Ramsar Technical Reports

Ramsar Technical Report No. 6

Healthy wetlands, healthy people

A review of wetlands and human health interactions

Pierre Horwitz, C. Max Finlayson, Philip Weinstein

World Health Organization

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Ramsar

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Coordinating authors: Pierre Horwitz, C. Max Finlayson, Philip Weinstein

Despite the production of more food and extraction of more water globally, wetlands continue to decline and public health and living standards for many do not improve. Why is this – and what needs to change to improve the situation? If we manage wetlands better, can we improve the health and well-being of people? Indeed, why is this important? This report seeks to address these questions.

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Ramsar Technical Reports are designed to publish, chiefly through electronic media, technical notes, reviews and reports on wetland ecology, conservation, wise use and management, as an information support service to Contracting Parties and the wider wetland community in support of implementation of the Ramsar Convention. All Ramsar Technical Reports are peer-reviewed by the members and observers of the STRP and independent experts.

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Preface

At the 9th meeting of the Conference of the Contracting Parties to the Ramsar Convention, in Resolution IX.2 (Ramsar 2005b) the Parties instructed the Scientific and Technical Review Panel (STRP) to undertake a review of the issues and interactions between wetlands and human health, in recognition of the fact that these matters had not previously received significant attention under the Convention. This topic subsequently attained further significance with the adoption of the theme for the next COP as "Healthy Wetlands, Healthy People".

The Panel established an expert Working Group to progress this task, under the initial leadership of the STRP Chair and the Deputy Secretary General. The Panel established a scope, approach and outline contents for this review report, and it invited a number of additional human health and wetlands experts to contribute to the drafting. The report drafting team has been led by Professors Pierre Horwitz, Max Finlayson, and Philip Weinstein, and the report preparation has received significant input from Drs Robert Bos and Martin Birley from the World Health Organization (WHO), Professor Chris Skelly, and a number of other invited experts, STRP members (notably Rebecca D'Cruz and Ritesh Kumar) and observers as contributing authors.

The STRP determined that its initial report should focus on providing advice to wetland managers and decision-makers on the range of often complex issues concerning wetlands and human health interactions, but it also recognized that this report should be the first stage in the exploration of the issues and recommended to the 10th meeting of the Conference of the Contracting Parties (COP10) that the Panel should be asked to undertake further work on a number of aspects of the issues that have emerged as gaps (see Resolutions X.10 and X.23). Amongst these the Panel recognized a need, especially in relation to the COP10 theme, to provide a better understanding of what is meant by "wetland ecosystem health", including in relation to the commitments under the Convention concerning the maintenance of the ecological character of wetlands.

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Executive Summary

Managing Wetlands and Fostering Human Health

Wetland ecosystems, including rivers, lakes, marshes, rice fields, and coastal areas, provide a well-defined set of ecosystem services that contribute to human well-being and poverty alleviation. While it is impossible to imagine human life without water, the importance of the relationship between wetlands and water is less well recognized, and this relationship has changed over time.

Technology, engineering and medicine have intervened in the way we manage water and wetlands to successfully improve aspects of and foster human health. Over the same period, increasing human populations and increasing rates of consumption by humans, alterations to land use and land cover and the practices of irrigation, all associated with agriculture, urban expansion, and global environmental change, have collectively and substantially adversely modified wetland systems, in terms of both water quality and water quantity.

Reconceiving this relationship will be central for wetland management: developing strategies that support the maintenance of both wetland ecological character and human health concurrently through the implementation of the Ramsar Convention on Wetlands (Ramsar, Iran, 1971) and other processes.

Wetlands are often seen only as the source of vector- or water-borne diseases, and a widespread misinterpretation of wetlands as 'the problem' for human health requires careful treatment and attention. Better land and water management is required, including a richer sense of the roles of biodiversity in parasite regulation, to emphasize the benefits that humans derive from wetlands. Understanding these and other benefits provide the basis for fostering human health and well-being while managing wetlands. Wetland managers must have information that will allow them to articulate, and respond professionally to, these claims.

Some groups of people, particularly those living near wetlands, are often highly dependent on wetland ecosystem services and are directly harmed by their degradation; in other instances wetlands are the basis of economic structures and are embedded in cultural expressions. These benefits can also determine human health, directly and indirectly, by contributing to other forms of well-being (like providing security and basic materials for a good life and fostering good social relations).

If wetlands are more than a source of disease, if they play an important role in sustaining human health and well-being, and if they continue to be lost and degraded more rapidly than other ecosystems, then more effective treatment of the tradeoffs between different forms of benefits will be required.

Wetlands as settings for public health

Ecosystems are implicitly recognized in considerations of public health in virtually all of its endeavours, yet the management of ecosystems is generally given a low priority against the medical imperatives of attending to curing disease. The Millennium Ecosystem Assessment sought to re-emphasise that ecosystem services are indispensable to the well-being and health of people everywhere, and in stating this case the Assessment involved environmental health practitioners, epidemiologists and others in the process.

Ecosystem services, ecosystems and ecological thought, and their application for health policy, is best expressed in the discipline of health promotion and its agreed charters, for instance, the 1986 *Ottawa Charter for Health Promotion* (Geneva: World Health Organization), and can be located in the 'healthy settings' agenda. To public health practitioners, then, wetland ecosystems can be usefully articulated as *settings* for people's health, where the influences of cultural, economic and political factors are also located.

Wetland ecosystems are settings that *determine* human health and well-being through a number of characteristic influences, such as:

- a source of hydration and safe water;
- a source of nutrition;
- sites of exposure to pollution or toxicants;
- sites of exposure to infectious diseases;
- sites of physical hazards;
- settings for mental health and psycho-social well-being;
- places from which people derive their livelihood;
- places that enrich people's lives, enable them to cope and to help others; and
- sites from which medicinal products can be derived

These influences can either enhance or diminish human health depending on the ecological functioning of wetlands and their ability to provide ecosystem services. It follows then that losses of wetland components, and disruptions to wetland functions and ecosystem services, will have consequences for human health along any or all of these lines. Furthermore, adverse health outcomes are likely to be distributed in an unequal way, i.e., along socio-economic lines. Management interventions for wetlands must also seek to address these inequities.

Seen in this way, problems in which the environment is considered to have been implicated in health outcomes cannot be solved by medical approaches to health alone. Rather, broader approaches are needed, drawing on a wider scientific base, including ecological and social sciences. This presumes that humans are not separable from the natural environment, and that socio-economic factors mediate human health.

Healthy wetlands, healthy people, and other relationships

Despite the Ramsar Convention's text and language that centers around wise use and ecological character, the phraseology of 'healthy wetlands' (and healthy rivers, healthy ecosystems, healthy parks, healthy landscapes, and so on) persists in common and professional use.

If used in a way that acknowledges that humans are an intrinsic part of ecosystems, the phrase "healthy ecosystem" can be justified: humans are implicated in activities that degrade ecosystems, yet humans can also be agents for the maintenance or restoration of ecosystems. And the health of humans is *in some way* a measure of the health of the ecosystem in which they live and depend, and vice versa. 'Health' is also powerful metaphor for the condition of an ecosystem, and ecosystem approaches to human health make critical contributions to public health.

A claim to 'healthy ecosystems' comes from judgments about the desirability of a certain ecological character. It is also explicit about the health of components of the ecosystem (including humans) and whether organizations responsible for managing ecosystems are adaptive and responsive to changes in those ecosystems.

There are at least four ways of perceiving the relationship 'healthy wetlands, healthy people'. Human health outcomes can be either adverse or improved, depending upon whether or not ecosystem services are either degraded or maintained/enhanced. One view is that it is possible to demonstrate that a wetland ecosystem can provide a range of ecosystem services in which you find people with improved health (the so-called 'double dividend'). The opposite of this is where people with adverse health outcomes are found in degraded ecosystems (the classic 'unhealthy wetland').

However, two paradoxes exist. First, degraded ecosystem services *can* provide benefits to people in such a way that there are positive health outcomes. Secondly, maintained or enhanced ecosystem services *can* have problematic consequences for human well-being.

These paradoxes exist because human interactions in wetland ecosystems are complex and involve choices: tradeoffs between benefits that will occur when wetlands are developed or in which some services are promoted or favoured over others. This introduces a need to assess carefully the direct benefits and potential direct and indirect losses when managing wetlands and, in some instances, to reach compromises and agreed tradeoffs between services and beneficiaries.

Benefits of wetland ecosystems for human health

The benefits of wetland ecosystems for human health can be approached in at least three interrelated ways: by recognizing the human needs that are met by water in its setting; by recognizing the health products that come from wetland ecosystems; and by recognizing the economic value of wetlands in a full sense, in a way that allows individuals within wetland ecosystems to sustainably improve their socio-economic conditions.

Human needs: Health benefits will accrue when human social and cultural *needs* are satisfied by access to wetlands. Health relates most easily to the direct survival requirements (a full spectrum of which includes water for food, water for drinking, cooking and eating, washing, cleaning, health and healthcare, and for waste removal and assimilation). Water is needed to generate income and material well-being, and access to it generates prestige and social identity, contributes to social cohesion, allows for recreation while providing an aesthetic opportunity, all embedded within moral, cultural and spiritual needs.

Health products: Health benefits will accrue to societies in general and individuals in particular when products of wetlands can be used for pharmaceutical or other medicinal purposes. Wetland-associated animals, fungi, bacteria, and lower plants (algae), some of them living in extreme conditions, provide the most productive sources of new natural products. The medicinal qualities of these are a good example of the continued value of traditional knowledge to health care today. Links between wetland biodiversity and human health should focus less exclusively on the obvious (such as birds, large mammals, or plants) and more on the "hidden biodiversity" (such as fungi and bacteria).

Economic value: As a general rule, as socio-economic status improves for individuals, their health outcomes improve as well. Wetland ecosystem services contribute to the material well-being (and socio-economic status) of individuals and populations, and they can be valued in economic terms. Valuation studies in general highlight the significant contribution of wetlands to local, national, regional and global economies. Several of these studies also indicate that when both the marketed and non-marketed economic benefits are included, the total economic value of an unconverted wetland is frequently greater than that of a converted wetland.

Wetland management for water and sanitation

Wetland ecosystems provide a sophisticated water treatment service involving depositional environments, aerobic water columns, anaerobic sediments, microbial suites, and wetland vegetation all contributing to the assimilation and extraction of pollutants and pathogens. Wetland landforms are also adjusted hydrologically to hold increased volumes of water.

Adverse health outcomes of insufficient water are direct in terms of human water requirements for survival, and indirect in terms of lack of access to drinkable water and water suitable for sanitation and hygiene. Poor quality water (as unsafe water), inadequate sanitation, and insufficient hygiene are the major risk factors for diarrheal disease, which is the second leading contributor to the global burden of disease. An important share of the total burden of disease worldwide – around 10% – could be prevented by improvements related to drinking water, sanitation, hygiene, and water resource management.

Large inequalities exist globally, regionally, and locally in access to safe drinking water and adequate sanitation, and these trends need to be considered in wetland management processes. Lack of access to safe drinking water and poor sanitation usually affects the poorest sectors of society, with follow-on affects for food security. Rural populations are often disadvantaged compared to urban ones, and this situation is significant in most developing countries where women often shoulder the largest burden for collecting drinking water. Recognizing and managing for ecosystem services that provide quality water will improve human health in these circumstances.

Wetland management for food security

Wetlands, through the services they provide, contribute to human health through the provision of food security: ensuring food availability, buying power or social capital to access food with cash or through barter, sufficient nutrients from the available food, and a resource of genetic material contained within wetland organisms.

The world's major food items, core requirements for human health, come from wetland ecosystems. Rice, a staple food item for almost half the world's population, is grown in a wide range of environments, mostly wetland ecosystems. Rice receives 35–45% of the world's irrigation water and some 24–30% of developed freshwater resources. Inland fisheries and aquaculture contribute about 25% of the world's production of fish; both can be critical to local food security with an irreplaceable value to human nutrition and local and regional incomes, often with high levels of participation in catching, farming, processing and marketing.

Wetland ecosystems, managed appropriately for their resources, have a prominent role in maintaining dietary diversity, contributing to a multi-dimensional agenda focused on nutritional and health status, socio-cultural traditions, income generation, and biodiversity conservation. This attention helps to address both a trend towards increasing dietary focus on starch and oils and another trend in which the variety of foods are diminished, resulting in deficiencies in micronutrients and attendant health consequences.

A major tradeoff must be acknowledged, and possibly renegotiated, in the context of food security. It is often the act of trying to increase food production, both within and outside wetlands, that results in degradation of wetlands and causes the loss of other ecosystem services.

Wetland management for livelihoods and lifestyles

Addressing wetland management as if people's lives, and their livelihoods, depended upon it will undoubtedly contribute to human health. A wetland manager and a health service provider should seek to sustain community livelihood in the context of the wetland, first by understanding the community situations by listening to their stories, hopes and wishes, and then by acting in accordance with them, within a context of local and traditional knowledge, government requirements, and market forces.

Wetland management will also play a significant role in the choices people make about the lifestyles they lead. For those people who live in wetland settings, their different behaviours and activities will be a proximal determinant of their health, for example how much exercise they get, the mental relief or stimulation they receive, and whether they are exposed to disease-causing risks. Lifestyle factors are related to the ecosystem services, particularly leisure, recreation, sporting activities, education, and cultural heritage (frequently including a spiritual significance of water), and they provide for both physical and mental health given human affinities for wetlands and watercourses.

Wetland management for reducing the risks of exposures to disease

Humans can be exposed to health risks in wetland ecosystems: toxic materials, water-borne or vector borne diseases. While steps can be taken to ameliorate these risks, the risks can increase (sometimes dramatically) if disruption occurs to ecosystems and the services they provide.

Human health can be affected by *acute or chronic exposure to toxicants*, through the media of water, wetland sediments, or even air when sediments become dessicated and airborne or burnt. The nature of these exposures is exacerbated by human behaviours and activities and they can result whenever ecosystem services have been eroded – especially when the hydrological services that maintain biological, geological and chemical processes have been distorted by human activities of over extraction of water. Drainage and diversions of water are the two activities responsible for the majority of such changes.

Wetlands are often the loci for communicable disease, where microorganisms (the pathogens) are transmitted through water, people, animals, surfaces, foods, sediments or air, any or all of which can be associated with wetlands. Infectious diseases associated with wetlands have profoundly influenced the discipline of public health, and this is probably the source of the erroneous oversimplification that wetlands are bad for human health.

