general-source marine litter during 1997–2007 (Ribic *et al.* 2010).

Persistent toxic chemicals

Toxic pollutants include the trace metals cadmium, lead and mercury, pesticides and their by-products such as dichlorodiphenyltrichloroethane (DDT) and chlordecone, industrial chemicals and combustion by-products. They are still used in many places and thus continue to accumulate in aquatic systems, leaving a legacy of sediment contamination; they are found in 90 per cent of water bodies. The pollutants of greatest concern are persistent, toxic and bioaccumulative (Chapter 6). Organisms can accumulate contaminants from water, sediment and food, acquiring tissue contaminant levels much higher

Box 4.11 Toxic chemicals

Goals
Reduce marine and freshwater pollution

Indicators
Concentration of organochlorines in predatory fish species; concentration of persistent organic pollutants in Arctic air

Global trends
Some progress

Most vulnerable communities
Coastal populations; populations dependent on fish for food

Regions of greatest concern
Polar regions

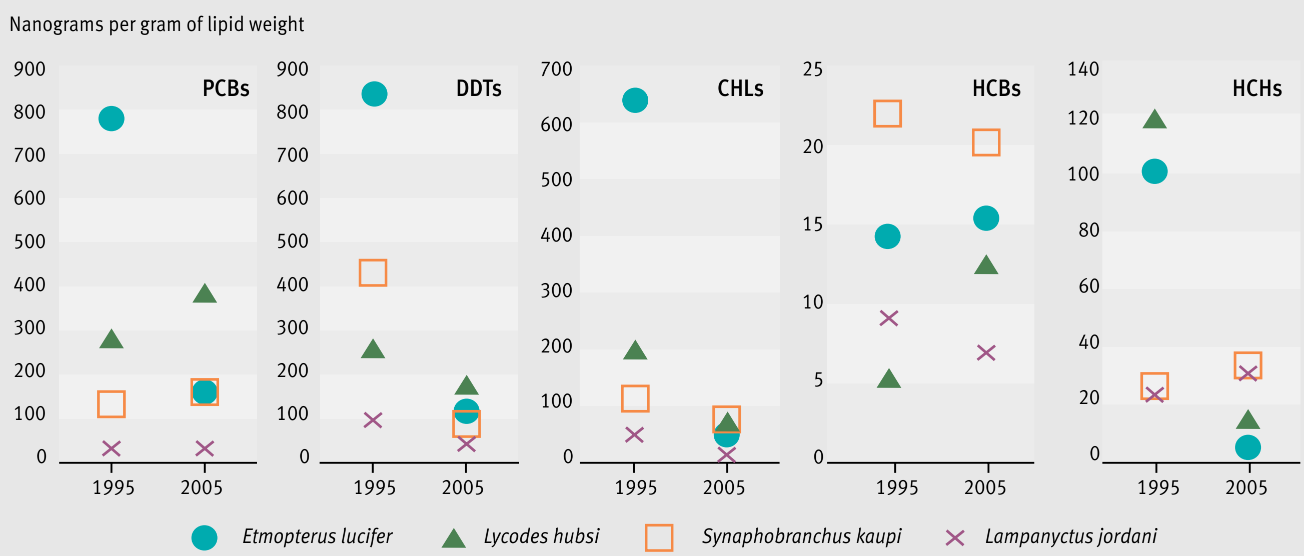
than those in the surrounding environment. Organochlorine compounds such as polychlorinated biphenyl (PCB) or DDT concentrate in fatty tissues, remain for long periods and biomagnify up the food chain, with the highest concentrations found in top predators.

Concentrations of many persistent organic pollutants (POPs), which tend to accumulate in the Arctic (Hung *et al.* 2010), have decreased in Arctic air samples since the early 1990s (Chapter 2). Tissue concentrations of at least three organochlorine chemicals in 12 deep-sea fish species in the Western Pacific (Figure 4.13) (Oshihoi *et al.* 2009) and PCB concentrations in at least four fish species in San Francisco Bay (Davis *et al.* 2003) have also fallen since the mid-1990s (Chapter 6).

Emerging water quality concerns
Although conventional toxic pollutants are declining in many industrialized areas, additional contaminants are raising new concerns, for example the use of flame retardants such as polybrominated diphenyl ethers (PBDEs), a type of POP, has increased exponentially over the past 30 years in Europe, North America and Japan (Schwarzenbach *et al.* 2010). There are also mounting concerns about pharmaceuticals and personal care products that are not removed by most sewage systems, and thus enter the environment after use. The long-term risks to aquatic organisms and humans are largely unknown, although it is clear that pharmaceuticals and endocrine-disrupting compounds can have biological effects at very low concentrations (Schwarzenbach *et al.* 2010).

Nanoparticles and microplastics are relatively new water pollutants (Chapter 6). Nanoparticles – particles measuring 1–100 nanometres, or billionths of a metre – are increasingly used in modern life. An emerging field of nanoecotoxicology is examining their environmental fate and potential impacts on aquatic ecosystems (Hassellöv *et al.* 2008; Navarro *et al.* 2008). Microplastics, from the deterioration of plastic objects, may contain additives that accumulate in aquatic organisms (GESAMP 2010; Ryan *et al.* 2009), and their concentrations, especially in marine systems, are expected to follow increases in global plastic consumption. Additional types of pollutants about which little is

Figure 4.13 Trends in organochlorine contamination in selected deep-sea fish species, 1995–2005



PCBs = Polychlorinated biphenyls
DDTs = Dichlorodiphenyltrichloroethanes
CHLs = Chlordane compounds
HCBs = Hexachlorobenzenes
HCHs = Hexachlorocyclohexanes
Note: Samples were collected from the Western Pacific off the coast of Japan.

Source: Oshihoi *et al.* 2009

Box 4.12 Ballast water and invasive species

Invasive species, a form of biological pollution, pose great threats to aquatic ecosystems and can cause severe environmental and economic damage. Ballast water is a major vector for transporting species around the world. The Ballast Water Convention of 2004 required the implementation of management plans, with open-ocean ballast exchange commonly used to reduce introductions. Since this is unfeasible in many shipping routes, some countries, including Denmark and Australia, have instituted regulations requiring ballast water treatment to kill resident organisms.

Box 4.13 Water security

Goals
Secure adequate sustainable freshwater supply

Indicators
Human water security threat

Global trends
Deteriorating

Most vulnerable communities
Developing countries with increasing water demand

Regions of greatest concern
Africa, West Asia, Asia and the Pacific, Latin America and the Caribbean

currently known will doubtless continue to be identified. Although not new, industrial, medical, military and accidental releases of radioactive substances are of renewed concern, as illustrated by the water contamination after the 2011 tsunami damaged Japanese nuclear power plants. Invasive alien species also remain a problem for many coastal areas (Box 4.12; Chapter 5).

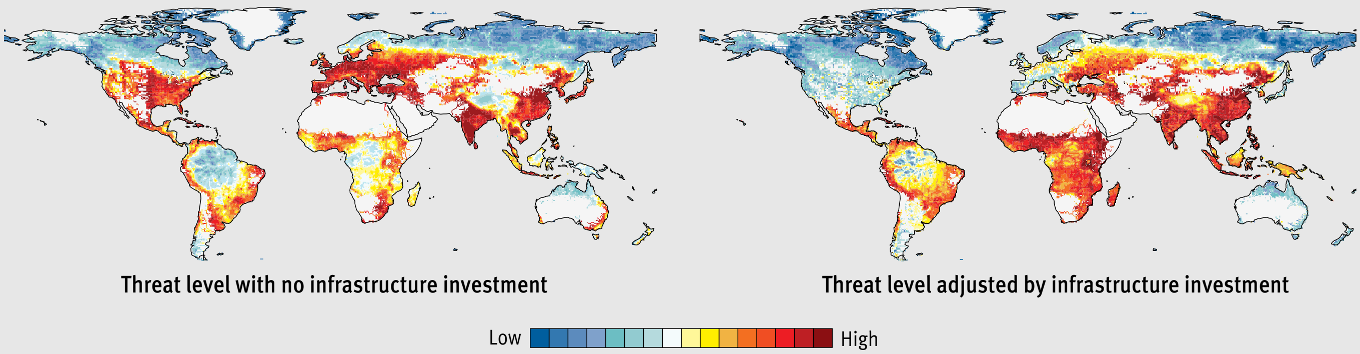
CROSS-CUTTING ISSUES

Water security and human health

As previously noted, regional differences exist regarding both absolute water availability and the limitations placed on it by inadequate infrastructure. Both relate to water security, as does water pollution, because they can all affect the range of human and environmental water uses. Despite improvements, lack of access to drinking water of adequate quality and quantity remains one of the largest human health problems globally. Inadequate water supply is an inherently regional phenomenon, however, caused by basin-level water scarcity, regional water quality, inadequacies of infrastructure and governance, cultural perspectives and inequitable water pricing.

Although the MDG target on water supply was met in 2011, more than 600 million people will lack safe water supplies in 2015. *© Kibae Park/UN Photo*

Figure 4.14 Threats to water security with and without infrastructure investment, 2000



Source: Vörösmarty *et al.* 2010

Water security
Although several definitions for water security have been proposed since the 1992 Rio Earth Summit, none has been universally accepted (Oswald Spring and Brauch 2009). Varying definitions, leading to numerous indices based on different criteria, make it difficult to generate trend data. The Ministerial Declaration of the Hague broadly defines water security to include the protection and improvement of freshwater and marine ecosystems, sustainable development and political stability, with the aim of providing every person with access to "enough safe water at an affordable cost to lead a healthy and productive life", as well as protecting vulnerable communities from water-related risks and hazards (World Water Council 2000).

About 80 per cent of the world's population lives in areas with high water security threats, the most severe category encompassing 3.4 billion people, almost all in developing countries. Water security threat here refers to the cumulative effect of 23 drivers that have an impact on water resources, categorized into watershed disturbance, pollution, water resource development and biotic factors (Vörösmarty *et al.* 2010). More people are likely to experience severe water stresses in the coming decades because of increased demands (Chapter 1) in addition to altered precipitation patterns associated with climate change.

Figure 4.14 highlights the global threat to human water security and compares it with the magnitude of threat after adjusting for the effects of previous and current infrastructure investment. With higher investments in infrastructure in the industrialized countries, the figures show that human water security can be increased, overcoming the various threats to water resources (Vörösmarty *et al.* 2010), while low investments in developing countries means their water security remains poor. Investments must be coupled with adequate institutional capacity, and because infrastructure development often occurs at the expense of aquatic biodiversity and environmental quality, it is imperative that environmental risks related to investments are considered and appropriately mitigated.

Box 4.14 Access to improved water

Goals
Ensure equitable access to improved drinking water supply

Indicators
Proportion of population without an improved drinking water source; rural-urban equity

Global trends
Significant progress on improved supply; modest progress on rural-urban equity

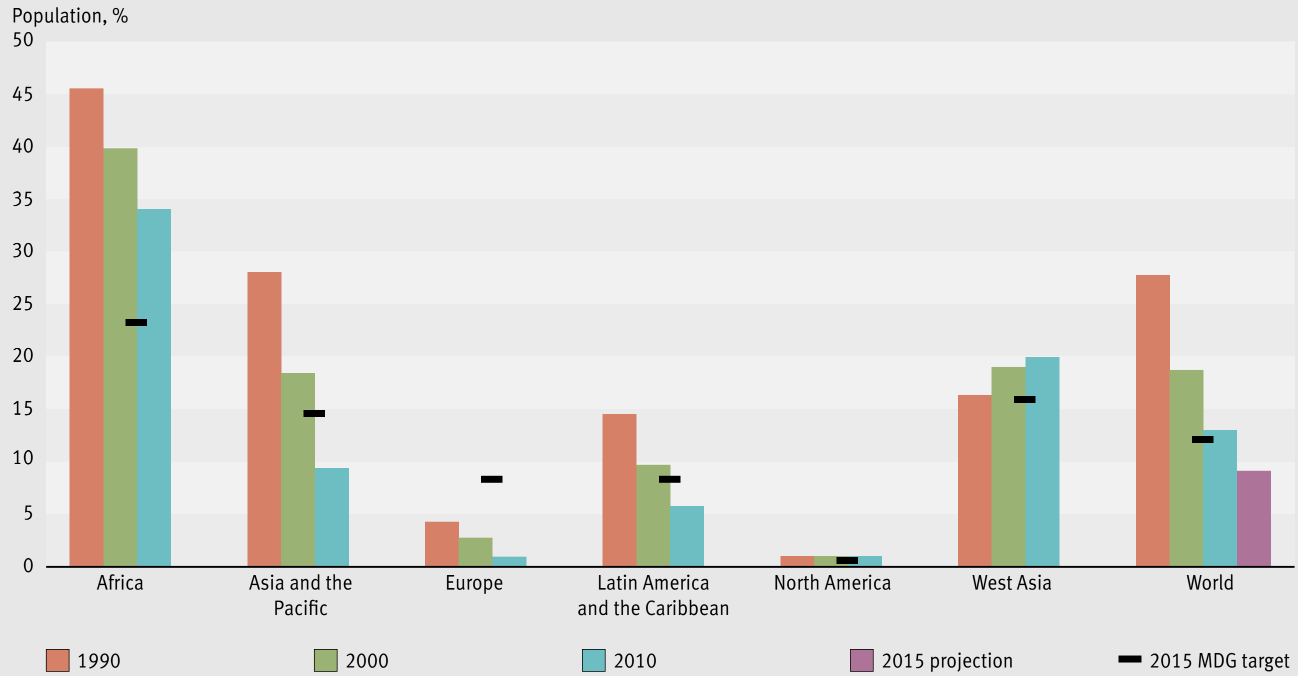
Most vulnerable communities
Poor in developing countries and rural areas

Regions of greatest concern
South Pacific sub-region; most of Africa, especially the West Indian Ocean sub-region

Equitable access to improved drinking water
Although water security is an increasing problem in many regions of the world, significant progress in access to improved drinking water has been made since 1990. However, several regions, including most of Africa and other rural areas in developing countries, still lack access to improved drinking water sources (UNDESA 2010). The UN General Assembly declared access to clean water and sanitation as a human right in July 2010, although the right is not yet recognized or applied in many countries.

Recent data suggest that the MDG drinking water target was met in 2010 (Figure 4.15). However, there are important inequities in this improvement. Whereas only 4 per cent of people in urban areas lacked access to improved drinking water in 2010, in rural

Figure 4.15 Population without access to improved drinking water, 1990–2015



Note: As defined by WHO/UNICEF, an improved drinking-water source is one that, by nature of its construction or through active intervention, is protected from outside contamination, particularly from faecal matter.

Source: WHO 2012

areas 19 per cent of residents lacked such access. Progress towards achieving MDG 7c primarily reflects increased use of technology and infrastructure to overcome poor water quality or water scarcity (WHO 2012).

Water-related diseases

Water-related diseases, as defined by the World Health Organization (WHO), include those caused by microorganisms and chemicals in drinking water; diseases like schistosomiasis,

Box 4.15 Water-related diseases

Goals
Reduce water-related human health hazards

Indicators
Water-related-disease deaths measured as disability-adjusted life years (DALYs); number of reported cholera cases

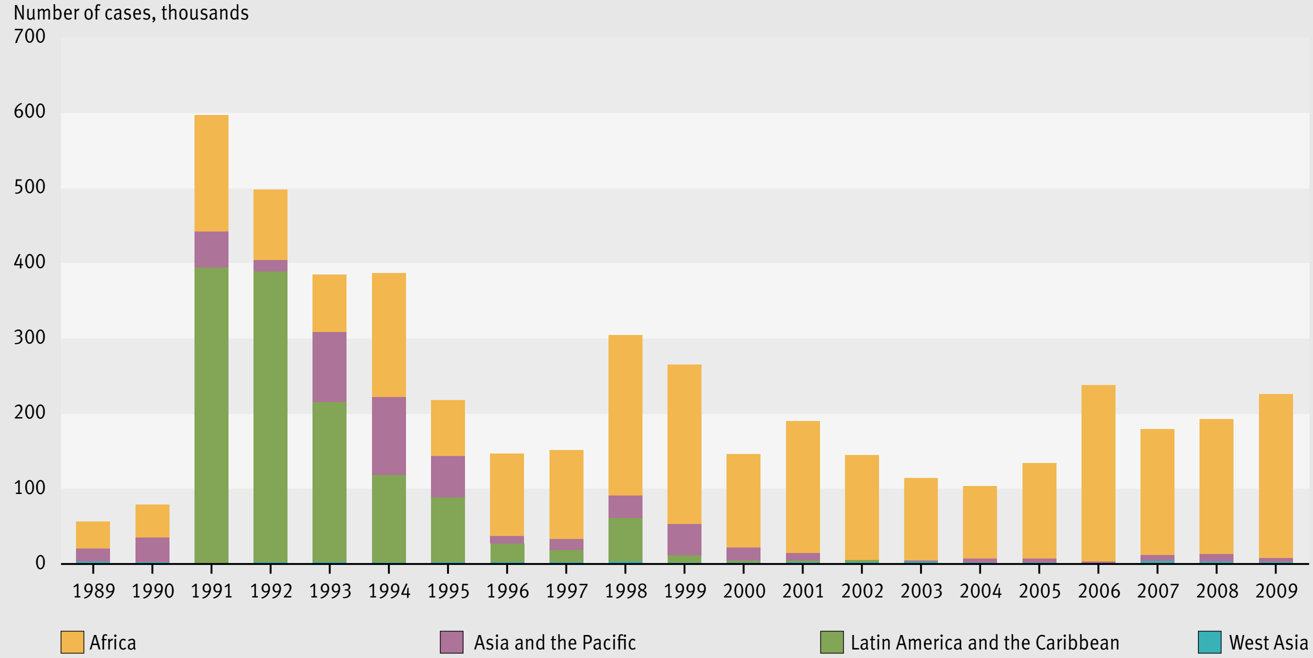
Global trends
Some progress

Most vulnerable communities
Poor in developing countries and rural areas; communities that have experienced natural disasters

Regions of greatest concern
Africa

Dengue fever and malaria, both diseases transmitted by mosquitoes, are most problematic where there is stagnant water in which mosquitoes can breed. *© Salem Alkait/iStock*

Figure 4.16 Cholera cases by region, 1989–2009



Note: Reported cases are an underestimate of total cases because many go unreported.