For *water-borne or vector-borne diseases*, numerous examples now exist to demonstrate that significant interactions occur between the host, agent, and aquatic environment factors, and these must broaden the traditional perspectives of public health and their epidemiological approaches into one more closely aligned with the science of ecology. This is an area where wetland managers have a significant contribution to make.

While wetlands can be associated with an increased incidence of globally significant and locally important infectious diseases (such as cholera, malaria and schistosomiasis), the removal of wetlands or alteration of their water regimes is not generally the only disease management option that should be considered. The incidence of many of these diseases can instead be reduced through an integrated approach ensuring provision of clean water, improved sanitation, modified behaviours to reduce exposures, and – most importantly – good management of wetlands.

The incidence of a range of infectious diseases is increasing in recent times. Emerging infectious diseases occur when there is a changed vector or parasite distribution, or a change to host susceptibilities. Usually these mechanisms have in turn been driven by human activities that have led to ecosystem disruptions, so that the ecosystem service of disease control is diminished. A special case is when human and animal pathogens that have in the past been controlled successfully become resistant in the water environment and to most disinfectants and/or antibiotics. This resistance has been mediated by discharge from sewage systems and discharge from animal production areas. Both result in drug residues and the presence of antibiotic resistant isolates in the receiving environment.

Wetlands management for psycho-social health, and the effects of disasters

Wetlands, in their myriad forms, become embedded in the human psyche in formulations of "sense of place". Changes to wetlands, to their products, to their ability to deliver a livelihood, or their becoming a source of toxic exposure or disease, can influence a person's mental health by becoming a source of psychological stress. These potentialities are increasingly recognized as being part of the wetland manager's and public health practitioner's spheres of prevention and intervention.

Physical hazards, externalities like floods, earthquakes, hurricanes/typhoons/cyclones, and drought, can magnify any of these exposures; in fact, because most people live in, on or near wetlands, the conditions of the wetland and its ability to absorb external forces will determine to a large extent the degree to which human health is affected. The disease burden following major disaster events ranges from psycho-social issues to infectious diseases, to physical injury and systemic chronic illness. The pathways to such disease events may be direct or indirect and may affect a spectrum of community members including those directly injured, rescuers, people who have lost property, belongings or capacity to sustain a livelihood, families of those injured, and, from there, the more general population.

Wetland management: changes in perspectives required

Attitudinal shifts and reorientation of perspectives within and outside the field of wetland management will ensure that human health and wetland ecosystems are managed to benefit one another.

Using systems thinking, wetland managers realize that there are consequences of their actions, and they undertake those actions *knowing* about them, notwithstanding the fact that we live in a complex and uncertain world. Where tradeoffs are being made, they need to be considered and valued according to principles of sustainability and equity rather than ignored or dealt with exclusively in financial terms.

The wetland manager is responsible for biodiversity and its conservation, including parasites and parasite-host relationships and the ways they contribute to ecological functions. Too often these aspects of ecological character are ignored or diminished in emphasis, but they are a critical component of disease regulation.

It is not acceptable to reason that we can manage wetlands for biodiversity alone; in fact, to do so will be counterproductive. A people-centred approach in wetland management, which does not diminish the importance of biodiversity, will help realize the co-benefits of sustainable ecosystem management and, for instance, achievement of the Millennium Development Goals.

Resolving matters of tradeoffs across levels of human involvement, from the personal to the global, can be achieved through dialogue, using a deliberative rather than hierarchical approach, to ensure that the local interests of people are not marginalized by more powerful forces.

Identifying principal partners and responsible stakeholder groups, often across disciplines and between sectors where barriers and boundaries exist, requires a particular form of engagement that wetland managers need to develop as part of their skill set: patience, tolerance of these 'others', and a willingness to reciprocate.

Wetland management: higher levels of policy development

To embrace the breadth and richness of the relationship between wetland ecosystems and human health and well-being will require policy interventions promoted by, but extending well beyond, the wetland sector. Policy interventions are proposed to be non-specific and non-targeted. Promoting cross-sectoral governance, institutional structures, and action-oriented teams will maximize the likelihood of wetland ecosystems and human health co-benefits.

Rationalized incentive structures need to exist for the wetland ecosystem services that currently sit outside of markets. Payments for ecosystem services, development of water markets and water-pricing, improved allocation of rights to freshwater resources to align incentives with conservation needs, and elimination of subsidies that promote excessive use of ecosystem services, are some of the policy approaches that can be taken.

Capacity building, improving communication, and empowerment of groups particularly dependent on ecosystem services or affected by their degradation, including women, indigenous people, and young people, will improve the likelihood of better management of the ecosystems that provide ecosystem services.

Societal understandings of wetland and water management are not just technical issues, but also social and political ones as well. Policies must aim at measures to reduce consumption, raise awareness, develop curricula, empower communities, and promote participation in issues where the wetland / human health nexus exists.

Policies will need to be aimed at dramatically improving irrigation efficiencies and promoting other technologies capable of productivity gains in agriculture without concomitant upscaling of water, ecosystem and energy costs. Similarly, the strategic development of appropriate mechanisms to enable health costs to be satisfactorily included in wetland management is also an essential ingredient of the needed policy development.

Claims and counter-claims of ownership (for instance, local people's claim to knowledge of medicinal properties when scientific development also claims discoveries, with ensuing disputes over patent rights and payment benefits) can also have important policy implications. In light of the Convention on Biological Diversity's recent Nagoya Protocol on Access and Benefit Sharing, the Ramsar Convention can be used to protect cultural knowledge and biodiversity where traditional medicines and new product potentials both exist in wetlands.

Wetland management: new instruments and approaches

Instruments and approaches likely to be used by the health sector to respond to health effects and

the health outcomes of disruptions to ecosystem services should be understood and employed by wetland managers. These will include the monitoring and surveillance of disease causing agents and interventions aimed at prevention, burden-of-disease assessments, health impact assessments, community health assessments, risk assessments, and community and stakeholder engagement. **Working with the World Health Organization and other health professionals, the Ramsar Convention can adapt these instruments for their use in wetland settings.**

This report

The purpose of this review report is to provide an accessible source of information to help improve understanding of the often complex inter-relationships between wetland ecosystems and human health and well being. The primary audience for this report is intended to be wetland conservation and wise use practitioners, from wetland managers at the site level to decision makers at national and international levels. The information in the report should help in facilitating dialogue between wetlands and human health professionals in their respective efforts to maintain and improve wetland ecological character and people's health.

Wetlands as *settings* for health and well-being. An example from Halong Bay, Vietnam, where food and water are derived by house boat inhabitants, the context in which exposures to diseases, toxicants and natural disasters might occur, and where lifestyles and livelihoods are pursued. *(Photo: Pierre Horwitz)*

Healthy wetlands, healthy people

1. The Wetland/Health Nexus

1.1 On the global drivers of wetland change

An increasing and increasingly consumptive human population lies at the basis of wetland change. Population expansion in rural and urban environments in both developed and developing countries creates a significant demand for the provision of food. It also creates a demand for potable water which is not insignificant, provided usually by reservoirs and groundwater abstraction. Urban expansion itself requires land use change (mainly through land clearing or deforestation, drainage and wetland infilling, often in that sequence). The urban demand for potable water and wetland conversion therefore also drives altered water regimes. Together these trends have caused substantial changes to river flow patterns, downstream coastal ecosystems and wetlands (Finlayson et al. 2005; Agardy & Alder 2005; Vorosmarty et al. 2005; Vorosmarty et al. 2010) and have led to river depletion affecting more than half of the large rivers around the world (Falkenmark & Lannerstad 2005; Nilsson et al. 2005).

Increases in agriculture over the past century have led to substantial improvements in global food security through higher and more stable food production. Increased agricultural production has also contributed to economic growth in many countries and provided for ever-expanding urban areas. Agriculture, including rangelands, now covers roughly 40% of the world's terrestrial surface (Foley et al. 2005), with croplands covering more than 50% of the land area in many river basins in Europe and India and more than 30% in the Americas and Asia (Millennium Ecosystem Assessment 2005). Through these trends in land use, agriculture has become a main contributor to global environmental change (Foley et al. 2005).[1]

Changes in land use, land cover, drainage and irrigation have thereby substantially modified the global hydrological cycle in terms of both water quality and water quantity. For example, irrigation now comprises 66% of all water withdrawals (Scanlon et al. 2007) and accounts, by far, for the largest share of consumptive water use (Falkenmark & Lannerstad 2005). Agriculture has also led to a redistribution of the spatial patterns of evapotranspiration globally, decreasing it in areas of large-scale deforestation and increasing it in many irrigated areas (Gordon et al. 2005), with impacts on climate and ecosystems in some regions (Gordon et al. 2008). Agriculture has further contributed to a doubling of nitrogen fixation (Galloway et al. 2004), and a tripling of phosphorus use (Bennett et al. 2001) at the global scale over the last century. Increased nutrient loading has caused widespread eutrophication and hypoxic zones (Diaz 2001) in aquatic systems.

Used water, such as wastewater and stormwater, carries effluent from industrial, agricultural and urban activities. Such effluent can include a very broad range of organic and inorganic chemicals, from heavy metals to pesticides, antibiotics and hormones, as well as nutrients. These create exposure issues for human health and changes to aquatic ecosystems, often demanding energy-intensive treatment options and more appropriate reuse. Land and water use changes can also result in acidification, salinisation, waterlogging and desertification, and these too produce water quality responses.

Individually or collectively the ecosystem effects of these impacts include decline in downstream fisheries, affecting subsistence as well as industrial fisheries; decline in water quality with a potential impact on the safety of drinking-water and recreational waters; and increase in water scarcity resulting in a loss of wetlands and coastal ecosystems that can be important, for example, in nutrient retention and local livelihoods (Millennium Ecosystem Assessment 2005). Some of the changes have negative feedback on the food and fiber production in agricultural systems themselves, for example through reductions in pollinators (Kremen et al. 2002) and degradation of land (Bossio et al. 2007). These adverse changes have varied in intensity and some are seemingly irreversible, or at least difficult or expensive to reverse, such as the extensive dead zones in the Gulf of Mexico and the Baltic Sea (Dybas 2005).

Superimposed as a planning issue, and embedded within the above global trends, are projected changes in climate. These are likely to affect wetlands significantly, in their spatial extent, distribution and function (Parry et al. 2007); changes in precipitation will alter water availability and stream flows affecting ecosystem productivity, with lower seasonal water availability reducing water quality and exacerbating other pressures (Finlayson et al. 2006). Overall, it is projected that there will be more adverse than beneficial impacts on wetlands, with inland and coastal

1 These first few paragraphs have been adapted from Gordon et al. 2010.

systems likely to experience large and early impacts. These impacts will in turn affect the relationships between wetlands and human well-being and health.

1.2 A persistent problem remains

A top priority for most governments is food security for their own people, and thus economic development and land-use change has a higher priority in many societies than does ecosystem maintenance. In fact, there is a lack of recognition by other sectors that the success of their business and their continued use of water depends heavily on wetlands and their services (Ramsar Convention 2008a). This lack of attention to ecosystem maintenance would seem to stem from the perception of the supposed limitless resilience of nature. To wetland managers this lack of recognition is also perhaps an internal issue: a failure to communicate interests and a view of the world in a way that is meaningful for these other sectors.

1.3 The response of wetland management

Understandings of these ecosystem changes are becoming deeper, almost daily, but descriptions of the variety and severity of changes have been repeatedly stated for decades now (and indeed were a key driver for the development of the Ramsar Convention in the late 1960s), yet the alarming trends continue. An evaluation of messages and directions in wetland management is therefore timely.

Wetland management traditionally derives its knowledge base from the fields of aquatic chemistry and biology, and hydrology, amongst others. However, this disciplinary training does not equip wetland managers for the challenge of addressing the drivers of ecosystem change as described above – the societal processes that produce the need for more food and more water and land use change.

Similarly, a focus for wetland management has come from a perception of the centrality of the conservation of biological diversity. This attention to the welfare of other species, while perfectly appropriate and morally reasonable in its own right, requires wetland management to articulate concerns in these terms, rather than in terms more familiar to those sectors who deal directly with the drivers of ecosystem change – those sectors dealing with human welfare. The biodiversity messages are readily over-ridden by louder, more dominant humanitarian ones.

In texts and policy documents, the language of wetland management is one of a separation between humans and their surroundings, even a dominion over their surroundings, where the simplest interpretation of our surroundings – to use the environment immediately – is the preferred approach.

Finally, the command and control approach of conventional natural resource management, most commonly observed in the developed world, where the ‘environment’ is compartmentalised and exploited for efficiency of constant yields, places wetland management at the wrong end of the decision-making chain, where it must deal reactively with the consequences of this approach.

Together the core messages and directions of wetland management will ameliorate the effects of ecosystem change at best; at worst, they might even be perceived as being part of the problem, thus reinforcing the drivers of frequently adverse ecosystem change.

1.4 A new central theme for wetland management?

If anything, the evidence points to an increasing disconnect in any meaningful relationship between the well-being of people and the quality of their surroundings, in this case the health of wetland ecosystems. There is a case to be made that this relationship should be central for wetland management.

The first United Nations World Water Development Report noted that a healthy and unpolluted natural environment is essential for human well-being and sustainable development, and further stressed that wetland (aquatic) ecosystems and their dependent species provide a valuable and irreplaceable resource base that helps to meet a multitude of human and ecosystem needs which are essential for poverty alleviation and socio-economic development (United Nations & World Water Assessment Programme 2003). The report also noted that human health provides one of the most striking features of the link between water and poverty.

Finlayson et al. (2005) and others have emphasised that failure to tackle the loss and degradation of wetland ecosystems and their species, such as that caused by the development of agriculture and water resources, could undermine progress toward achieving the human health and poverty components of the Millennium Development Goals.

Changes in land cover and use and wetland extent to accommodate expanding agriculture and industrial and urban development have had beneficial outcomes for many people, but many ecosystems have been managed as though they were disconnected from the wider landscape, with scant regard for maintaining the ecological components and processes that underpinned their ecological character (Molden et al. 2007). The consequences of such approaches include the loss of fisheries, loss of storm protection and nutrient retention, with negative feedback on food and fibre production. Human health has also suffered, for example, directly through increased prevalence of insect-borne disease or through changes in diet and nutrition or the loss of ecosystem properties that control erosion and ameliorate floods (Corvalan et al. 2005 a, b). Poor people in rural areas who use ecosystems directly for their livelihoods are likely to be the most vulnerable to such changes in ecosystems (Millennium Ecosystem Assessment 2005).

The adverse consequences of increased interactions between people and wetland ecosystems have received more attention in recent years, with Finlayson et al. (2005) in particular emphasising the strength of the fundamental relationship between ecosystems and human health and poverty, and therefore the importance of developing environmental management strategies that support the maintenance of both wetland ecological character and human health concurrently. Almost in parallel it has become apparent that many problems where the environment is determined to have impacts on human health cannot be solved by 'traditional' health approaches alone. Rather, broader approaches are needed to analyse interactions between humans and the surrounding environment (Corvalan et al. 2005 a, b), often drawing on a wider scientific base, including ecological and social sciences, and accepting that humans are not separable from the natural environment.

1.5 A role for public health?

A fundamental and underlying part of this complexity is the paradox that wetlands can provide for people directly or indirectly, yet are also associated with a number of adverse health factors. In many parts of the world they support the propagation of disease vectors. They pose a challenge to safe disposal of human excreta. Access to health services may be more difficult for wetland human populations (see Corvalan et al. 2005b). The complexity of such relationships is shown by the historical links between malaria and humans in parts of Europe (Box 1.1). Another telling example concerns the correlations between climate change and human health (Box 1.2).

If wetland ecological character and human health are treated as being inextricably linked, it should be no surprise that the incidence of many diseases varies with short- and long-term trends in that relationship. By extension, for a variety of vector-borne, water-borne and other 'environmental' diseases, appropriate, scientifically based public health interventions can only be devised with an understanding of the relationship between wetland ecological character and human health – i.e., the ecology of the vectors, pathogens and diseases themselves. The complex interactions and reciprocity of those interactions between people and wetlands is also illustrated by the debilitating effect of HIV/AIDS, which reduces the capacity of groups of people to support their wider well-being through fishing and other basic activities, or indeed where the changing nature of the biophysical environment may condition sexual relationships and sexual mixing patterns in a community and consequently heighten their HIV risk (Mojola 2009).

Obvious health issues for wetland ecosystems include water associated illnesses, such as malaria and the other vector-borne diseases whose transmission depends on vector species that are inextricably linked to the aquatic environment. The link between safe drinking water and wetland ecosystem services is also easily perceived. Less obvious is the role that wetland-specific social determinants of health may play in the transmission of HIV/AIDS, but, on the other hand, as just indicated, it is clear that communities associated with wetland ecosystems and burdened by HIV/AIDS, malaria, tuberculosis or a range of water-borne diseases will have less capacity to contribute to wetland management.

There is an imperative to consider at all times a reciprocal relationship between humans and ecosystems. Less clear for non-health professionals may be specific links between wetland condition and maternal/child health and the burden of childhood illness. These will be closely associated with institutional health determinants like the capacity of the health services to reach members of the communities associated with wetland ecosystems (and of individuals to access health services), and the difficulty of constructing adequate sanitation facilities in wetland areas. Constraints and opportunities in this connection require location-specific analysis during the different seasons of the year.

1.6 Principles of public health

To meaningfully connect human health and wetland ecosystems requires an understanding of the principles of public health, as well as a brief history of their development. Today's definition of health was agreed sixty years ago and adopted by the founding Member States of the World Health Organization as part of the WHO Constitution. It emphasizes the public health principles and concepts that evolved during the second half of the 19th and the first half of the 20th century: *Health is a complete state of physical, mental and social well-being and not merely the absence of disease and infirmity*. This definition has not only stood the test of time, but it has proved its universal value over and again when new health paradigms appeared against the backdrop of changing geo-political or socio-economic landscapes. In some parts of the world, a spiritual well-being dimension has been added, but this is not a globally accepted feature.

There are three generally accepted principles of public health. First, the **highest duty of public health is to protect populations from risks and dangers to health.** This duty belongs to government. It includes the performance of basic public health functions, such as ensuring the quality of medicines and the safety of food, water, and blood supplies. It also includes a responsibility to ensure that populations have the information and the means to protect their health. Obviously, it also includes regulatory functions and requires the investment of public funds. Second, the **highest ethical principle of public health is equity**. This can be expressed in simple terms. People should not be denied access to life-saving or health-promoting interventions for unfair reasons, including those with economic or social causes. Third, **the greatest power of public health is prevention**. Medicine focuses on the patient, but public health seeks to address the causes of ill health in ways that provide population-wide protection.

An explanation of current thinking on public health principles cannot be understood without placing the concepts in a historic perspective. Reviewing the 60 years between 1948 and 2008 it becomes clear, however, that the issues addressed by public health have not changed. The first World Health Assembly in 1948 established as the four priority areas for the Organization's Programme of Work the control of malaria and tuberculosis, the improvement of mother and child care, the reduction of child mortality due to vaccine preventable diseases, and the management of health risks through environmental sanitation.

The eight Millennium Development Goals that emerged from the 2000 Millennium Declaration include four goals with specific public health targets, shown **in bold** in this list of MDGs:

Goal 1: Eradicate extreme poverty and hunger
Goal 2: Achieve universal primary education
Goal 3: Promote gender equality and empower women
Goal 4: Reduce child mortality
Goal 5: Improve maternal health
Goal 6: Combat HIV/AIDS, malaria and other diseases
Goal 7: Ensure environmental sustainability
Goal 8: Develop a Global Partnership for Development

Apart from the new arrival of HIV/AIDS (target 7), the associated MDG targets to be achieved by 2015 could be applied with ease to the priority areas set in 1948:

Target 5: reduce by two thirds the mortality rate among children under five
Target 6: reduce by three quarters the maternal mortality ratio
Target 7: halt and begin to reverse the spread of HIV/AIDS
Target 8: halt and begin to reverse the incidence of malaria and other major diseases
Target 9: reduce by half the proportion of people without sustainable access to safe drinking water and to adequate sanitation.

In other words, in spite of the dramatic changes the world has witnessed over the past 60 years, the public health priorities have remained remarkably constant. That is another way of saying that at the priority public health issues recognized over 60 years ago have yet to be resolved.

Moving beyond the above priority areas, goals and targets, but staying within the scope of this report on wetlands, it is useful to distinguish the following categories of health outcomes (Table 1.1). These categories can be used to structure the analysis of the association between wetlands and health, and the relevance of these health outcomes to wetland ecosystem services will be explored in Sections 3-5 of this report.

1.7 The determinants of health

Health determinants are factors that influence our state of health. They can be arranged hierarchically, as demonstrated in Figure 1.1, as concentric spheres that move outwards progressively from the individual. These categories and subcategories of health determinants can be used as a framework to structure the analysis of the association between particular wetland types and health in specific settings.

There are complex interactions between health determinants that we cannot generally capture by mathematical models. Many of the health determinants

Table 1.1: Examples of the main categories of health outcomes

Main categories of health outcomes	Examples
Nutritional problems	Protein-energy and micro-nutrient deficiencies and excesses; food safety
Communicable diseases	Malaria and other vector-borne diseases, diarrheal diseases, sexually transmitted infections / HIV/AIDS, respiratory infections.
Non-communicable diseases	Acute and chronic poisoning from hazardous chemicals and minerals, cancers, cardiovascular diseases, dust-induced lung disease
Injuries	Drowning, traffic-associated accidents, accidents related to the use of machinery in agriculture and construction
Psychosocial disorders and well-being	Suicide, depression, (communal) violence, substance abuse, stress, fear of disasters; happiness, fulfilment, social integration

can change in both positive and negative directions. In doing so, they can enhance or diminish the health outcomes experienced by the community. Some of the health determinants can be managed so as to enhance community health, for example the quality of water supplies. Others, such as age, cannot be managed.

1.8 The wetlands and public health relationship – the early days

In considering the historic perspectives of the wetlands-health nexus, it is important to go back further than the 60 years of WHO history. Malaria features predominantly in this earlier story, even before the nature and transmission pathway of the disease had both been unveiled in 1898. In 16th-century Spain, for example, strict laws were made prohibiting the siting of irrigated rice production systems within certain boundaries around towns, based on the observed association with the incidence of fevers (Najera 1988).

Once the nature of this association had become known (i.e., some mosquito species of the genus *Anopheles*, which breed in clean freshwater, and exceptionally brackish water systems, serving as the vector), the step to environmental management measures to reduce vector populations and interrupt transmission was a logical and easy one to take. Such "source reduction" strategies included mainly water management measures, among which the drainage of wetlands featured prominently. This contributed substantially to the reduction of malaria transmission in a number of settings, including in Southeast Asia, the Indian subcontinent, and Central and South America. The best-known example from Europe is the drainage of the Pontine marshes near Rome (Box 1.1).

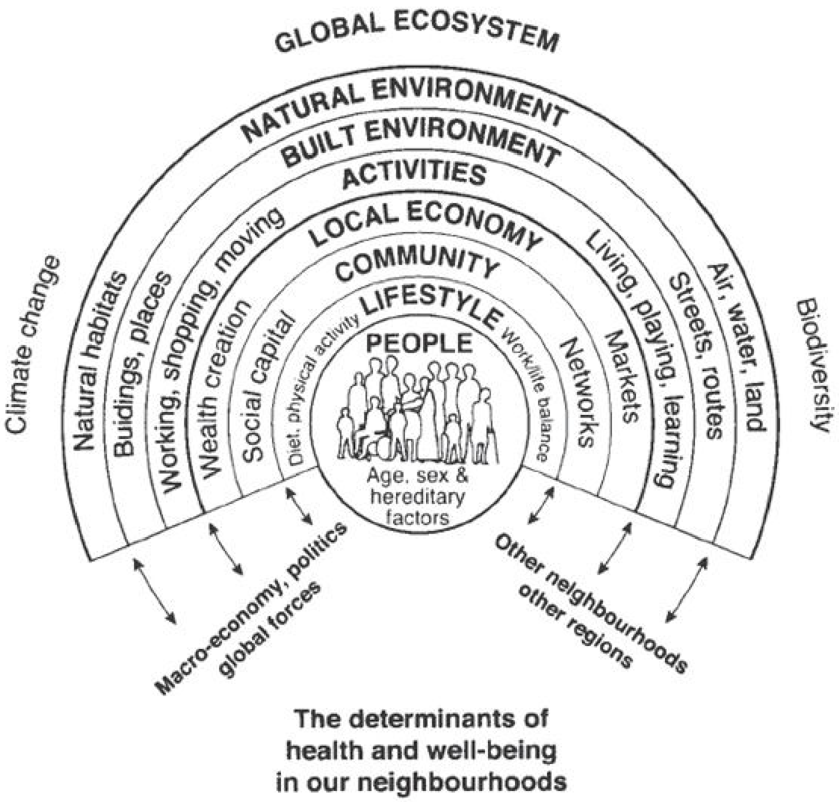


Figure 1.1: The health map (Barton & Grant 2006, used with permission)

Box 1.1: A Historical case study: Rome, Wetlands and Malaria

Perhaps the most telling interaction among deforestation, wetlands, and human health arises in the so-called Pontine territory, a broad, flat, well-watered plain to the south of Rome. In early times, it was an abundantly fertile region and, Roman historian Livy reported, once supported numerous settlements (Rackham 1947). Its early capacity to support crops and animal husbandry made it a key target of Roman acquisitiveness into the fourth century BCE. In the following centuries, the nature of the Pontine region altered radically, although the changes are traceable only through later incidental references and anecdotes (Koot 1991). What is clear is that, by the first century BCE and perhaps even earlier, the area had become dominated by stagnant swamps and marshes – a change that may perhaps be reflected in a redesignation by the Romans of the *ager Pomptinus,* or Pontine field, as the *Pomptinae paludes,* or Pontine marshes (Traina 1988). Deforestation was probably a major factor in this change, although there may have been other contributors. Sallares (2002) points to the possible adverse impact on the area's natural drainage pattern of the construction of a road (the Via Appia) across the Pontine plain in the late fourth century BCE. Subsequent Roman attempts to drain the marshes – such as that by Marcus Cornelius Cethegus in 160 BCE – were unsuccessful because the flatness of the land impeded the effective removal of water, and may even have exacerbated rather than alleviated the problem as further areas of standing water were created. The Pontine marshes became, it seems, both too marshy and too pestilential to farm, for a pronounced infestation of malaria accompanied this ecological change. Literary and archaeological evidence indicate that the population of the region collapsed. Not until Mussolini's public works projects in the 20th century could the Pontine marshes once more become widely inhabited and cultivated.

-- adapted from O'Sullivan et al. 2008

Two important lessons can to be learned from this era prior to the establishment of the WHO. One is that from our present-day perspective there may be conflicts of interest between biodiversity conservation and public health. The massive drainage of wetlands is obviously no longer a viable option in malaria control programmes, but there may be more subtle instances where drainage is deemed to be an important part of such efforts. This means that the professionals managing wetlands and those managing public health programmes must develop the skills to enter into a productive dialogue to find optimal solutions in such situations.

The second is that wetland policy makers and managers will have to gain insight into the epidemiology of water-associated diseases. In communicable diseases, transmission pathways may be complex. In non-communicable diseases, confounding factors may obscure the attribution of specific determinants to long-term health effects. For both of these, different options for health interventions may yield results different from those expected based on conventional wisdom. The cost-effectiveness of different interventions, in particular when considering environmental management options versus medical interventions, may be substantially different if externalities in terms of costs and effects are taken into account.

1.9 The choices we make: tradeoffs and economic approaches

In decision-making for wetland management, issues of potential relevance or importance span a remarkable spectrum. They include the management of flora and fauna, access to harvestable items like timber, fish or edible plants, and the nature of sediment, water quantity and quality. Beyond these fundamentals are the presence of waterborne pollutants, human sanitation, water-related diseases, disease emergence related to small and large dams, catchment land use, livelihoods in or around wetlands, property prices, patterns of human movement and transport, human nutrition and wetlands, and wetlands as sources of beneficial drugs. Some of these issues occur in the short term, others long term, some local, others regional or global. Compounding factors occur, like the implications of climate change for human health issues associated with wetlands (Box 1.2). Inevitably choices need to be made in decision-making where conflicting outcomes might be reasonably predicted, requiring a tradeoff: '*the opportunity cost of selecting one alternative over the other*'.