Source: WHO 2010

Box 4.16 Diarrhoea in children in Africa

At any given time, over half the world's hospital beds are filled with people suffering from water-related diseases (UNDP 2006). Diarrhoeal diseases make up more than 4 per cent of the global disease burden, 90 per cent being linked to environmental pollution and lack of access to safe drinking water and sanitation (Prüss-Üstün *et al.* 2008). Africa has the highest burden of diarrhoea-related childhood deaths, accounting for 70 per cent of the 1.3 million deaths of children less than five years old in 2008. Not surprisingly, access to basic sanitation is also poorest in sub-Saharan Africa, with 330 million people lacking access to proper sanitation (WHO 2011a).

whose vector spends part of its life cycle in water; diseases like malaria with water-related vectors; and others such as legionellosis carried by aerosols containing certain micro-organisms.

Such diseases are a major public health concern, especially in Africa. Globally, diarrhoea related to inadequate sanitation and water supply was the second largest contributor to the 2004 global disease burden, claiming more than 70 million disability-adjusted life years (DALYs), years lost due to ill-health, disability or early death (Box 4.15) (Prüss-Üstün *et al.* 2008). Global health statistics indicate that Africa and South Asia contain the areas most severely affected by waterborne disease (WHO 2004).

The WHO is focusing on reducing 25 different water-related diseases (WHO 2011a). There have been some notable successes in the reduction of onchocerciasis, malaria, schistomiasis and cholera. However, globally reported cholera incidence – which serves as a proxy where complete data on water-related disease trends are lacking – has increased in recent years, mainly in Africa (Figure 4.16). In 2009, 45 countries from all continents reported 221 226 cases of cholera (Figure 4.16). Water-related diseases are a continuing public health problem in developing countries lacking access to adequate drinking water and sanitation, as further evidenced by the cholera epidemic in Haiti following the 2010 earthquake (Walton and Ivers 2011).

Water-energy-climate nexus

Water, energy, economic development and climatic change are interdependent issues. Increases in human population and per-person consumption related to economic development drive energy demands. Meanwhile the use of fossil fuel energy produces greenhouse gas emissions that contribute to climate change, which has effects on water, including extreme weather events, loss of ice cover, water scarcity and sea level rise. In turn, responses to climate change have implications for the water environment. Some

Table 4.2 Observed and projected impacts of climate change on key hydrological variables

Key variables	Observed trends	Projections for the 21st century
Precipitation	The trend is unclear; increases in general precipitation over land from 30º N to 85º N; notable decreases from 10º S to 30º N	Total precipitation is projected to increase (by 1–3% per ºC of temperature rise), with varying changes at the regional scale
Precipitation intensity	Disproportionate increase in volume of precipitation in heavy or extreme precipitation events; intensification in extreme precipitation on global scale	Heavy precipitation is projected to increase by approximately 7% per ºC of temperature rise
Droughts	Drought increased in the 20th century measured by the Palmer Drought Severity Index, although some areas became wetter and/or drought intensity has lessened	Drought intensity will increase in some areas and seasons; patterns are complex and difficult to predict
Tropical cyclones	High degree of uncertainty about any detectable change being related to climate change	Likely increase in average tropical cyclone maximum wind speed but decreased frequency; changes in frequency and track are uncertain
Glaciers and snow cover	There is a decrease in glacial masses, but not in all regions, and decreased snow cover in northern hemisphere regions; peak run-off from glacier and snowmelt is earlier	Continued decrease in glacial mass and snow cover
Sea level	Sea levels increased by about 0.2 metres over the 20th century; a rise equivalent to 0.3 metres per century has been recorded since the early 1990s, although it is not clear if this is an acceleration in long-term sea level rise	Sea level is projected to rise by 0.2–0.6 metres by 2100, although the upper end of the range could be much higher
Ocean acidification	The mean surface ocean pH has decreased from 8.2 to 8.1	pH is projected to decrease to 7.7 or 7.8 by 2100 if present trend persists
Sea surface temperature	Increased by 0.5º C since 1980	Continued increase

Source: IPCC 2011; Feely *et al.* 2009; World Bank 2009; IPCC 2007c

forms of solar energy consume significant quantities of water, often in arid regions. With increasing water scarcity, some regions also rely on desalinization of marine water, requiring large energy inputs (World Bank 2009). In addition, droughts have the potential to decrease hydropower production (Box 4.21).

Climate change impacts on the water cycle and ocean warming

The hydrologic cycle refers to the continuous movement of water through the oceans, atmosphere and over and under land surfaces. There is strong evidence that climate change is altering global and regional hydrologic cycles (Bates *et al.* 2008; IPCC 2007a; Kundzewicz *et al.* 2007), with impacts predicted to be manifested as changing precipitation patterns, increased intensity of extreme weather events and consequent natural disasters, retreating glaciers resulting in altered river discharge regimes, and more intense droughts in semi-arid regions (Table 4.2) (IPCC 2007b).

Although there is considerable uncertainty regarding projected impacts on specific water systems, climate change has the potential to seriously affect water management (Bates *et al.* 2008). Nonetheless, the global impacts of other human activities on the hydrologic cycle – urbanization, industrialization, water resources development – are likely to exceed those related to climate change, at least for the next two to three decades (Gordon *et al.* 2005). If climate change impacts are to be addressed, the cost of the additional water infrastructure needed by 2030 to provide a sufficient quantity of water for all countries is estimated at US$9–11 billion per year (UNFCCC 2007), 85 per cent of this in developing countries. There are additional costs associated with flood

Box 4.17 Climate change impacts on human security

Goals
Mitigate and adapt to adverse effects of climate change on the water environment

Indicators
Extreme precipitation; glacial retreat; drought intensity; water sector costs of climate change adaptation

Global trends
Some progress on adaptation and mitigation strategies; little or no progress on funding and implementation

Most vulnerable communities
People dependent on rain-fed agriculture and/or glacial melt; those relying on non-renewable groundwater in the long term

Regions of greatest concern
Arid regions, tropics, and coastal areas that experience cyclones and hurricanes

risk management and water quality protection (Parry *et al.* 2009). There are signs of increased awareness of mitigation and adaptation needs: of 191 water projects funded by the World Bank between 2006 and 2008, 35 per cent incorporated mitigation and adaptation measures for climate change impacts (World Bank 2009). At the same time, however, local and regional efforts to increase protection against floods and other extreme events are likely to have significant negative impacts on aquatic ecosystems themselves.

The most direct climate change impact on oceans is increased sea surface temperature (SST), which has risen by 0.5ºC globally since the 1980s and is predicted to continue increasing throughout the 21st century (IPCC 2007a). Global precipitation is predicted to increase at a rate of 1–3 per cent per degree of surface warming (Wentz *et al.* 2007), with more extreme precipitation events predicted for many tropical and temperate regions (IPCC 2011; Gorman and Schneider 2009).

Melting ice sheets and sea level rise

Sea level rise is caused by ocean thermal expansion and by melting glaciers and ice sheets (IPCC 2007a). Although average global sea level has remained relatively constant for almost 3 000 years, it increased by approximately 170 mm during the 20th century (IPCC 2007b), and is projected to rise by at least another 400 mm (+/-200 mm) by 2100 (IPCC 2007a). Measurements from 1993 to 2008 indicate that sea levels are already rising twice as fast as in previous decades (Cazenave and Llovel 2010) and are exceeding the rise predicted by climate models.

Although there is considerably variability associated with these and other estimates of sea level rise (Levitus *et al.* 2009; Ishii and Kimoto 2009), 25–50 per cent of sea level rise observed since 1960 has been attributed to thermal expansion (Cazenave and Llovel 2010; Antonov *et al.* 2005; Willis *et al.* 2004). Some variability may result from water impounded in reservoirs, which is estimated to have reduced sea level rise by 30–55 mm over the past 50 years (Chao *et al.* 2008). Small glaciers and ice caps exhibited significant mass losses over the 20th century (Dyurgerov and Meier 2005) and freshwater run-off from melting land-based ice sources will increase in the future. However, with losses accelerating over the past 20 years, melting Greenland and Antarctic ice sheets have become the biggest contributors to sea level rise, and will remain the dominant contributor to sea level rise in the 21st century if current trends continue (Rignot *et al.* 2011; Rignot 2008).