If wetlands play an important role in sustaining human health and well-being, and if wetlands continue to be lost and degraded at rates more rapid than other ecosystems (Finlayson et al. 2005), it is possible that something is wrong with the way we negotiate these tradeoffs. This is largely attributed to

Box 1.2: Wetlands, climate change and human health

The global burden of disease attributable to anthropogenic climate change up to the year 2000 was reviewed by the World Health Organization in 2002. Taking into account the uncertainty with climate change models and making conservative assumptions about climate-health relationships, the review indicated that climatic changes that had occurred since the mid-1970s could already have caused over 150,000 deaths and about 5 million 'disability-adjusted life years' (DALYs) through increased incidence of diseases such as diarrhea, malaria, and malnutrition that occur mainly in developing countries. Further, it was estimated that climate-change-induced excess risk of various health outcomes could double by 2030 (McMichael et al. 2004). Large increases were predicted for the relative risk of flooding, with more modest increases in diseases such as malaria and malnutrition. However, as malaria already kills over 1,600 per million people in Sub-Saharan Africa, small changes may still indicate a substantial disease burden.

Specific data for malaria risk in Africa have also been used to predict increased risk in exposures of 16-28%, but such analyses do not account adequately for non-climatic confounding factors (socio-economic issues, immunity patterns, and drug resistance) or the variation of specific climate-disease relations among locations. Patz et al. (2005) emphasise the weakness of using statistical models for such extrapolations and recommend combining such approaches with process-based models that capture the ecological relationships of the malarial vector.

They also point to the influence of changes in land use and land cover on ecologically-mediated infectious diseases and recommend that, to assess future climate-change impacts on health, future projections of land-use change must also be considered. Ethical questions about climate change and human health are also being raised; for example, Africa with an estimated 90% of malaria has generally low per capita emissions of greenhouse gases that cause global climate change. Further, the ecological condition and health of many African wetlands is unknown, with many of them unmapped or adequately described (Taylor et al. 1995; Finlayson et al. 1999). The absence of basic ecological knowledge on many wetlands could hinder efforts to incorporate ecological relationships into the process models being recommended as a basis for extrapolations about future risks of water-borne diseases. Further information on the basic ecology of wetlands and their species, and the often complex interactions that will affect human health, will be needed to inform decision making. Specific regional assessments of the impacts of climate change on human health will allow the relationships with wetland ecosystems to be highlighted. For example, McMichael (2009) produced the following summary of the main health risks from climate change for Australia:

1. Increased illness events and deaths from more frequent and severe heatwaves, especially in urban environments.
2. Increased injury, death and post-traumatic stress disorders from increases in other extreme weather events, especially floods, storms, cyclones (moving further south), and more extreme bushfires.
3. Increased risks of infectious food-poisoning (gastroenteritis) from salmonella, campylobacter, various temperature-sensitive vibrios, and others.
4. Changes in the range and seasonality of outbreaks of mosquito-borne infections – dengue fever in northern Australia (likely to spread south, down both eastern and western coasts), Ross River virus disease, Barmah Forest virus disease, and others.
5. Freshwater shortages in remote (especially indigenous) communities, with consequences for hygiene and sanitation.
6. Regional increases in the production of various plant-derived aeroallergens (pollens, spores) that cause or exacerbate asthma.
7. A potentially serious range of adverse health impacts of more severe droughts and long-term drying conditions on rural communities. These include adverse impacts on mental health (depression and suicides); child emotional and developmental experiences; exposures to extremes of heat, dust, smoke; freshwater shortages and hygiene; local food availability; changes in health-related behaviors (e.g., alcohol, smoking, self-medication).

McMichael (2009) added the spectrum of risks to well-being and health from the anticipated increase in geopolitical instability in the Asia-Pacific region due to climate change, and the increase in flows of environmental refugees, with substantial implications for mental health and nutritional problems, infectious disease risks, and conflict situations. Wetland ecosystems are implicated directly (health risks 2, 3, 4 and 5 above) and indirectly in each of the other health risks.

policy decisions that fail to internalize and factor in the values of wetland ecosystem services in a manner that supports their retention or rehabilitation. In many cases the tangible and financial benefits arising through wetland degradation or conversion are taken into account when making such decisions, whilst the substantial value arising from wetland ecosystem services which are not traded into formal markets, and thereby do not generate cash flows, are not. Incomplete knowledge of the value of these services can lead to perverse incentive systems which favour degradation and conversion of wetlands without considering the consequent loss of human welfare and impacts on human health and overall well-being. Quantifying and valuation of wetland ecosystem services in a way that makes them comparable with the returns derived from alternative uses can facilitate improved policy and decision making (Turner et al. 2000).

1.10 The aim of this report

In response to many of the issues outlined above, the Ramsar Convention on Wetlands has devoted increasing attention to developing the scientific concepts behind the theme 'healthy wetlands, healthy people' and sought greater understanding of how people and wetlands interact, for example, through analyses of the interactions between agriculture and wetlands (Wood & van Halsema 2008), fisheries and wetlands (Ramsar Convention 2005c), forestry and wetlands (Blumenfeld et al. 2009), and, in this instance, the interactions between human health and wetlands.

The slogan 'Healthy wetlands, healthy people', which was also the theme of the 10th meeting of the Conference of the Contracting Parties (COP10) in 2008, implies an interaction between wetland ecology and management and the health of people, with consequent social and cultural interactions between people and wetlands. This is seen as an extension of the multi-disciplinary approaches adopted through the Millennium Ecosystem Assessment (2005) and subsequent global assessments that have addressed human well-being and ecosystem services.

The interactions between human health and wetlands are expanded in this report through an examination of the linkages between human health and ecosystem services obtained from wetlands, with an emphasis on human health as a component of human well-being that is linked inextricably with wetland ecological character.

With this background, the purpose of this review report is to provide an accessible source of information to help improve understanding of the often complex inter-relationships between wetland ecosystems and human health and well-being. The primary audience for this report is intended to be wetland conservation and wise use practitioners, from wetland managers at the site level to decision-makers at national and international levels. The information in the report should help in facilitating dialogue between wetlands and human health professionals in their respective efforts to maintain and improve wetland ecological character and people's health.

Key questions: our problem statements

How can we manage wetlands better?

If we manage wetlands better, can we improve the health and well-being of people?

Why is this question important? Despite producing more food globally and extracting more water globally, wetlands continue to decline and for many people public health and living standards do not improve.

Why is this – and what needs to change in order to improve the situation?

The depth and detail of coverage in the report have benefited by the accessibility of information in recent global overviews such as the Millennium Ecosystem Assessment (2005), the World Water Development Report (UN WWDR 2006), the Comprehensive Assessment of Water Management in Agriculture (Molden 2007), and the UNEP Global Environment Outlook 4 (2007). These surveys represent both a global consensus by scientists on key issues affecting wetland ecosystems, water and people and up-to-date widely reviewed compilations of science-based evidence. These are particularly important when considering the implications of efforts to achieve the Millennium Development Goals, with their emphasis on biodiversity in virtual isolation of wider ecosystem issues, if they run counter to efforts to achieve wetland conservation. The Millennium Ecosystem Assessment in particular has emphasised the strength of the fundamental relationship between wetland ecosystems and their services and human health, and therefore the importance of developing environmental management strategies that support the maintenance of both wetland ecological character and human health concurrently (Finlayson et al. 2005). It is contended that at a metaphorical level these linkages are being established – further scientific evidence is needed to support these and enable more informed decisions that consider the complexities involved.

2. From ecological character to ecosystem health: the Ramsar Convention, and wetland ecosystems as settings for human health

2.1 Introduction

How can we build upon the existing frameworks for understanding wetlands, and for understanding human health, to produce an holistic picture, a conceptual model for the relationship between them? A composite approach for assessing the ecological character of wetlands has been devised and adopted by the Ramsar Convention on Wetlands, with particular application for assessing the reference or baseline condition of sites listed as internationally important (Ramsar Convention 2008b). In addition to including the ecological components and processes that are generally seen as comprising a wetland, explicit attention is given to the ecosystem services provided by that wetland.

Ecosystem services have been described by the Millennium Ecosystem Assessment (2005) as "the benefits that people receive from ecosystems", and they are broadly categorised as provisioning, regulating, cultural, and supporting services. By incorporating ecosystem services within ecological character (Ramsar Convention 2005a), the Ramsar Convention has explicitly recognized the links between the components and processes and the services provided by wetlands. Human well-being is therefore seen as inextricably associated with ecological character through the services that a wetland provides. As human health is encompassed by human well-being (Figure 2.1), it is also linked with the ecological character and the services provided by wetlands and is not limited to an absence of disease or illness. Furthermore, human health can be seen as commencing with the basic right to sufficient water for health and well-being[2].

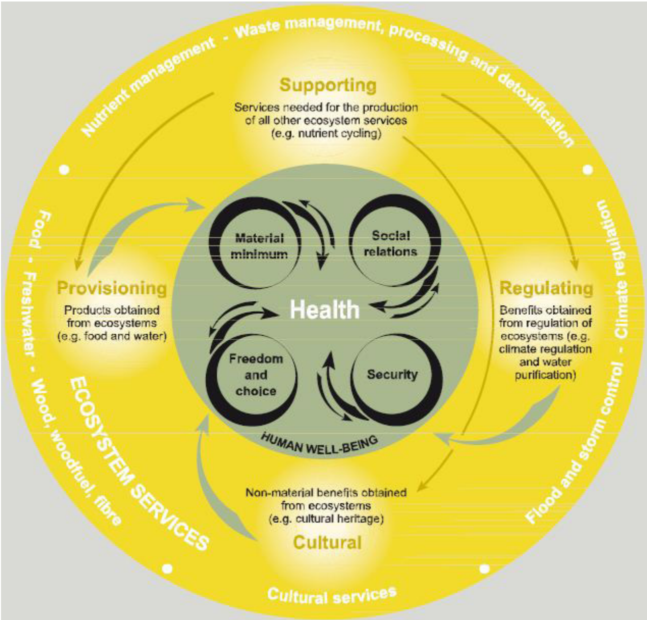


Figure 2.1: Associations between health, human well-being, and ecosystem services (from Corvalan et al. 2005b).

The simplest presentation of the framework is shown in Figure 2.2, the 'central maxim': ecosystem services are defined as benefits for human well-being, ecosystem services are included in 'ecological character' so that human well-being is included in wetland assessments, and human health is the central component of human well-being. In fact, there are broader implications of this for the conservation objectives of the Ramsar Convention: since conservation equates to maintenance of ecological character, the conservation imperative relates to protecting ecosystem services and human well-being as much as it does to protecting, for example, biodiversity.

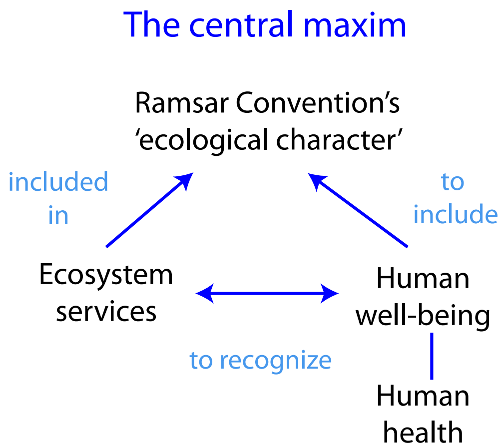


Figure 2.2: The central maxim

2 Scanlon et al. 2004 reasoned that since water is so essential for survival and health, and the "right to life" and "health and well being" are human rights according to the Universal Declaration of Human Rights (United Nations 1948), it is implicit that adequate water for health is a human right as well. This has not yet been clearly defined in international law, but in July 2010 the UN General Assembly formally recognized the right to water and sanitation with a resolution acknowledging that clean drinking water and sanitation are integral to the realisation of all human rights. Commentators argue that while it is non-binding and a long way from a treaty on the right to water and sanitation, it is still a welcome step in the right direction.

Ecological character and ecosystem services are subject to change through natural processes and at times are driven by large episodic events, but also often through human agency, with a feedback to human well-being and human health. Drivers of change in wetlands have been seen as natural processes (e.g., Mitsch & Gosselink 2000), as anthropogenic actions that come from well-defined areas of human endeavour, or as systemic effects of which humans are a part. The last mentioned is shown by the analyses and approaches used in the Millennium Ecosystem Assessment (2003, 2005) and adopted by the Ramsar Convention (2005a). This approach is used as a basis for examining the links between changes in ecological character and human health as a consequence of human activity.

Numerous examples exist of the link between ecological character and human health; a change in hydrological regime, nutrient status, or trophic structure of a wetland may elevate population numbers of vectors of human pathogens; changing water regimes might mobilise chemicals toxic to humans or agricultural products; or reduced productivity of wetland ecosystems can have direct or indirect health consequences for people whose livelihoods depend upon that productivity. Some detailed examples are given in Section 4 (Table 4.1 specifically).

How then can we tell whether a wetland is 'healthy'? Ecosystem health is a conceptual approach that seeks to be explicit about human well-being and human health as being a part of an ecosystem, not separate from it. It covers *both* an ecosystem approach to dealing with matters of human health and its use as a metaphor of health for ecosystem assessment. This chapter covers the conceptual development of this framework to enable wetland managers to gauge the 'health' of a wetland ecosystem and the role of human health in that assessment.

2.2 Ecological character

The text of the Ramsar Convention includes the requirement that "Each Contracting Party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing, or is likely to change" (Article 3.2). Through a series of formal decisions (principally its Strategic Plan and Resolutions), the requirement in Article 3.1 to "promote the conservation" of Ramsar sites has been equated to "maintenance of ecological character" of these sites. The definition of 'ecological character' reads as "the combination of the ecosystem components, processes, benefits / services that characterise the wetland at a given point in time" (Ramsar Convention 2005a). Ecosystem benefits are defined in accordance with the Millennium Ecosystem Assessment (2005) definition of ecosystem services.

A treatment of the constituent parts of what makes up ecological character must embody not just a list of the components, processes and benefits/services, but what they represent *in combination*. Further, the ecological character description of a wetland provides the reference or baseline description of a wetland at a given point in time (the terms that have been used in the Ramsar guidelines for ecological character are provided in Table 2.1). The description *can* be used to assess change and form the reference for the following activities:

- the development and implementation of a management plan designed to maintain the ecological character of the site;
- the design of a monitoring program to detect change in ecological character;
- the regular evaluation of the results of the monitoring program to assist on-site management;
- the assessment of the likely impact of proposed actions on ecological character; and
- the reporting of changes in the ecological character of Ramsar Sites as required under the Convention's Article 3.2.