Box 4.18 Sea level rise

Goals
Mitigate and adapt to adverse effects of climate change on the water environment

Indicators
Sea level rise; cost of adaptation to sea level rise

Global trends
Very little to no progress

Most vulnerable communities
Coastal areas, island communities, high-density populations in deltas

Regions of greatest concern
Coastal areas (deltas and African coast), small island developing states, the Arctic, Antarctica and high mountain regions

Box 4.19 Ocean acidification

Goals
Protect and restore marine ecosystems and their services

Indicators
Ocean pH

Global trends
Deteriorating

Most vulnerable communities
Communities dependent on tropical fisheries that rely on coral reef ecosystems and other calcareous primary producers

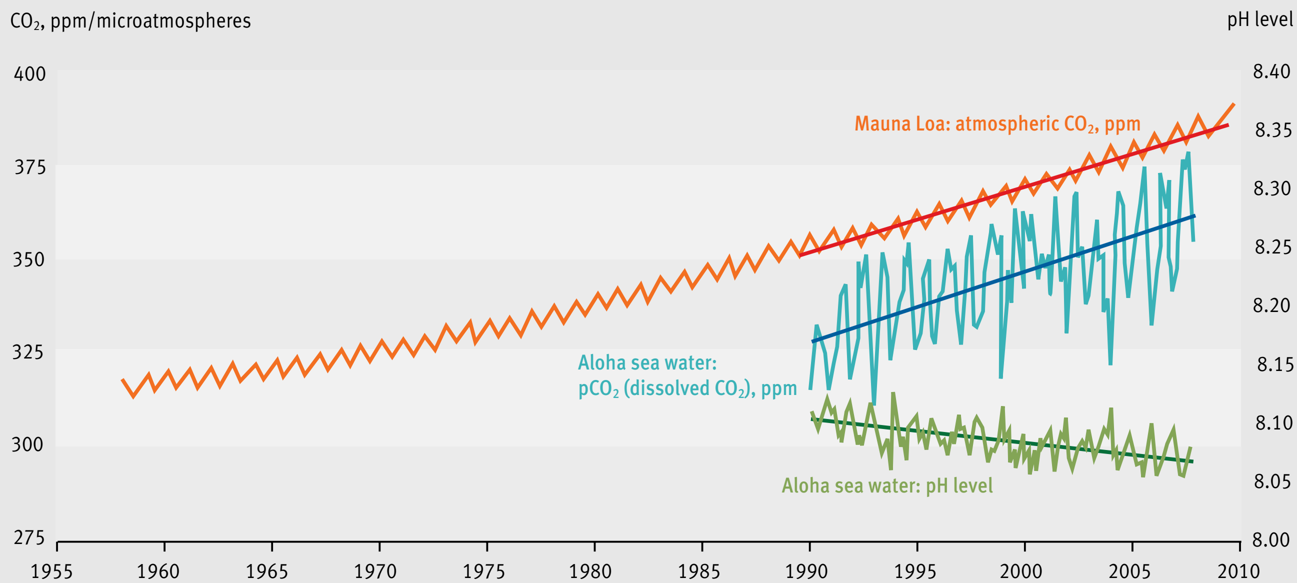
Regions of greatest concern
Tropical oceans

Because of the high concentrations of human populations and infrastructure in coastal zones (McGranahan *et al.* 2007), many countries are vulnerable to sea level rise and associated coastal and low-lying community flooding (Chapter 7). Developing countries, particularly small island developing states (SIDS) and deltaic areas, are especially vulnerable (IPCC 2007c), many with limited capacity to adapt to rising sea levels or recover from associated losses. The estimated costs of coastal adaptation range from US$26 billion to US$89 billion per year by the 2040s, depending on the magnitude of sea-level rise (World Bank 2010).

Ocean acidification

The oceans annually absorb a substantial proportion of anthropogenic carbon dioxide (CO_2), which reacts with water to form carbonic acid, thereby making the ocean more acidic. The mean surface ocean pH has already decreased from a pre-industrial average of about 8.2 to a present value of 8.1, though there are regional differences (Figure 4.17; Chapter 2), and Feely *et al.* (2009) project a pH decrease to a mean of about 7.8 by 2100. Ocean acidification may be approaching the planetary boundary (Rockström *et al.* 2009).

Figure 4.17 CO_2 concentrations and ocean acidification in the North Pacific, 1960–2010



Source: Feely *et al.* 2009

Increased ocean acidity affects marine animals with carbonate shells and skeletons, calcareous algae and other organisms (Langdon and Atkinson 2005). Affected organisms include reef-building corals as well as animals critical to ocean food webs, including several important human food sources such as crabs and molluscs. Combined with higher water temperatures, ocean acidification is thought to be a major cause of coral bleaching, destroying coral reef ecosystems around the world (Hoegh-Guldberg *et al.* 2007), with some studies projecting a rapid contraction of tropical coral reefs by 2050 (Chapter 5) (Logan 2010). Coral reefs provide important ecosystem services, such as spawning and nursery grounds for some commercially important fish species. Impairment of these ecosystems and their services are becoming increasingly evident and illustrate the need for governance to enhance their protection.

Ocean acidification is threatening marine life, particularly corals and shellfish. It could have a devastating effect on communities dependent on fishing and aquaculture. *© Extreme-photographer/iStockv*

Impacts of energy development on water resources

While global data are lacking, the energy sector is believed to account for approximately 40 per cent of total water withdrawals in the United States and European Union (EU) (Glennie *et al.* 2010). Water demands for energy range from extraction and processing of raw materials to driving hydropower turbines and cooling thermoelectric plants, including nuclear. Fossil fuel extraction can also have serious impacts on water quality.

Oil and gas exploration and production can affect both freshwater and marine ecosystems. Newly proven technologies are accelerating the expansion of new natural gas wells in shale gas basins (EIA 2011). Associated water resource impacts are currently being researched, including aquifer contamination with potentially explosive methane levels (Osborn *et al.* 2011), surface and groundwater contamination, streams receiving water discharges (Johnson *et al.* 2007), and high consumptive water use for well drilling and completion (Chapter 7). Oil sand exploitation also requires large water volumes and can produce severe water pollution (Kelly *et al.* 2010).

Box 4.20 The Deepwater Horizon oil spill

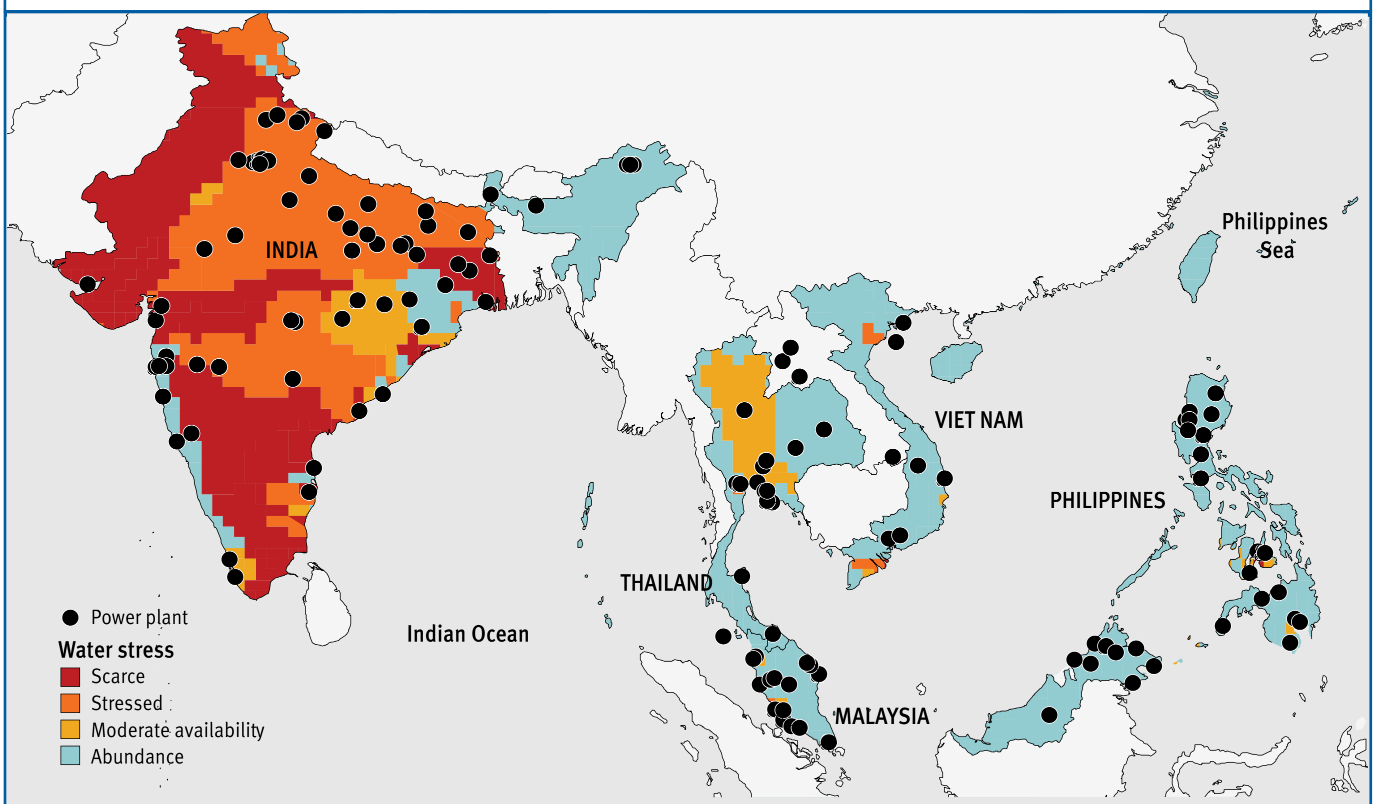
The *Deepwater Horizon* oil spill of 4.9 million barrels of crude oil into the Gulf of Mexico in 2010 was the largest accidental marine oil spill in history. Although the economic and ecological costs have not yet been fully quantified, it caused extensive damage to marine life, wildlife habitats, fishing and tourism. Unlike previous oil spills, in which most of the oil dissipated or evaporated, immense underwater plumes and thick layers of dissolved oil remained on the seafloor in spring 2011, tar balls continued to wash ashore and wetlands marsh grass continued to foul and die.

Source: National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011

Oil spills continue to pose an environmental threat, particularly to marine ecosystems. Although the number of oil tanker spills has decreased significantly since the 1970s and 1980s (ITOPF 2010), the recent large spill associated with offshore oil and gas exploration in the Gulf of Mexico is evidence of ongoing risks to marine ecosystems (Box 4.20). Nevertheless, with increasing global oil and gas demands, such offshore activity is expected to increase over the next two decades, facilitated by the resolution of maritime boundaries and improved access to previously inaccessible areas as Arctic ice melts. The Arctic contains approximately 20 per cent of the world's undiscovered but technically recoverable oil and gas resources (Bird *et al.* 2008; AMAP 2007), but the region is uniquely vulnerable to oil spills because of its remoteness, harsh physical environment, the aggregation of large numbers of marine mammals and the slow rate of oil degradation in cold water.

The most water-intensive form of electricity production is biomass, followed by hydropower, oil, coal and nuclear, gas, some concentrated solar power systems and geothermal, solar photovoltaics, and wind. Exact values vary greatly, depending on electricity generation type and location (Glennie *et al.* 2010). Many forms of concentrated solar power, for example, which may be most effective in arid areas exhibiting high solar energy levels, also require significant quantities of water for cooling, sometimes as much as fossil-fuel-powered plants. There are cases in which water scarcity is already affecting energy production. More than half of existing or planned capacity for major power companies in South and South East Asia, for example, is located in water-scarce or water-stressed areas (Figure 4.18) (WRI 2010).

Figure 4.18 Thermal power and hydropower plant locations and water stress levels in five countries of South and South East Asia



Note: Water stress indicators represent the ratio of total withdrawals to utilizable water, but do not reflect anticipated demographic or climate changes such as the timing or quantity of precipitation.

Source: Sauer *et al.* 2010/WRI

Box 4.21 The impacts of drought on hydropower production

Droughts have significantly decreased hydropower output in Eastern Africa over the past ten years, adversely impacting national economies. Low water levels in Lake Victoria between 2004 and 2006, for example, reduced hydropower output in Uganda by 50 megawatts, contributing to a fall in the economic growth rate from 6.2 per cent to 4.9 per cent over this period (Karakezi *et al.* 2009).

Climate change mitigation policies can also affect water demands for electricity production. Capture and storage of carbon emissions from coal-fired plants, for example, can increase water consumption by 45–90 per cent (Glennie *et al.* 2010). Further, increasing the proportion of electricity generated from biomass or some types of concentrated solar power is likely to have significant negative impacts on water availability, highlighting the need for selecting power generation types that use less water and more efficient technologies (Chapter 12).

Water governance

Water problems frequently translate into inadequacies of water governance (RCSE-SU and ILEC 2011; UNESCO 2006), as illustrated by many of the water goals laid out in Table 4.1.

Adaptive freshwater management and integrated planning

Agenda 21 of UNCED called for "integrated approaches to the development, management and use of water resources" (UNCED 1992), subsequently leading to the development of several integrated management paradigms, including integrated water resources management (Global Water Partnership 2000), integrated lake basin management (International Lake Environment Committee 2006), and integrated coastal zone management, as mentioned in the Jakarta Mandate on Marine and Coastal Biodiversity (CBD 1997) and other outputs of the Convention on Biological Diversity (CBD). Integrated management approaches also offer a degree of protection against the negative impacts of natural disasters such as the devastating earthquake and tsunami that struck Japan in 2011.

The need for integrated approaches was formalized in Paragraph 26 of the Johannesburg Plan of Implementation, which states that governments should develop integrated water resources management and water efficiency plans by 2005 through actions at all levels (WSSD 2002). This overall target has not been met. However, data from studies in 2003 and 2005, primarily involving developing countries, and for 2008 and 2012 for all countries, do suggest significant headway – from the development of plans to their implementation – particularly in developed countries (Figure 4.19). Progress appears to have slowed, however, in developing countries (UN-Water 2012).

Some water professionals and policy makers suggest that in some cases the integrated management concept is insufficiently specific for practical implementation (Placht 2007; Watson *et al.*

Box 4.22 Integrated water management

Goals
Develop and implement integrated management strategies and plans; protect and restore freshwater ecosystems and their services

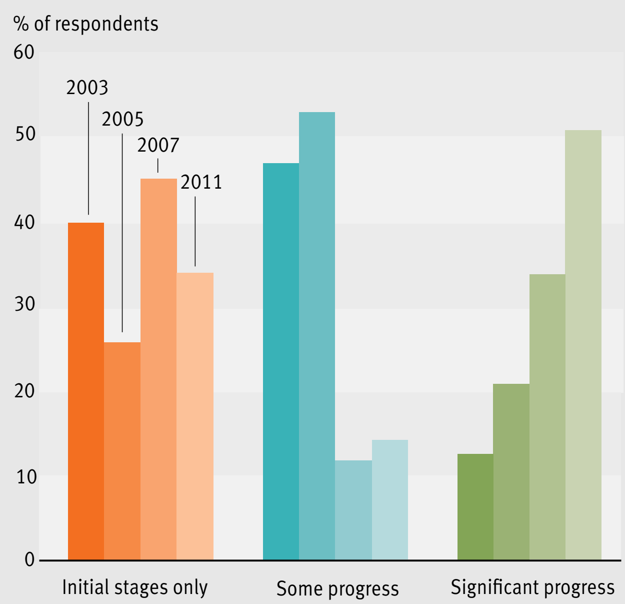
Indicators
Progress made towards developing and implementing integrated water management plans

Global trends
Some progress in certain areas; insufficient data for others

Most vulnerable communities
Populations in developing countries directly dependent on freshwater systems for well-being and livelihoods

Regions of greatest concern
Developing regions, particularly those with water shortages and/or water quality degradation

Figure 4.19 Progress in the development and implementation of integrated water management plans



Source: Global Water Partnership 2006; UN-Water 2012

Coastal sand dunes buffer the coastline against wave damage and protect the land from saltwater intrusion. *© Rui Miguel da Costa Neves Saraiva*

2007), and is slow to get under way owing to many institutional, economic, political and resource constraints (Brauch *et al.* 2009; Lansky and Uitto 2005). Further, although integrated water management proposes cross-sectoral coordination, all relevant government agencies and key water stakeholders may not be in agreement (Biswas 2004). Because participatory approaches do not always ensure consideration of gender perspectives, a systematic assessment of the differing impacts of economic development on women and men is also necessary to ensure that water issues affecting both genders are part of programme planning, implementation and evaluation, including ensuring institutional and organizational changes for gender equality as an ongoing commitment (Bennett *et al.* 2005). Further, although integrated management can be applied at many levels, from village to basin to national to transboundary, there are management issues particular to each of these levels (Lenton and Muller 2009), necessitating both bottom-up and top-down approaches. Existing evidence, however, suggests that integrated policies have focused largely on higher-level activities such as national policy reforms or the establishment of river basin organizations, rather than on on-the-ground implementation of integrated management activities at the local level (Perret *et al.* 2006).

The European Commission (EC) applied integrated water resources management principles in its Water Framework Directive in 2000, and a flood risk management directive in 2007. Further, although implicit in goals such as Paragraph 26 of the Johannesburg Plan of Implementation, there is no global multilateral environmental agreement specifically directed at aquifer conservation. There are, however, several regional groundwater initiatives, including the 2008 establishment of the Africa Groundwater Commission (AMCOW 2008). Because poor groundwater governance is a major issue, recognizing groundwater systems in national laws would be a first step towards improved groundwater governance, followed by establishing sustainable institutions and financing.

While social science literature on regional experiences with integrated water management and international river basin management is increasing, there is little data on the state and trends of such approaches, particularly their long-term benefits and impacts. Research has focused more on the concept and its application, and less on relevant policy implementation, highlighting the need for better progress indicators as well as continued monitoring frameworks to assess effectiveness (RCSE-SU and ILEC 2011; UN-Water 2012). Certain policy initiatives have supported, *inter alia*, international river basin regimes, and include the Transboundary Water Assessment Programme (TWAP), to be implemented by UNEP for the purpose of developing a methodology for monitoring and assessing trends regarding, among other things, environmental and human water stresses, pollution, population density and water system resilience.