Table 2.1: Comparison of terms for describing the ecological character of wetlands

Millennium Ecosystem Assessment terms to apply in Ramsar guidelines and other convention usages	Terms used in previous Ramsar guidelines and other documents
Ecosystem components: physical, chemical, biological (ecosystems, species, genes)	components, features, attributes, properties
Ecological processes within and between ecosystems	processes, interactions, properties, functions
Ecosystem services: provisioning, regulating, cultural, supporting	services, benefits, values, functions, goods, products

(Source: Ramsar Convention 2005a; 2006)

2.3 Ecosystem services provided by wetlands

Table 2.2 outlines the breadth of issues likely to be included in an assessment of the ecological

Table 2.2: A proposed scheme for describing ecological character (Ramsar Convention 2008)

Ecological components	Ecological processes	Ecosystem services#
1 Geomorphic setting: in the landscape, catchment or river basin, including altitude, upper/lower zone of catchment, distance to coast where relevant, etc. **2** Climate: overview of prevailing climate type, zone & major features (precipitation, relative humidity, temperature, wind) **3** Habitat types (including comments on particular rarity, etc.), & Ramsar wetland types **4** Habitat connectivity **5** Area, boundary & dimensions: site shape (cross-section & plan view), boundaries, area, area of water/wet area (seasonal max/min where relevant), length, width, depth (seasonal max/min where relevant) **6** Plant communities, vegetation zones & structure (including comments on particular rarity, etc.) **7** Animal communities (including comments on particular rarity, etc.) **8** Main species present (including comments on particular rare/endangered species, etc.); population size & proportion where known, seasonality of occurrence, approximate position in distribution range (e.g., whether near centre or edge of range) **9** Soil: geology, soils & substrates; soil biology **10** Water regime: water source (surface & groundwater), inflow/outflow, evaporation, flooding frequency, seasonality & duration; magnitude of flow and/or tidal regime, links with groundwater **11** Connectivity of surface waters & of groundwater **12** Stratification & mixing regime **13** Sediment regime (erosion, accretion, transport & deposition of sediments) **14** Water turbidity and colour **15** Light reaching the wetland (openness or shading) & attenuation in water **16** Water temperature **17** Water pH **18** Water salinity **19** Dissolved oxygen in water **20** Dissolved or suspended nutrients in water **21** Dissolved organic carbon **22** Redox potential of water & sediments **23** Water conductivity	**1** Primary production (S)* **2** Nutrient cycling (S)* **3** Carbon cycling **4** Animal reproductive productivity **5** Vegetational productivity, pollination, regeneration processes, succession, role of fire, etc. **6** Notable species interactions, including grazing, predation, competition, diseases & pathogens **7** Notable aspects concerning animal & plant dispersal **8** Notable aspects concerning migration **9** Pressures, vulnerabilities & trends concerning any of the above, and/or concerning ecosystem integrity	**1** Drinking water for humans and/or livestock (P)* **2** Water for irrigated agriculture (P)* **3** Water for industry (P)* **4** Groundwater replenishment (R)* **5** Water purification/waste treatment or dilution (R)* **6** Food for humans (P)* **7** Food for livestock (P)* **8** Wood, reed, fibre & peat (P)* **9** Medicinal products (P)* **10** Biological control agents for pests/diseases (R)* **11** Other products & resources, including genetic material (P)* **12** Flood control, flood storage (R)* **13** Soil, sediment & nutrient retention (R)* **14** Coastal shoreline & river bank stabilization & storm protection (R)* **15** Other hydrological services (R)* **16** Local climate regulation/buffering of change (R)* **17** Carbon storage/sequestration (R)* **18** Recreational hunting & fishing (C)* **19** Water sports (C)* **20** Nature study pursuits (C)* **21** Other recreation & tourism (C)* **22** Educational values (C)* **23** Cultural heritage (C)* **24** Contemporary cultural significance, including for arts & creative inspiration, & including existence values (C)* **25** Aesthetic & "sense of place" values (C)* **26** Spiritual & religious values (C)* **27** Important knowledge systems, importance for research (C)*

* Ecosystem Services are categorised by the Millennium Ecosystem Assessment as provisioning (P), regulating (R), cultural (C) or supporting (S). Some may appear in the "processes" section as well as the "services" section.
#(For nature conservation value as an ecosystem 'service' (S)*, see items under 'components' and 'processes')

character of a wetland, including physical, chemical and biological components, ecological processes, and an array of ecosystem services: provisioning, regulating, cultural, or supporting. In some instances processes are also listed as services, and, further, the categorization does not account for the scale at which the processes or services may operate. Nevertheless, the categorization provides a basis for describing the ecological character of a wetland and for identifying key issues for management consideration and the role of wetlands in supporting human health. It must be emphasized that not all categories of information in Table 2.2 apply to all wetlands, based on biogeographic and social considerations.

2.4 Wetland ecosystem services and human well-being

One of the significant achievements of the Millennium Ecosystem Assessment has been to produce numerous conceptual models for the relationship between ecosystem services and the constituents of human well-being; one of these is shown in Figure 2.3.

Figure 2.3 depicts the strength of linkages between commonly-encountered categories of ecosystem services and components of human well-being, and it includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkage. For example, the ability to purchase a substitute for a degraded ecosystem service offers a high potential for mediation. The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human well-being depicted here, other factors influence human well-being as well, including other environmental factors and economic, social, technological and cultural factors. In turn ecosystems are affected by changes in human well-being.

Wetland ecosystems, including rivers, lakes, marshes, rice fields, and coastal areas, provide many services that contribute to human well-being and poverty alleviation. Some of the most important wetland ecosystem services affecting human well-being are outlined below (modified from Finlayson et al. 2005):

- *Fish supply.* Inland and coastal fisheries are particularly important in developing countries, and they are sometimes the primary source of animal protein to which rural communities have access. Wetland-related fisheries also make important contributions to local and national economies.

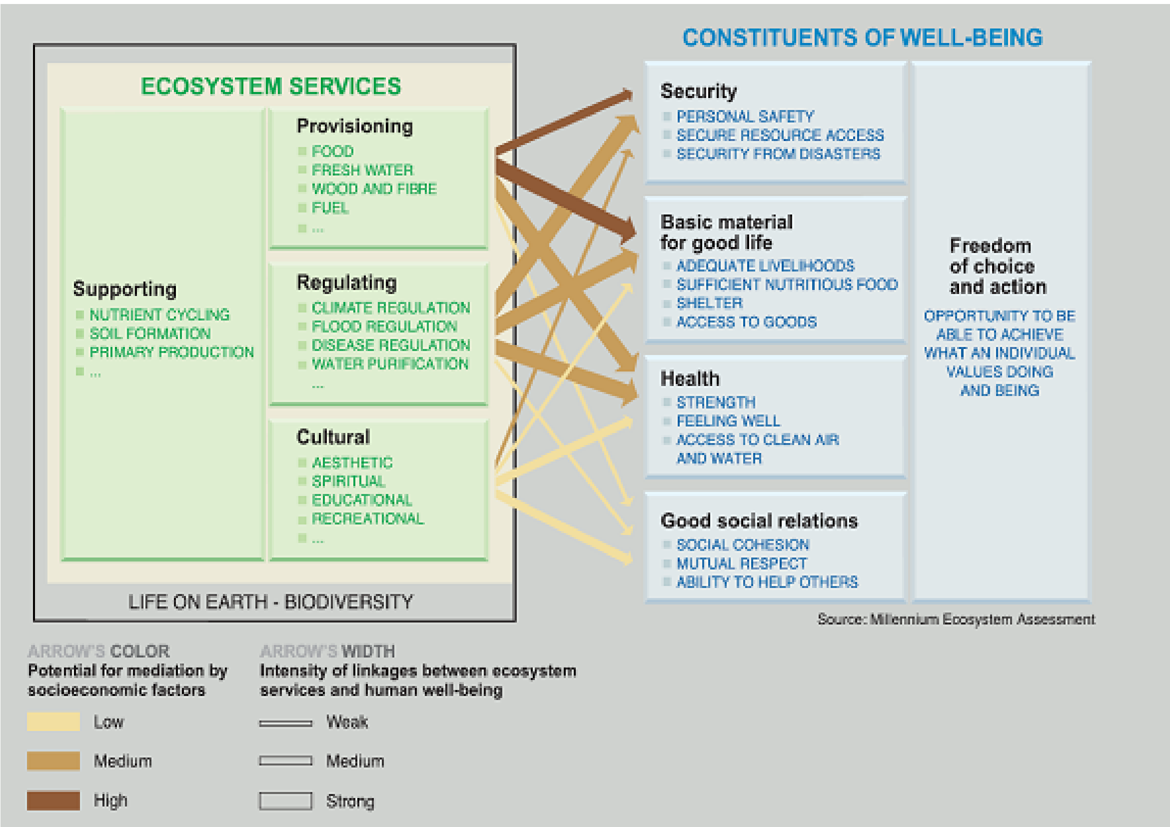


Figure 2.3: The relationships between ecosystem services, human well-being and health (reproduced from Corvalan et al. 2005b).

- *Supply of fresh water.* The principal supply of renewable fresh water for human use comes from an array of inland wetlands, including lakes, rivers, swamps, and shallow groundwater aquifers. Groundwater, often recharged through wetlands, plays an important role in water supply, with an estimated 1.5–3 billion people dependent upon it as a source of drinking water. Rivers have been substantially modified around the world to increase the water available for human consumption. Recent estimates place the volume of water trapped behind (documented) dams at 6,000–7,000 cubic kilometers.
- *Water purification and detoxification of wastes.* Wetlands, and in particular marshes, play a major role in treating and detoxifying a variety of waste products. Some wetlands have been found to reduce the concentration of nitrate by more than 80%.
- *Carbon storage.* One of the most important roles of wetlands may be in the regulation of global climate change through sequestering and releasing a major proportion of fixed carbon in the biosphere. For example, although covering only an estimated 3-4% of the world's land area, peatlands alone are estimated to hold 540 gigatons of carbon, representing about 1.5% of the total estimated global carbon storage and about 25-30% of that contained in terrestrial vegetation and soils.
- *Cultural services.* Wetlands provide significant aesthetic, educational, cultural, and spiritual benefits, as well as a vast array of opportunities for all forms of visits, including for recreation and tourism. Wetlands provide nonmarketed and marketed benefits to people, and the total economic value of unconverted wetlands is often greater than of converted wetlands.
- *Hydrological services.* Wetlands deliver a wide array of hydrological services – for instance, swamps, lakes, and marshes assist with flood mitigation, promote groundwater recharge, and regulate river flows – but the nature and value of these services differs across wetland types. Flooding is a natural phenomenon that is important for maintaining the ecological functioning of wetlands (for example, by serving as a means for the natural transport of dissolved or suspended materials and nutrients into wetlands) and particularly for sustaining the delivery of many of the services they provide to millions of people, particularly to those whose livelihoods depend on floodplains for flood-recession agriculture and pasturage and for fish production. Many wetlands diminish the destructive nature of flooding, and the loss of those wetlands increases the risks of floods occurring.
- *Mitigation of climate change impacts.* Sea level rise and the increases in storm surges associated with climate change will result in the erosion of shores and habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport, and increased coastal flooding, and these, in turn, could increase the vulnerability of some coastal populations. Wetlands such as mangroves and floodplains can play a critical role in the physical buffering of climate change impacts.

Some groups of people, particularly those living near wetlands, are highly dependent on these services and are directly harmed by their degradation. In other instances, people derive many benefits from wetlands, both economic and culturally, and as shown in Figure 2.3 these benefits determine human health both directly and also indirectly by contributing to other forms of well-being, like providing security, basic materials for good life, and good social relations.

2.5 Public health and health promotion: recognizing ecosystems

Public health, like environmental management, has undergone significant shifts in thinking, approaches and priorities over the past half century. One of them has been to recognize ecosystems as being 'settings' for a range of determinants of health.

After the Second World War (particularly during the 1950s and 1960s), the approach taken to public health by governments around the world shifted to a reliance on new technological solutions (i.e., synthesis and application of pesticides and medicines) and an extension of access to basic health services, including supply of drinking water and sanitation, in a scaled-up manner. Dramatic successes in the control of some communicable diseases were seen, followed by equally dramatic resurgences of ill-health when the approaches were not economically sustainable and did not build on the capacities and involvement of local communities. The period was characterised by a strong health-sectoral focus and the demise of previous multidisciplinary frameworks and intersectoral approaches to health care.

Partly as a response to these shifts, they were followed in the 1970s and 1980s by a focus on equity, involving the concept of Primary Health Care (PHC), which:

> is essential health care based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through their full participation and at a cost that the community and the country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination. It forms an integral part, both of the country's health system, of which it is the central function and main focus, and of the overall social and economic development of the community.

This culminated for public health in the 1978 Declaration of Alma Ata, which set in motion the process towards Health for All by the Year 2000.

Essential elements of PHC include: education concerning prevailing health problems and the methods of preventing and controlling them; promotion of food supply and proper nutrition; an adequate supply of safe water and basic sanitation; maternal and child health care, including family planning; immunization against the major infectious diseases; prevention and control of locally endemic diseases; appropriate treatment of common diseases and injuries; and provision of essential drugs.

During the 1980s and 1990s, the focus on environmental and social determinants elevated their importance, exemplified by parallel processes: the 1986 Ottawa Charter for Health Promotion and the 1992 UN Conference on Environment and Development. For the latter, the first principle of Agenda 21 states that human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.

The linkage between ecosystem services and human health is consistent with the Ottawa Charter for Health Promotion, which recognized as prerequisites for health: peace, shelter, education, food, income, a stable ecosystem[3], sustainable resources, social justice, and equity (World Health Organization 1986). The Ottawa Charter, and more recently the Bangkok Charter for Health Promotion in a Globalised World (Bangkok Charter 2006), identified five major strategies for promoting health:

1. building healthy public policy;
2. creating supportive environments;
3. strengthening community action;
4. developing personal skills; and
5. re-orienting health services.

3 But note that systems theorists argue that seeking to make ecosystems 'stable' will be counterproductive (see Section 2.9).

The linkage between ecosystem services and human health is most clearly expressed in the text about "creating supportive environments":

> Our societies are complex and interrelated. Health cannot be separated from other goals. The inextricable links between people and their environment constitutes the basis for a socio-ecological approach to health. The overall guiding principle for the world, nations, regions and communities alike, is the need to encourage reciprocal maintenance – to take care of each other, our communities and our natural environment. The conservation of natural resources throughout the world should be emphasised as a global responsibility.
>
> Changing patterns of life, work and leisure have a significant impact on health. Work and leisure should be a source of health for people. The way society organizes work should help create a healthy society.
>
> Health promotion generates living and working conditions that are safe, stimulating, satisfying and enjoyable.
>
> Systematic assessment of the health impact of a rapidly changing environment – particularly in areas of technology, work, energy production and urbanisation – is essential and must be followed by action to ensure positive benefit to the health of the public. The protection of the natural and built environments and the conservation of natural resources must be addressed in any health promotion strategy.

The central tenet of the Ottawa Charter was that "health is created and lived by people within the settings of their everyday life: where they learn, work, play and love". This established the **healthy settings** approach to health promotion, defined by the WHO as:

> A setting is also where people actively use and shape the environment and thus create or solve problems relating to health. Settings can normally be identified as having physical boundaries, a range of people with defined roles, and an organizational structure. Action to promote health through different settings can take many different forms, often through some form of organizational development, including change to the physical environment, to the organizational structure, administration and management. Settings can also be used to promote health by reaching people who work in them, or using them to gain access to services, and through the interaction of different settings with the wider community.

Examples of settings include schools, work sites, hospitals, villages and cities, and islands, and more recently the suggestions that watersheds can be considered in the same way (Parkes et al. 2008).

Locating wetland ecosystems in public health – a road map

The message here is that *ecosystems* are implicitly recognized within the discourse of public health in just about all of its endeavours, yet mostly marginalised against the imperatives of attending to curing disease. The Millennium Ecosystem Assessment sought to re-emphasise that ecosystem services are indispensable to the well-being and health of people everywhere, and it involved environmental health practitioners, epidemiologists and others in the process of stating this case.

These types of endeavours are expressed in the discipline of health promotion and its agreed charters. Within these areas, ecosystems and ecological thought, and their application for health policy, are located in their richness in the Healthy Settings agenda.

To public health practitioners, then, wetland ecosystems can be usefully articulated as settings for people's health.

2.6 Patterns of health: epidemiological transitions, poverty and inequality

Several developments need a brief description to put the management of wetland ecosystems into the context of public health.

With an increasing number of actors on the public health stage, there evolved a stronger emphasis on the comparative advantages of each actor, particularly in terms of technical solutions. This gave rise to a number of conventional "vertical programmes": those that sought to address specific and located health issues. At the same time there has been a greater demand for health evidence in order to justify investing in health. To standardize across such programmes, the concept of the DALY (Disability Adjusted Life Year) was launched in the 1990s. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. Hence any health issue can be measured using a standardized instrument and compared to another. For example is the burden of disease in one wetland setting higher or lower than that in another? Using instruments like DALYs and burdens of disease enable comparisons and trends between and within countries, and over time.

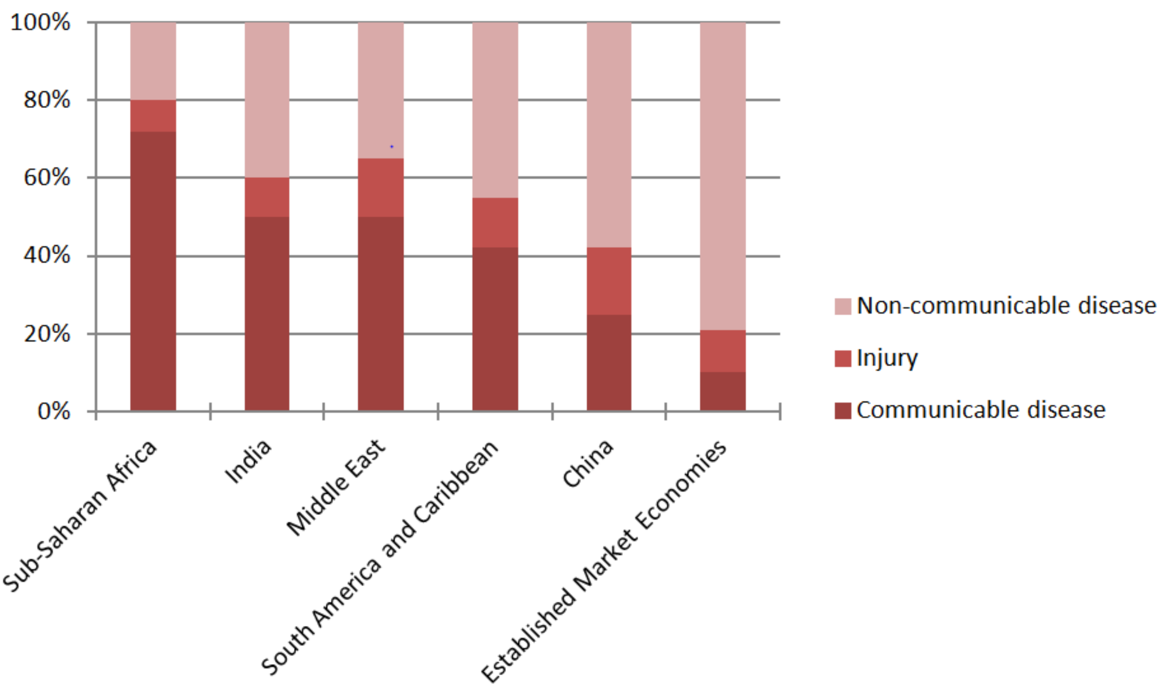


Figure 2.4: Changes in the burden of disease associated with economic development

For instance, as economies develop, and as these shifts in public health emphasis have occurred, there is marked transition in the pattern of illness. This has implications for the kinds of health impact that take priority. It is also a cause of common mistakes (like when low frequency cancer mortality receives a higher priority than high frequency diarrhea-related mortality). The diseases with the highest frequencies in less developed countries (communicable diseases such as malaria, respiratory infections, diarrhea, HIV/AIDS, protein energy malnutrition, and injuries) are markedly different to those in more developed countries – for these, non-communicable diseases such as heart, lung and circulation disorders and cancers, obesity, and depressive illness have the highest frequencies. These epidemiological transitions occur over time within countries or groups of countries (Figure 2.4), and they demonstrate both the contextual nature of determinants of health and the relative importance of different ecosystem services, depending upon where the greater burden of disease lies.

These shifts are relevant for our management across the full diversity of wetland ecosystem services. For example, in less developed countries our interventions will be targeted at those services relevant to livelihoods and exposures to diseases, and in more developed countries they will be targeted at wetland ecosystem services of importance to lifestyle and diet.

The discussion of the epidemiological transition is based at a macroeconomic level – comparing differences between countries. A second level of analysis is equally important – comparing socio-economic groups within countries (Box 2.1).

In all countries, for all health outcomes, and for many health determinants, there are marked differences in the frequency according to socioeconomic quintiles. For example, life expectancy declines eastwards from central London due to decreasing socioeconomic status, approximated as one year of expected life lost for each tube stop traveled east from central London (London Health Observatory 2007). The example in Figure 2.5 indicates the importance of socio-economic groups as a determinant of under-5 mortality in five different countries.

The data for malaria (as measured by the proportion of children with parasites detectable in their blood stream) in the Gambia (Clarke et al. 2001) is also illustrative; among the poorest children, the proportion is highest.

The consequence of this variation for wetland management is clear – there will be different priorities for safeguarding the health of wetland communities in poor and rich countries. Further, there will be differences in vulnerability between wetland communities depending on their socio-economic status. The discussion of wetlands and health should be disaggregated accordingly.

Referring back to Figure 2.3, this section also shows the strength of linkages between ecosystem services and human health, the degree to which socio-economic factors might mediate these linkages, and how different vulnerabilities can be represented. For example, where water quality continues to be degraded, the prevalence of disease will most likely continue to increase, and this will be particularly true for vulnerable people in developing countries. In this case the linkage between a wetland ecosystem providing fresh water and a human health conse-

Box 2.1: The social determinants of health

The inequities in how society is organized mean that the freedom to lead a flourishing life and to enjoy good health is unequally distributed between and within societies. This inequity is seen in the conditions of early childhood and schooling, the nature of employment and working conditions, the physical form of the built environment, and the quality of the natural environment in which people reside. Depending on the nature of these environments, different groups will have different experiences of material conditions, psychosocial support, and behavioural options, which make them more or less vulnerable to poor health. Social stratification likewise determines differential access to and utilization of health care, with consequences for the inequitable promotion of health and well-being, disease prevention, and illness recovery and survival.

This unequal distribution of health-damaging experiences is not in any sense a 'natural' phenomenon but is the result of a toxic combination of poor social policies and programmes, unfair economic arrangements, and bad politics. Together, the structural determinants and conditions of daily life constitute the social determinants of health.

-- Commission on Social Determinants of Health (2008)

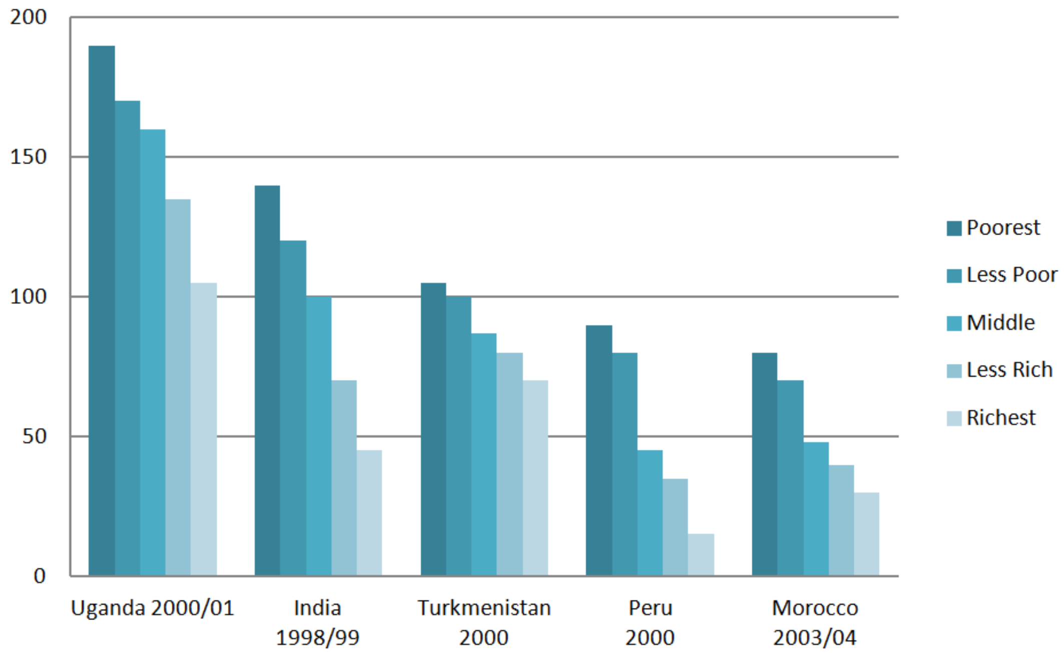


Figure 2.5: The under-5 child mortality as a function of socio-economic group in five countries
(Commission on Social Determinants of Health 2008)

quence is mediated, since people who are more socio-economically vulnerable are more likely to be both exposed to, and susceptible to, waterborne diseases, and technological fixes and alternatives are less likely readily available (see Sections 4.2 and 5.3 below).

2.7 Bringing them together: Health issues and health determinants in wetland settings

Examples of broad classes of wetland ecosystem-related consequences for human health, all of them mediated by socio-economic status, are shown in Table 2.3, along with examples of wetland ecosystem services that contribute to preventing ill-health or relate in another way to health consequences.

2.8 Drivers of change

The consequences for human health of changes to wetland ecosystems are indicated at least in part in Table 2.3; there is a similar list of consequences for human health if wetland components or processes are changed, and indeed if ecological character changes in the way that components, processes, and services combine. Changes to wetland ecosystems are classifiable according to human conditions (indirect drivers of change) and human activities (direct drivers of change) (Millennium Ecosystem Assessment 2005; Figure 2.6). Most authorities would agree that threats to global biodiversity can be grouped under five interacting categories (overexploitation; air, water and soil pollution; flow modification; destruction or degradation of habitat; and invasion by non-native species) and that environmental changes occurring at the global scale, such as nitrogen deposition, warming, and shifts in precipitation and runoff patterns, are superimposed upon all of these threat categories. This has recently been summarized by Vorosmarty et al. (2010), highlighting the urgency of these issues and threats.

Links between direct and indirect drivers of wetland change and opportunities for the Ramsar Convention to provide guidance on interventions and how they link to human well-being are clearly outlined in the conceptual framework from the Millennium Ecosystem Assessment (Figure 2.6). A central premise of the framework is that all direct drivers of wetland change are linked with one or more indirect drivers, and conversely, that the effect of an indirect driver on a wetland is mediated through one or more direct drivers. Indirect drivers do have immediate effects on human well-being, but these are not related specifically to wetlands. To date, most guidance provided by the Convention has addressed direct drivers with the exception of guidance on wetland policies and planning issues. There is currently no guidance that specifically addresses human health and wetlands management, although this can in some cases be inferred through the links that occur between wetland ecosystems and human health, as discussed below.