Marine governance

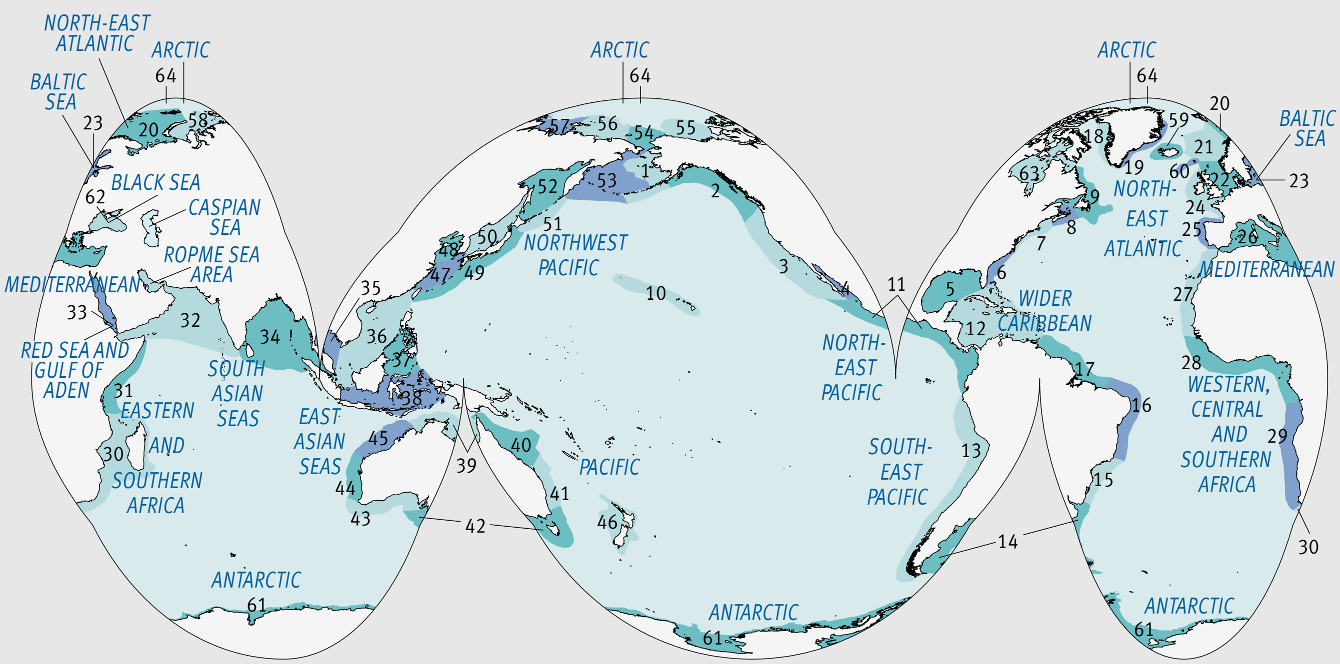
Marine systems are a major food source, a means of transport for international shipping, a tourism attraction and a climate change regulator. Coastal dunes and tidal wetlands are important buffers against tidal flooding. A number of international conventions have been established to protect the marine environment, demonstrating significant levels of international cooperation, although a common limitation is their dependence on national legislation that may reflect other agendas.

Regarding international agreements, the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention) and the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL) address marine pollution. The United Nations Convention on the Law of the Sea (UNCLOS 1982), ratified by 160 countries and in force since 1994, represents a unified approach towards shared use of the oceans and their resources, addressing navigation, economic rights, pollution, marine conservation and scientific exploration. Notwithstanding the concern with increasing marine litter, the conventions are generally viewed as positive frameworks for controlling and preventing marine pollution. The 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments exemplifies collaborative actions to address the introduction of alien invasive species, which can cause significant environmental and economic damage.

Another noteworthy international effort is the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), adopted by 108 governments and the EC in 1995. Although not enforceable, the GPA was designed to guide national and regional authorities in undertaking sustained action to prevent, reduce and/or eliminate marine degradation from land-based activities. Many countries profess to subscribe to its goals, providing a means for developing collaborative strategies to address coastal and offshore water degradation from influent freshwaters. Marine spatial planning, similar to land planning or zoning on public lands, is another emerging area of possibilities for marine governance.

The regional seas conventions (UNEP and independent conventions), other action plans, and the large marine ecosystem concept promulgated by the US National Oceanic and Atmospheric Administration (NOAA), also represent integrated management approaches (Figure 4.20). Development and implementation of these plans differ, however, depending on the countries involved, with some programme guidelines being binding on the participating states while others are not.

Figure 4.20 Map of 18 regional seas and 64 large marine ecosystems, 2011



Large marine ecosystems of the world

1. East Bering Sea
2. Gulf of Alaska
3. California Current
4. Gulf of California
5. Gulf of Mexico
6. Southeast US Continental Shelf
7. Northeast US Continental Shelf
8. Scotian Shelf
9. Newfoundland-Labrador Shelf
10. Insular Pacific-Hawaiian
11. Pacific Central-American Coastal
12. Caribbean Sea
13. Humboldt Current
14. Patagonian Shelf
15. South Brazil Shelf
16. East Brazil Shelf
17. North Brazil Shelf
18. West Greenland Shelf
19. East Greenland Shelf
20. Barents Sea
21. Norwegian Shelf
22. North Sea
23. Baltic Sea
24. Celtic-Biscay Shelf
25. Iberian Coastal
26. Mediterranean Sea
27. Canary Current
28. Guinea Current
29. Benguela Current
30. Agulhas Current
31. Somali Coastal Current
32. Arabian Sea
33. Red Sea
34. Bay of Bengal
35. Gulf of Thailand
36. South China Sea
37. Sulu-Celebes Sea
38. Indonesian Sea
39. North Australian Shelf
40. Northeast Australian Shelf-Great Barrier Reef
41. East-Central Australian Shelf
42. Southeast Australian Shelf
43. Southwest Australian Shelf
44. West-Central Australian Shelf
45. Northwest Australian Shelf
46. New Zealand Shelf
47. East China Sea
48. Yellow Sea
49. Kuroshio Current
50. Sea of Japan
51. Oyashio Current
52. Okhotsk Sea
53. West Bering Sea
54. Chukchi Sea
55. Beaufort Sea
56. East Siberian Sea
57. Laptev Sea
58. Kara Sea
59. Iceland Shelf
60. Faroe Plateau
61. Antarctic
62. Black Sea
63. Hudson Bay
64. Arctic Ocean

Note: ROPME is the Regional Organization for the Protection of the Marine Environment, one of the regional seas programmes.

Source: UNEP/DEWA/GRID-Geneva 2011

Box 4.23 Competition and conflict

Goals
Strengthen institutional coordination mechanisms

Indicators
Number of conflictive and cooperative events; number of institutions and treaties

Global trends
Some progress

Most vulnerable communities
Communities in transboundary basins with inadequate institutional frameworks

Regions of greatest concern
Those with water stress and undergoing rapid development

The open oceans beyond national jurisdiction comprise almost half the planet's surface, with rapidly advancing technology opening major new oceanic frontiers for commercial uses including fishing, shipping, resource exploration and for potential marine engineering such as deep-ocean CO_2 sequestration. The open oceans and deep-sea ecosystems, including seamounts, trenches and canyons, cold water corals and hydrothermal vents, exhibit a wealth of biodiversity. Larger, slow-growing, long-lived and heterogeneously distributed species are adapted to stable conditions in these environments, and are particularly sensitive to environmental stresses. Governance of areas beyond national boundaries is weak and fragmented, however, and requires strengthening in preparation of increasing human activities and their impacts on areas within national jurisdictions, as well as to ensure conservation and sustainable use of the open oceans.

Water as a basis for conflict and cooperation

Competition for shared water resources can cause conflicts, particularly at the local level, with water needs usually immediate, and resources often inadequate to address all competing needs. Intrastate conflicts occur between rural and urban sectors – such as agricultural, industrial and municipal – and between water-reliant livelihood activities – such as fishing, agriculture and livestock grazing. Population growth, economic development and climate change can exacerbate management issues. Further, about 40 per cent of the global population lives in transboundary river basins that cover nearly half of the Earth's land surface and provide more than 60 per cent of global freshwater flows (Figure 4.21), imparting an additional management difficulty.

There also are increasing incidents of deliberate or threatened poisoning of water supplies (Pacific Institute 2011; Greenberg 2009). Sixty-nine water conflicts were documented for 2000–2010 in the Water Conflict Chronology List maintained by the Pacific Institute, compared to 54 recorded for 1975–1999. Although specific incidents were not described in detail, De Stefano *et al.* (2010) found about 67 per cent of 1 831 reported water events for 1948–1999 were cooperative, with only 28 per cent being conflictive in nature; by 2000–2008, the proportion of conflictive events had increased slightly, to 33 per cent. Infrastructure and water quantity were consistently the major issues likely to generate conflict (Figure 4.22). Although

Figure 4.21 International river basins, 2000

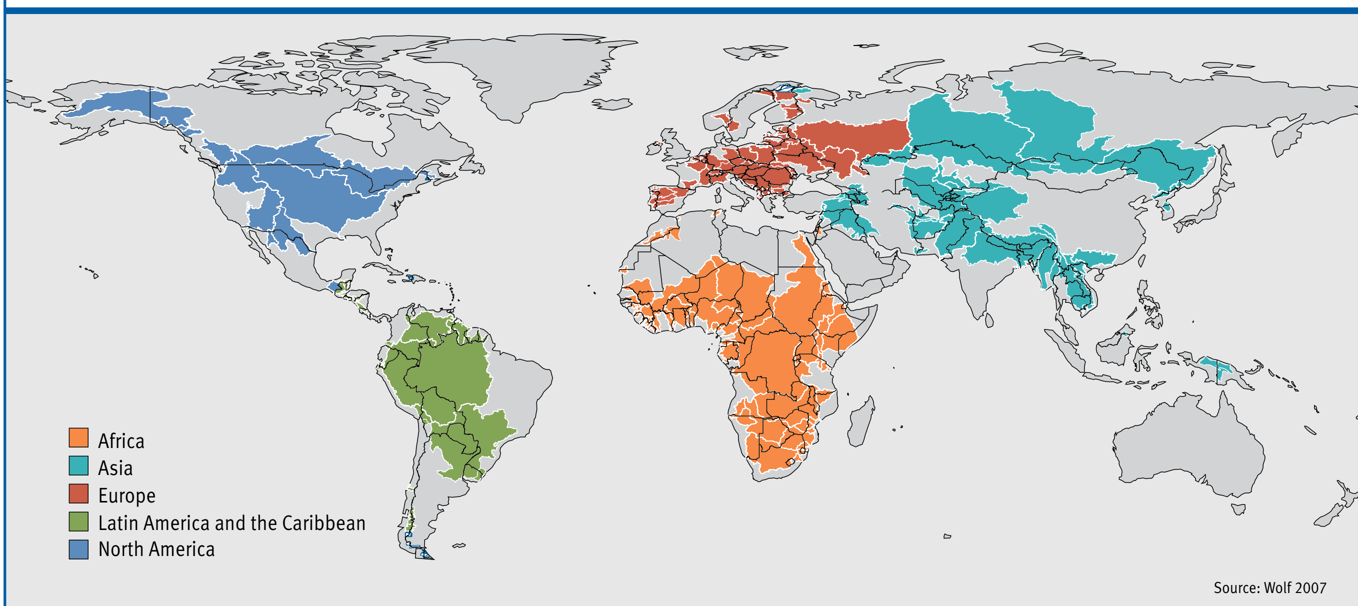
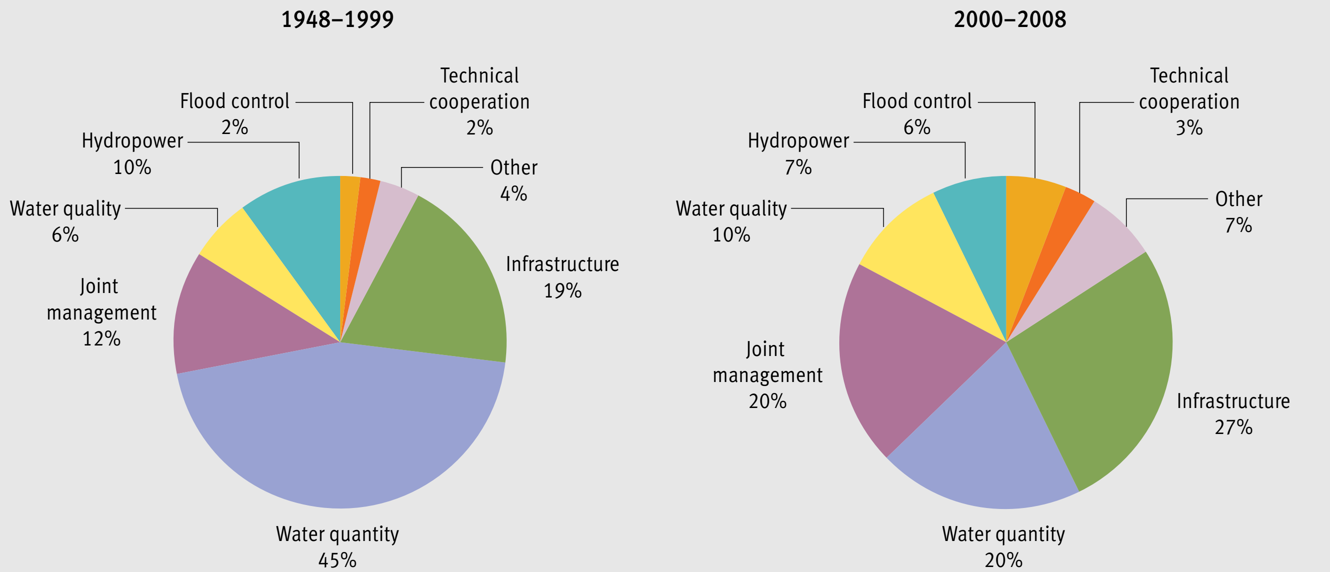


Figure 4.22 Freshwater conflict by type of issue, 1948–1999 and 2000–2008



Source: De Stefano *et al.* 2010

water conflicts have occurred in many locations, and disputes could increase in the future (Kundzewicz and Kowalczak 2009; Greenberg 2009), current evidence suggests greater potential for cooperation than for conflict, particularly at the international level (De Stefano *et al.* 2010).

About 158 of the 263 international freshwater basins still lack cooperative management frameworks, while less than 20 per cent of the 106 basins with water institutions have multilateral agreements in effect (De Stefano *et al.* 2010). Evidence suggests, however, that freshwater systems with established transboundary basin organizations can usually improve cooperation, major examples including the Lake Victoria basin and the La Plata, Mekong and Senegal River basins (Chapter 8). In fact, about 295 international water agreements have been signed since 1948. There are relatively few transboundary groundwater institutions, though codification of the law of transboundary aquifers by the UN International Law Commission (ILC), adopted by resolution of the UN General Assembly in 2008, is a major advance.

While transboundary basin organizations have facilitated so-called hydro-diplomacy, conflict management and dispute resolution (Oswald Spring 2007), there also are contrary examples. Although water scarcity in the Senegal River basin resulted in cooperation, the subsequent building of dams precipitated violent conflict (Kipping 2009). Further, with population growth and climate change, water scarcity may lead to new conflict constellations, including climate-induced degradation of freshwater resources, declining food production and increased storm and flood disasters, which may further undermine food security (WBGU 2008).

No similar analysis exists for potential conflicts related to overfishing and deep-sea mineral exploration in the open oceans, although several international agreements identified in the section on marine governance address them to varying degrees. The sustainable use of coastal areas and ocean resources requires effective coordination and cooperation at regional and global levels, with examples including UNEP's 13 regional seas programmes and the 64 large marine ecosystems (Figure 4.20). The EU Marine Strategy Framework Directive is another regional instrument, applicable in European waters under the jurisdiction of EU Member States that border the Baltic, Black and Mediterranean Seas and North-East Atlantic. Although the regional seas programmes and large marine ecosystems are consistent with UNCLOS and generally reflect the targets of the 2002 World Summit on Sustainable Development (WSSD), their achievement status remains unclear.

OUTLOOK AND GAPS

Freshwater and marine water issues remain high priorities globally, as evidenced by the multilateral agreements – including conventions and action plans – guiding the scope of this chapter. Table 4.3 summarizes trends and, where possible, provides an outlook of the state of the water environment, using indicators to evaluate progress towards the agreements in Table 4.1.

There has been progress since 1990 in achieving goals directly related to human well-being and economic development, including access to water supplies and reduction of some toxic pollutants threatening human health. Water-related diseases and water supply in the rural areas of developing countries, however, require increased attention. There has also been progress on water governance with the development of integrated water resource management plans and transboundary water agreements. However, these plans must now be implemented, adequately funded and enforced to improve aquatic ecosystems and the sustainability of their life-supporting goods and services.

Improving water security and ensuring equitable access to water resources remains a challenge. Against a background of continuing water degradation and overexploitation, the need for sustainable water supplies remains one of humanity's most critical resource needs. There also has been little to no progress in most regions in reducing nutrient loads to freshwaters and coastal areas, or for governance beyond national jurisdictions.

The complexity of the drivers and associated pressures on aquatic ecosystems is a key barrier to attaining internationally agreed goals directed at addressing their root causes. Lack of appropriate indicators or targets for many environmental, socio-economic and governance goals makes assessing progress towards achieving water-related goals and sustainable aquatic ecosystems especially problematic. Other major barriers include inadequate capacity, limited access to technology and funding, information and data gaps, and lack of quantifiable targets. More emphasis, including enhanced monitoring efforts, should be directed to acquiring reliable data on the impacts of climate change and extreme weather events on human health and well-being, and on environmental integrity. Unfortunately, monitoring of water quality, quantity and ecosystem health has been reduced in many regions. As a result, there are increasing uncertainties regarding assessment and management of the water environment, due both to data gaps and to the rapidly changing nature of water issues, including those related to climate change.

Men pulling a raft packed with their belongings through flood waters on a road in Pathum Thani, Thailand, in October 2011. *© ruchos/iStock*

Finally, analysis of the state and trends regarding the multilateral environmental agreements identified in Table 4.1 indicates a continuing major need for research, policy development and implementation on the national and international level. Data collection, including of gender-specific data, also requires greater attention, especially regarding the impacts of extreme weather events – storms, floods and droughts – on affected people. This should form a basis for future policy development, adoption and implementation to enhance the security and livelihoods of all affected by such events, including women, children and the elderly (Bennett *et al.* 2005). Although this assessment is limited by many data and information gaps, sufficient information exists to develop useful policy action to address the water and related land issues identified in this chapter.