Table 2.3: Examples of classes of wetland ecosystem-related determinants of human health and relevant ecosystem services

Health Issues and Determinants	Adverse Health effects	Examples of relevant wetland ecosystem services
Core requirements		
1. Access to sufficient safe water	Dehydration, poor hygiene	Drinking water for humans and/or livestock Groundwater replenishment Water purification/waste treatment or dilution Flood control, flood storage
2. Access to adequate nutrition	Malnutrition, stunting, obesity, diabetes	Role of wetlands in food provision (or consequences of changes in productivity) Soil, sediment & nutrient retention
Personal exposures and risks		
3. Exposure to pollution	Soil or water-borne inorganic chemicals Soil or water-borne microbial toxins Atmospheric particles or chemicals	Water purification/waste treatment or dilution Other hydrological services (i.e., hydrological maintenance of biogeochemical processes) Soil, sediment & nutrient retention
4. Exposure to infection	Water-borne diseases Vector-borne diseases Emerging infectious diseases	Drinking water for humans and/or livestock Biological control agents for pests/diseases
5. Exposure to psycho-social stresses	Depression, suicide (associated with hopelessness and helplessness) Grieving over loss of place ("Solastalgia")	Contemporary cultural significance, including for arts & creative inspiration, & including existence values Aesthetic and "sense of place" values Spiritual & religious values Important knowledge systems, & importance for research
Cross-cutting hazards		
6. Exposure to physical hazards	Floods and droughts, cyclones, hurricances, tsunamis, etc. Any or all of 1-5 above associated with a physical hazard where change to a wetland ecosystem has been implicated	Climate regulation Flood control, flood storage Soil, sediment & nutrient retention Coastal shoreline & river bank stabilization & storm protection Local climate regulation/buffering of change
Social determinants of health		
7. Livelihoods & working conditions	Work-place exposures Any or all of 1-6 above associated with loss of livelihoods from change to a wetland ecosystem	Water purification/waste treatment or dilution Any of 18-27 in Table 2.2
8. Lifestyles & living conditions	Home exposures. Reduction in physical exercise. Any or all of 1-7 above associated with a detrimental change in living conditions as a results of change to a wetland ecosystem	Recreational hunting & fishing, Water sports Nature study pursuits, educational values Understanding ecosystem behaviour Cultural heritage Contemporary cultural significance, including for arts & creative inspiration, & including existence
9. Access to medication	Pharmaceuticals Indigenous/traditional/herbal treatments	Medicinal products Cultural heritage Spiritual & religious values Important knowledge systems & importance for research

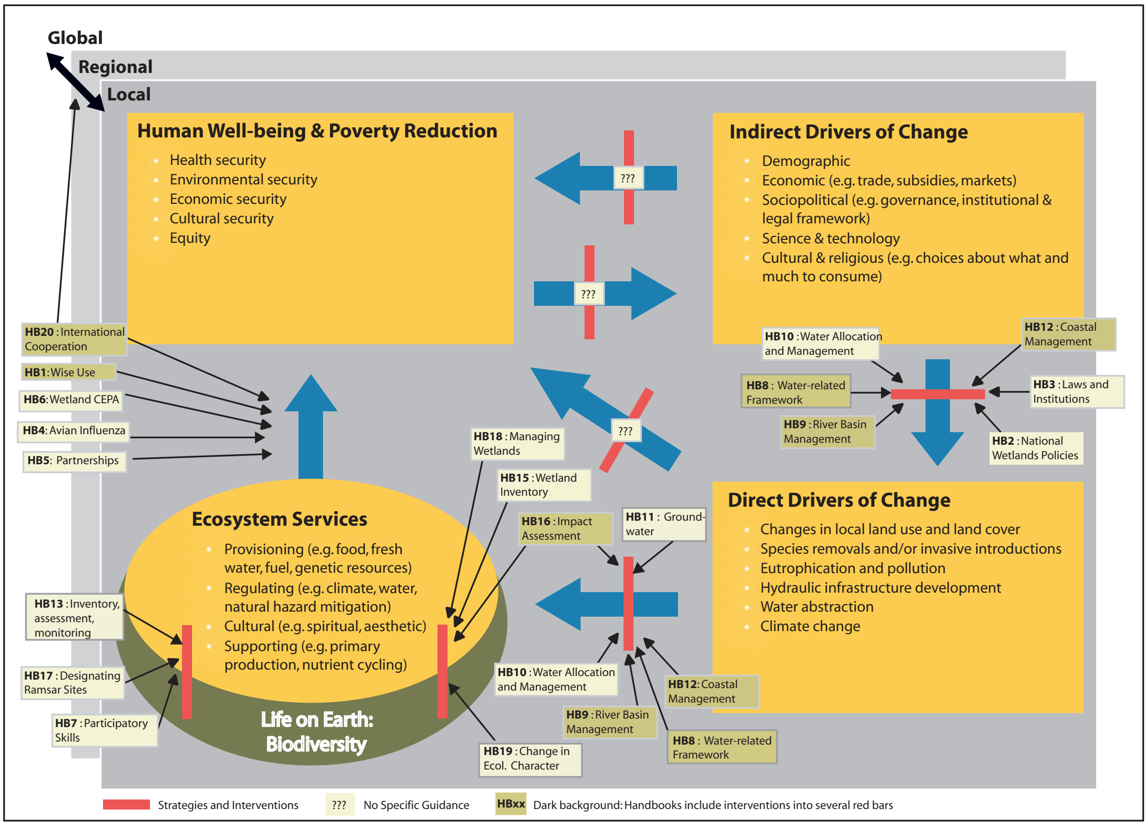


Figure 2.6: A conceptual framework for the wise use of wetlands: links between ecosystem services, drivers of change, human wellbeing and poverty reduction (Ramsar Convention 2006; see also Finlayson et al. 2005)

2.9 From healthy people to ecosystem health

The phraseology of 'healthy ecosystems', like 'healthy wetlands' and 'healthy rivers' (along with healthy parks, healthy landscapes and so on), is widely used and persists in both common and professional circles. This section seeks to examine how the term might be relevant and useful in a broad context of water and human health.

Use of the phrase 'a healthy wetland' implies a judgment on the state of a wetland (i.e., the state of a river, lake, marsh, rice field, coastal area, and so on). The text of the Convention actually refers to a wetland's state as its *ecological character*, subsequently defined as the "combination of ecosystem components, processes and benefits / services that characterize the wetland at any given point of time". In documenting these combined attributes of an ecosystem, wetland managers can determine the current *character* of a wetland, and by monitoring using established indicators, they can ascertain whether this character is changing over time and whether its subsequent state lies within predetermined *limits of acceptable change*. While these capabilities are crucial to the determination of *wise use* and consequently the management of wetlands, the concept is inadequate in three ways. First, it is difficult to make an instantaneous judgment about desirable states, because any state will have some sort of ecological character. Second, ecological character cannot help to reconcile the exchange of one ecosystem benefit or service for another, since all ecosystem benefits/services need to be valued. Third, and related to these, it addresses human well-being through ecosystem services, but this does not explicitly deal with ill-health and disease.

On ecological integrity

To address these limitations, some managers use the descriptors of 'integrity' or 'health'. According to Ulanowicz (2000), 'ecological integrity' has four attributes: i) system 'health' (the continued successful functioning of an ecological community); ii) the capacity to withstand stress; iii) an undiminished optimum capacity for the greatest ongoing developmental options; and iv) the continued capacity for ongoing change and development, unconstrained by human interruptions. When applied to wetland ecosystems, the attributes individually and collectively extend the concept of ecological character by adding a systemic understanding of the desirable properties and behaviour of ecosystems. In addition, the capacity to withstand stress implicitly incorporates diseases.

However, other questions arise. Can human interruptions *ever* be part of ecological integrity? Does human intervention to prevent the unwanted health consequences of a change in ecological character violate ecological integrity because it constitutes a human interruption? In addition, defining ecological integrity by comparison to that of a 'natural habitat' (e.g., Angermeier & Karr 1994) implies that it is a state free from human disturbance, and by extension, that the presence of humans disqualifies an ecosystem from having integrity on the grounds of 'not being natural'. This reasoning is problematic: what sort of human interruption and disturbance disqualifies an ecosystem as having integrity? This is further problematic since some cultural practices will be labeled as natural or unnatural, a practice that might very well be culturally insensitive and inappropriate.

Furthermore, the social construction that humans and their cultures are separate from nature might be considered to be 'the problem'; the dichotomy feeds a way of thinking that allows us to behave as if we were separate from nature, and to act as if we can control nature by virtue of being outside of it (see for example Merchant 1983).

When is a wetland ecosystem 'healthy'?

'Health' is another way of describing the condition of the 'whole'. When applied to humans, health is a complete state of physical, mental, and social well-being and not merely the absence of disease and infirmity. Used as a metaphor for all life, and any other systems, the phrase carries a powerful message, intuitively understood and desired by people. Health might be applied in a series of tiers: the health of an individual, the health of a population, and the health of an ecosystem, each nested within the next tier, where health might include a degree of dysfunction, disease, and/or illness and the health of one tier is dependent at least in part on the health of another tier.

For wetlands, this might apply as much to individuals and populations of fish, zooplankton or macroalgae, waterbirds, or humans, or to the nested tiers themselves. It can also apply to the landscape in which the wetland ecosystem is embedded (when 'coherence' becomes relevant; see Pritchard 2006). The phrase "healthy ecosystem" acknowledges that, like all life, humans are an intrinsic part of ecosystems; of course, humans are implicated in activities that degrade ecosystems, yet they can also be agents for their maintenance or restoration. The health of humans is in some way a measure of the health of the ecosystem in which they live and depend, and vice versa, but this is a relationship, not a correlation, as argued repeatedly in this report.

These views of reciprocity address any psychological or linguistic barrier that exists between humans (themselves) and the rest (their 'environment'), where 'nature' is 'other' than culture. In doing so it attempts to correct the dysfunction in western thinking and policy-making that separates people or their institutions from their context, surroundings, environment.

This reciprocity also dictates that ecosystem management must take an "upstream" vision and "proactive" stance. Dealing only with downstream, proximal, direct effects is reactionary, assumes linear causality, and fails to address system feedbacks, self-organization, complexity and uncertainty. Ecosystem approaches to human health (Lebel 2003) then give guidance over matters such as emerging infectious diseases, disease re-emergence, and anti-microbial resistance, and indeed social determinants of health like poverty and gender inequalities. They offer new and important ways of dealing with systemic consequences of complex interactions involving parasites, pathogens, hosts, their genes, their habitats, human behavior and institutional involvement. Ecosystem approaches give systemic meaning to the health profession's mantra of dealing with the causes rather than the symptoms and the imperative of embracing a strategy of prevention.

Using the language of 'systems' ***can*** help wetland managers convey the complexities of the interactions found among people, water and landscapes (Parkes and Horwitz 2009). Systems thinking is important because it addresses problematic 'conventional wisdom' about how nature (or society or an organization) works: it is not best understood by relatively simple, linear, equilibrium-based models. Systems thinking implores us to think about alternatives to 'controlling' a system, and to avoid predicting a system's behaviour without attending to complexity and uncertainty (unforeseen or unforseeable consequences).

Can healthy ecosystems be measured – are there degrees of health?

Various approaches have been used to measure the health of an ecosystem. They range from a description of symptoms of ecosystem disruption to the use of indicators of systemic attributes, the emergence of human or animal health disease, to qualitative principles.

It has been suggested that disease incidence within a human population can be used to measure the health of the ecosystem of which the community is a part (Rapport 1999), based on the conclusion that the presence of pathogens characterises unhealthy ecosystems. The reasoning underpinning this conclusion is that parasite-host relationships are normal parts of ecosystems, where there are very low probabilities that a pathogen will emerge or re-emerge randomly (Lebarbenchon et al. 2007). In addition, ecosystems with diverse biota and complex trophic structures will not support the repeated and continued emergence of a pathogen. Evidence suggests that changes to ecosystem 'states' can alter these parasite-host relationships and result in host switches producing increased disease incidence (see for example Keesing et al. 2010, and particularly the references to travel, trade and intensive agriculture).

The notion that the delivery of ecosystem services can be enhanced, maintained or disrupted provides a sensitive and useful indicator for the health or integrity of an ecosystem, and specific indicators for a full range of ecosystem services can be examined accordingly (Scholes et al. 2010). Another set of indicators can be derived from the claim that healthy ecosystems retain their vigour (productivity), their resilience (capacity to recover from disturbance), and their organization (their diversity and nature of interactions) (Rapport et al. 1998).

Is the behaviour of the system as a whole desirable or acceptable?

At any level of organization, it might also be argued that behaviours of a system can be desirable and acceptable if the organization of the system is flexible, adaptive and experimental at scales compatible with the temporal and spatial scales of critical ecosystem functions, such that it is unnecessary to pursue relentlessly some sort of stable state. This might be consistent with the Ramsar Convention's framework guidance on detecting, reporting and responding to change in ecological character, where management processes are established by institutions overseeing wetland management to describe ecological character, to develop a management plan (including management objectives and limits of acceptable change), to implement, monitor and respond accordingly (see Ramsar Convention 2008C). A healthy system then has *the organizational capacity to respond, adapt or evolve.*

2.10 Conclusion

A claim to 'healthy ecosystems' comes from the inclusion of the systems thinking required to make judgments on the desirability of an ecological character. It is also explicit about the health of components of the ecosystem (including humans), and about whether organizations are adaptive and responsive to ecosystem changes. In short:

i) an ecosystem can be shown to be 'unhealthy';
ii) 'health' is a powerful metaphor for the condition of an ecosystem; and
iii) ecosystem approaches to human health make critical contributions to public health.

3. Wetland ecosystem services and benefits for the health of human populations

3.1 Introduction

A recognition that *ecosystem services*[4] *are provided by a wetland setting in which determinants of human health exist* contributes to our understanding of the complex relationship that exists in social ecological systems. In doing so we take an ecosystem approach to health (*sensu* Lebel 2003), one that supports human health at the individual, population, and ecosystem level. As described earlier in this report, the term 'health' is used in the broadest possible sense consistent with the definition (as provided in Chapter 1) of health as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity". The definition reflects the spectrum of possible health effects that can result from human exposure to unhealthy wetland ecosystems, from thirst because of lack of water, through acute infectious disease and chronic toxicity because of contaminated water, to unhappiness because of an unstimulating environment, such that lack of access to ecosystems diminishes livelihoods or social interactions, as shown in Table 2.3.

However, it is insufficient to argue that this is best represented by a simple linear relationship where human health improves so long as ecosystem services are maintained or enhanced. While ecosystem services provided by wetlands support a range of benefits for people, and these are interpretable in terms of human health, this does not imply that only non-disrupted wetlands provide benefits for humans, or that disrupted wetlands provide only disadvantages for humans. In broad terms the situation is probably better represented as shown in Figure 3.1, with all four permutations possible.

4 Ecosystem services are defined as the benefits derived from ecosystems. Sometimes these are referred to as 'ecosystem goods and services'; effectively the terms mean the same thing.