Table 4.3 Progress towards goals (see Table 4.1)

A: Significant progress B: Some progress	C: Very little to no progress D: Deteriorating	X: Too soon to assess progress ?: Insufficient data

Key issues and goals	State and trends		Outlook	Gaps
1. Ecosystem				
Protect and restore freshwater ecosystems and their services	?	Half of countries have made significant progress towards developing and implementing integrated water resources management plans. It is unclear, however, how many reflect improved management of freshwater ecosystems. Many medium and large-scale dams have been constructed since 1990, especially in developing countries, disrupting the hydrologic regime integral to freshwater ecosystem function *See Chapter 5*	Pressure to build more dams and irrigation infrastructure will continue to be driven by increasing demand for energy and food	Global data on the state of freshwater ecosystems; quantifiable targets for ecosystem preservation and restoration from acute and chronic impacts
Protect and restore marine ecosystems and their services	D/B	D: Ocean warming and acidification is accelerating and stressing marine ecosystems, particularly coral reefs; 415 coastal areas are eutrophic of which 169 have hypoxic dead zones B: There are 18 regional seas conventions and action plans involving 143 countries that aim to improve ecosystem health, among other goals; 64 large marine ecosystems cover the world's coastal regions, some being effectively managed, while others lack funding and commitment of participating countries, resulting in slow progress B: See Chapter 5 regarding protected areas	Many tropical coral reefs could rapidly die by 2050 due to ocean acidification and warming; other significant threats to marine ecosystems include land-based pollution and lack of governance of high seas	pH target for oceans

Table 4.3 Progress towards goals (see Table 4.1) *continued*

1. Ecosystem *continued*				
Conserve and improve management of wetlands	D	See Chapters 3 and 5		
Ensure environmental water needs	D	Human water consumption jeopardizes ecosystems by utilizing environmental flows in nearly a third of major river basins	Expected to get worse as water demands increase	Data on monthly environmental flows required to maintain ecosystem services at the basin level; legal recognition of environmental water needs (Part 2); target to define and ensure that minimum environmental water requirements are met at the basin level; incorporation of environmental flows into basin allocation schemes
2. Human well-being				
Reduce water-related human health hazards	B	Increased access to improved water supply and sanitation has reduced water-related human health hazards globally and there have been notable successes in reducing some water related diseases; nevertheless, 3.5 million people still die each year from water-related diseases as of 2004; the frequency of paralytic shellfish poisoning has increased by a factor of five since 1970	Projected to continue improving access to water supply and sanitation. Africa projected to lag behind the rest of the world	Updated water-related disease and hazards data; mechanism for strict implementation of MDG at local scales
Ensure equitable access to improved drinking water supply	A/B	A: Population without access to improved drinking water supply has been reduced from 23% in 1990 to 13% in 2008 and is projected to be 9% by 2015 B: More improvement has been made in urban than rural communities, leaving large inequities in access; the reliability and quality of water supplies are of concern in many areas	Population without access to improved drinking water supply is projected to be 9% by 2015, meeting the related MDG	Data on safe (not just improved) drinking water access by region; mechanism for strict implementation of MDG; agreed definition of equitable
Secure adequate and sustainable freshwater supply	D/B	D: Global water withdrawals have tripled over the last 50 years to meet increasing demands, with groundwater particularly at risk; 80% of people live in areas with high levels of threats to water security, including 3.4 billion people in the most severe threat category B: Construction of dams is improving access to freshwater supply in many developing countries	More people are likely to experience more severe water stresses in coming decades; planetary boundaries for freshwater use are expected to be reached in the coming decades	Water security metric defined and data developed to allow tracking of trends over time (groundwater recharge; global withdrawals and consumption from the energy sector; global overlays of water scarcity and demand from energy); agreed definition of water security and related metrics
Develop programmes for mitigating the effects of extreme water-related events	B/D	B: Many governments report major progress towards implementation of disaster risk reduction strategies D: The number of drought and flood disasters increased by 38% and 230% respectively from the 1980s to the 2000s, while the number of people exposed to floods increased by 114%	Increased precipitation intensity and aridity is expected to accentuate extreme water-related events in many parts of the world	Holistic cost-benefit analyses of various adaptation and mitigation measures and impact analyses of mitigation efforts; policy integration, both horizontal (e.g. between sectors) and vertical (e.g. from global to regional to local); risk management strategies for vulnerable communities
Mitigate and adapt to adverse effects of climate change on the water environment	B/C	B: Broad adaptation tools, scenario-based approaches and adaptive management are being formulated at multiple scales; planned interventions in the water sector can be also be found in national adaptation programmes of action (NAPAs) of the least developed countries; 35% of World Bank water projects during 2006–2008 included mitigation and adaptation measures for climate change C: The costs of adapting to climate change are additional to those required to meet current MDG targets on water and sanitation, which are themselves underfunded	As scientific uncertainty is reduced at regional and local levels and awareness increases, mitigation and adaptation measures are expected to increase; climate change adaptation costs for the water sector and sea level rise will be at least US$35–100 billion per year	Reporting of mitigation and adaptation outcomes; monitoring and early warning for water-related climate extremes; long-term observatories for monitoring changes to the hydrologic cycle as a result of climate change
3. Water use efficiency				
Improve the efficient use of water resources	B	Irrigation efficiency is poor in many regions; irrigation technologies have become more efficient but have not been widely applied; some efficiency improvements have occurred through virtual water trade	The rate of implementation of water efficiency is not on track to keep pace with growing demand; virtual water trade could help efficiently redistribute water	Water resource efficiency trend data by sector (including energy sector) and country; virtual water trade trend data; efficiency impacts of virtual water trade; quantitative efficiency targets by sector; water allocation efficiency including environmental flows
4. Water quality				
Reduce and control freshwater pollution	?/C	No global datasets of freshwater quality have been available to assess overall trends; there have been some local water quality improvements but faecal coliforms in at least parts of most major river systems exceed WHO standards for drinking; gross algal and macrophyte productivity in lakes has increased by 74% globally	No outlook data identified	Global and regional data on sediment, nutrients, marine litter, toxic chemicals and emerging contaminants; rigorous global and regional water quality index based on comprehensive long-term data; water quality standards and targets for emerging contaminants

Table 4.3 Progress towards goals (see Table 4.1) *continued*

4. Water quality *continued*				
Reduce and control marine pollution	D/C/B	D: At least 415 coastal areas with serious eutrophication. Global nutrient run-off increased by approximately 15% since 1970. C: No statistically significant changes in the quantity of coastal or marine litter, although data are scarce for many regions B: Reduction of many contaminants in fish tissue; notable recent contamination events include the Fukushima nuclear crisis in Japan and the Deepwater Horizon oil spill in the Gulf of Mexico	Nitrogen loads to oceans are projected to increase from 43.2 million tonnes per year in 2000 to 45.5 million tonnes per year in 2030	Global and regional data on sediment, nutrients, marine litter, toxic chemicals and emerging contaminants
Improve sanitation coverage, including sewage collection, treatment and disposal	B	The population with access to improved sanitation increased from 54% to 61% during 1990–2008, though improvements are bypassing the poorest and most rural communities; 2.6 billion people (1 in 2.5) were without access to improved sanitation in 2008	Not globally on track to meet the MDG target of halving the proportion of people without access to improved sanitation	Water security metric defined and data developed to allow tracking of trends over time (groundwater recharge; global withdrawals and consumption from the energy sector; global overlays of water scarcity and demand from energy); agreed definition of water security and related metrics
5. Institutional and legal				
Recognize the economic value of water	?	See Chapter 5 for discussion of ecosystem services; Chapters 10, 11 and 12 give examples of water pricing schemes and market-based solutions that reflect the value of water and aquatic ecosystems	No outlook data identified	Data on scope, magnitude and value of water-related ecosystem services (e.g. value of wetlands as buffers against extreme events); goals and targets recognizing, protecting and valuing ecosystem services for human and environmental health and well-being
Develop and enforce legal frameworks and regulations	B	UNCLOS was ratified by 160 countries and the Global Programme of Action (GPA) adopted by 108 countries; legal frameworks for industrial and municipal wastewater discharge exist in most developed countries although non-point-source regulations lag behind; governance of areas beyond national boundaries is weak and fragmented; enforcement remains an issue in many regions.	No outlook data identified	Capacity to effectively assess and regulate environmental impacts beyond national jurisdictions
Strengthen institutional coordination mechanisms	B	Two-thirds of transboundary water-related events are cooperative, although the number of water conflicts has increased since the 1970s; 295 international water agreements have been signed since 1948; less than 20% of the 106 basins with water institutions have multilateral agreements in effect; 143 countries participate in 18 regional seas programmes, and the large marine ecosystem approach has delineated 64 management units globally	No outlook data identified	Metrics of coordination effectiveness
6. Water resources management				
Develop and implement integrated management strategies and plans	B/?	There has been an increased recognition of the need for integrated approaches for freshwater and marine system management; about half of countries have made significant progress towards developing and implementing integrated approaches to water resources management and water efficiency, but the 2002 WSSD target is far from being met; implementation is slowed by financial, legal and/or capacity barriers; there is insufficient data to evaluate the long-term effectiveness of integrated water resource management	Developing countries in particular will face difficulties implementing integrated management approaches due to lack of funding, capacity and governance	Reporting mechanism and meaningful governance indicators for countries' progress towards integrated water resources management, including the effectiveness of such approaches; implementation of policy goals
Develop adequate monitoring systems (national, regional and global)	C/D	Data are fragmented, lacks complete global coverage or is not regularly updated; marine monitoring and remote sensing data acquisition has increased, but global freshwater monitoring has declined and is now inadequate; modelling and remote sensing are complementing monitoring in many instances, but still rely on adequate data	Comprehensive monitoring systems will continue to be limited by financing and capacity	Metadata on existing data; agreed quantitative targets on comprehensive monitoring and reporting systems
Improve stakeholder participation and mainstream gender in water management	?	No quantitative global data are available to assess this goal; stakeholder engagement and gender mainstreaming is becoming more common globally, but is still lacking in many regions	No outlook data available	Data to assess stakeholder participation, including roles of women and men, and separating data by sex; institutionalized stakeholder participation; systematic gender impact assessment
Improve groundwater management	C/D/?	C: Arsenic and nitrates threaten aquifers in many countries D: Many aquifers are being drawn down at unsustainable rates; efficient management requires more data for quantitative assessment of the problem ?: Transboundary groundwater systems have been largely ignored due largely to insufficient data and lack of agreement	No outlook data available	Global level datasets on groundwater contamination, availability and withdrawal; transboundary management of groundwater resources (precluded by the data gap)

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