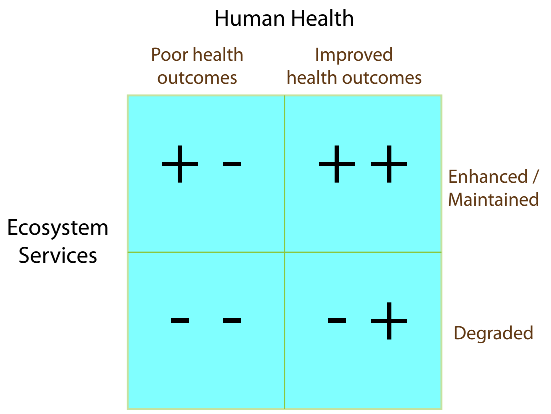


Figure 3.1: Four relationship permutations possible when considering the condition of ecosystem services and human health. The "healthy wetlands, healthy people" relationship is more than just the double positive quadrant.

The 'double dividend' (++ in Figure 3.1) arises when we consider ecosystem services provided by wetlands that support a range of health benefits for people. These might include the provision of fresh water and food items that have a direct link with human health, as well as other services that support wider economic productivity, poverty alleviation and increased food security, or are a potential source of new natural products. In addition, many wetlands have a well-known "insurance" value for many people, reducing their vulnerability to extreme events such as floods, while other wetlands, such as peatlands, play an important role in carbon sequestration. In this respect wetland ecosystem services make tangible contributions to human health and improve the lives of many people at local, regional and global scales, as has been outlined in recent global assessments (Covich et al. 2004; Corvalan et al. 2005b; Finlayson et al. 2005; WWDR 2006; UNEP 2007).

The same assessments have also outlined the many direct and indirect consequences for people when wetlands have been disrupted (resulting in degraded or lost ecosystem services through the many drivers of change that have been widely documented elsewhere). Under these circumstances there is no question that human well-being in general, and human health in particular, will be compromised (the double negative in Figure 3.1), and these types of situations are described at length in the next section. Although this emphasises the 'holistic' nature of the relationship between ecosystem health and human health, it is necessary nevertheless to adopt a more reductionist approach for the purposes of understanding particular health outcomes. A table of ecological exposure pathways can illustrate how health outcomes are related to diminished wetland ecosystem services (Table 3.1).

There are two other conceivable situations that can arise in the relationship. First, degraded ecosystem services can provide benefits to people in such a way that there are positive health outcomes (-+ in Figure 3.1).

Table 3.1: Examples of wetland ecosystem services and ways in which health effects might manifest as a result of diminished services

Ecosystem service	**Pathway**			
	Physical	**Microbial (acute)**	**Chemical (chronic)**	**Socio-Cultural**
Provision of drinking water	Insufficient water	Ingestion of virus/ bacteria/protozoa	Ingestion of toxins	Lack of access due to socio-economic circumstances
Recreational water (i.e., water sports, or fishing)	Drowning	Respiratory (aerosol) Transdermal Intestinal (ingestion)	Respiratory (aerosol) Transdermal Intestinal (ingestion)	Lack of access due to socio-economic circumstances
Water for irrigated agriculture	Vector-borne disease	Respiratory (aerosol) Transdermal Intestinal (ingestion)	Incorporation into food chain and ingestion	Heightened exposure due to socio-economic circumstances
Water for Industry	Accidents	Respiratory (aerosol) Transdermal Intestinal (ingestion)	Occupational exposure Incorporation into food chain and ingestion	Economic
Flood control/ flood storage	Drowning	Spilled sewage and corpses	Mobilised toxins from waste dumps	Trauma, psychiatric conditions, community capacity

Example 1. The application of DDT to wetlands, or drainage thereof, for malaria control (loss of ecological processes (supporting services) of the wetland to decrease infection rates);

Example 2. The conversion of a wetland into a reservoir (loss of regulating services of the wetland to provide water for humans during times of seasonal drought or irrigation for food); and

Example 3. Controlling water flows in rivers as flood mitigation strategies (loss of regulating services to alleviate loss of life or property).

Secondly, maintained or enhanced ecosystem services can have problematic consequences for human well-being (+- in Figure 3.1), and again numerous examples exist:

Example 1. The presence of mosquitoes in urban wetlands protected for nature conservation (with protection to supporting and regulating ecosystem services) exposes humans to arboviral diseases;

Example 2. The presence of large woody debris in rivers (regulating services, slowing down water flows, contribution to trophic web as supporting service) is hazardous for recreational swimming or boating and may even lead to loss of life.

As neat as it might seem, Figure 3.1 greatly oversimplifies the relationship. We are aware that the causal links between environmental change and human health are complex and layered, and often they are indirect, displaced in space and time, and dependent on a number of modifying forces. For example, climate changes can place stresses on agricultural production or the integrity of coral reefs and coastal fisheries, which, through a chain of links related to changes in harvested volumes, food quality, food storage and food distribution, might lead to malnutrition and/or related ailments. Similarly, deforestation may change human population demographics or alter local and regional climates, potentially affecting disease vector distributions and hence disease patterns over time.

Most of these consequences involve the choices we make in managing wetlands for their ecosystem services and/or human health. Wetland ecosystem services have linkages that exist within and between them. Food security, for example, might link to any or all of water quality, household income, plant genetic resources, and fisheries management. These linkages are often important and complex and imply that tradeoffs between benefits will occur when wetlands are developed or otherwise altered to promote or favour one or a few services over others. Decisions that lead to the (over)use of water for domestic urban purposes and market gardens enhance provisioning services (providing water for direct consumption and for production of vegetables), thereby yielding health benefits associated with nutrition and livelihoods. In the process, however, hydrological regimes change and regulating services (maintenance of anaerobic saturated sediments and their biogeochemical processes) are degraded, resulting in human exposures to burning sediments, or acidic metal-rich waters, or surface waters where mosquito breeding is enhanced, each of which might be detrimental for human health. So if water use is knowingly allowed, this represents a tradeoff: one set of ecosystem services for another, and one human health outcome for another (see Section 5.2 below).

This introduces the need to assess carefully the direct benefits and potential direct and indirect losses when managing wetlands and in some instances to reach compromises and agreed tradeoffs between services and beneficiaries.

It must be noted, however, that a comprehensive and specific assessment of wetland ecosystem services and benefits for human health has not hitherto been undertaken. Prior to the impetus provided by recent global assessments (such as the Millennium Ecosystem Assessment (2003, 2005), the World Water Development Report (WWDR 2006), and the Global Environment Outlook (UNEP 2007)), there was a greater emphasis on describing the adverse effects on human health of wetland degradation rather than on describing the benefits of maintaining healthy ecosystems, and as a consequence there is less information about those benefits. Thus there is still significant scope for collecting further information and teasing apart the many complex beneficial inter-relationships between wetlands and human health.

In this section we aim to provide approaches to understanding situations where ecosystem services might be perceived as providing a benefit to human health, in order to demonstrate the importance of ecosystem services for human health.

3.2 Health benefits and values of wetland ecosystem services

Health benefits derived from ecosystem services in general can be expressed by using a variety of approaches. For wetland ecosystems, most will revolve around the centrality of water. Indeed Parkes & Horwitz (2009), *inter alia*, see wetland ecosystems, or water catchments, "as not only a context for future collaboration and actions, but as real, ecosystem-based settings for individuals and society to (re)learn and (re)integrate the fundamental relationships between water, ecology and the determinants of health."

In this sense then, the benefits of wetland ecosystems for human health can be approached in at least three inter-related ways.

A) **Human needs:** Health benefits will accrue when human social and cultural *needs* are satisfied by access to wetlands, everything from survival to income generation to well-being and quality of life;

B) **Health products:** Health benefits will accrue to societies in general and individuals in particular as products of wetlands can be used for pharmaceutical or other medicinal purposes;

C) **Economic value:** As a general rule, as socio-economic status improves for individuals, their health outcomes improve accordingly. Wetland ecosystem services contribute to the material well-being (socio-economic status) of individuals and populations, and they can be valued in economic terms.

Health benefits as 'satisfying needs'

The water found in wetlands can be allocated for human use in different ways. Using the same reasoning as for the allocations of water for economic and environmental requirements, the social context of water in catchment management and the range of social variables that need consideration in any adequate analysis can be defined. The 'Sphere of Needs' model (Syme et al. 2008; reproduced in Figure 3.2) shows the range of needs that should be met to ensure socially sustainable outcomes. Health relates most easily to the direct survival requirements (a full spectrum of which includes water for food, water for drinking, cooking and eating, washing, cleaning, health and healthcare, and waste removal and assimilation). Water is needed to generate income and material well-being, and access to it generates prestige and social identity (see Box 3.1), which are core human requirements. Indeed, "abundant water stands for social well-being, deprivation of water is a classic symbol of poverty" (Strang 2005, p. 114).

Seen in these ways, human needs for water can be the reverse of the same coin (ecosystem) that gives them to humans as *services*. In fact, some of the more distant layers of the sphere represent cultural ecosystem

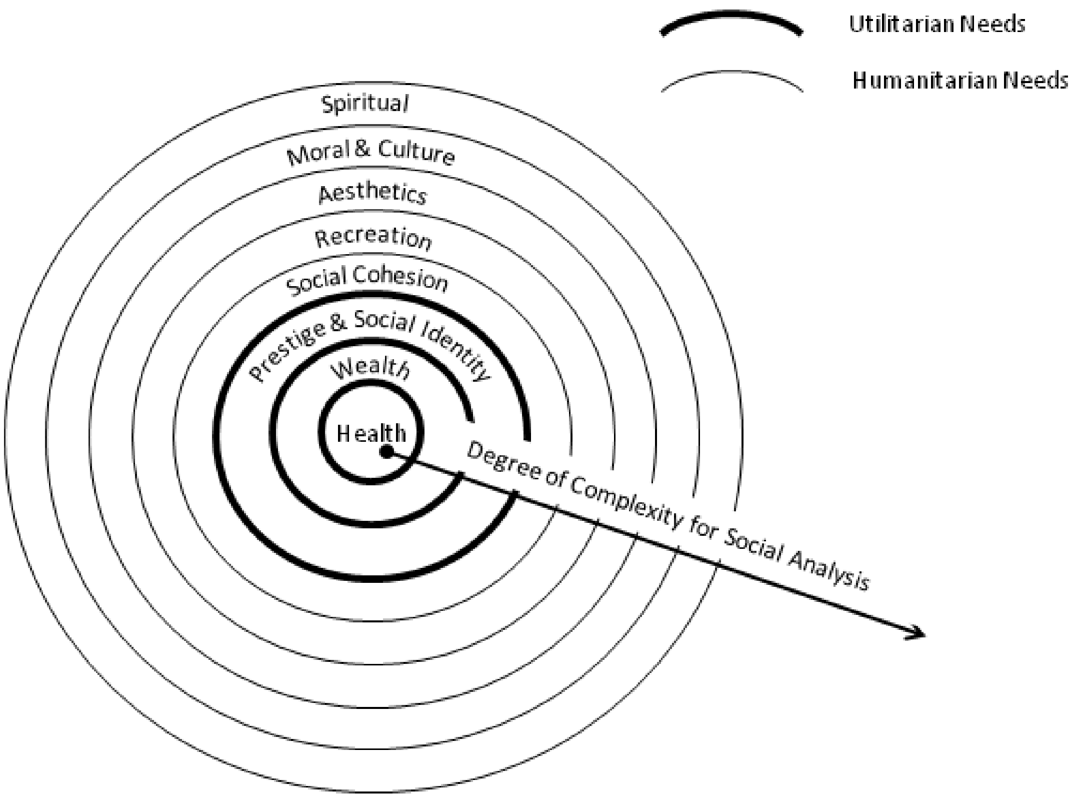


Figure 3.2: Sphere of needs met by water (from wetlands)(Syme et al. 2008)

services in their own right. Humans have a need for recreation to keep mentally and physically fit, and ecosystems provide us with a service that allows us to do so. Aesthetic appreciations of water involve the visual (as in views) but also other senses (like smell and the sound of water), each of which has a preferred state for people, and again a service that is provided by ecosystems.

Others are more complex, like the way water has become embedded in culture through rituals, habits, language and ceremonies (Syme et al. 2008); once embedded, water is needed to sustain behaviours in societies in particular ways. Wetlands in a certain condition provide for these needs, imposing a moral obligation on members of the community to consider what is appropriate for water and its settings. These needs generate meanings for water (and the ecosystem settings); Strang's (2005) ethnographic analysis revealed "major themes . . . presenting water as a matter of life and death; as a potent generative, and regenerative force; as the substance of social and spiritual identity; and as a symbol of power and agency".

Syme et al. (2008) make two important observations about this model. First, the needs are interrelated, so providing for one need may also take care of another, at least partially. All can be linked in some way to human health, for example, so it is not necessary (or even useful) to move from the core to the outside. Secondly the outer layers, with their increasing complexity and uncertainty, will make for more difficult analysis; seen in one way, they will be more difficult to quantify using standard measures for what is important (like money).

Traditional medicines and new natural products

A specific example of a wetland that makes a contribution to human health is the benefit that people derive by having access to traditional medicines, or new medicinal products, where wetland products (plants, animals, sediments or the water) are used (Table 3.2).

Although traditional medicines are dominated by those derived from flowering plants (most of them not from wetlands), it is wetland associated animals (such as leeches and frogs), fungi, bacteria and extremophile lower plants (algae)(e.g. Goss 2000) rather than flowering plants that provide the most productive sources of new natural products.

In some cases, there are close links between the new and old uses of organisms, sometimes from different wetlands on different continents. The medicinal leech (*Hirudo medicinalis*) from European freshwater wetlands provides a good example. Traditionally used for bleeding patients in medieval Europe, leeches are now the source of hirudin, the first major new anticoagulant brought into health care since heparin was discovered in the early 1900s (Moreal et al. 1996). The

Table 3.2: Access to medication and traditional medicines as a determinant of health in a wetland setting: health outcomes (health consequences for a population) that benefit humans, and are diminished as a response to, or caused by, disruption to ecosystem services provided by wetlands.

Health Determinant	Examples of wetland ecosystem services	Health effects, health outcomes from ecosystem services		Examples of disruptions to wetland ecosystems	Examples or case studies
		Benefits if services are maintained or enhanced	Consequences of disruption to the services		
Access to medication & traditional medicines	Medicinal products Cultural heritage Spiritual & religious values Important knowledge systems & importance for research	Improved treatment of illnesses due to pharmaceutical advances Maintenance of cultural connections & traditional treatments for ailments for indigenous peoples	Compromised care from loss of access to pharmaceutical advances Alienation of indigenous peoples from traditional treatments Alienation of indigenous peoples, loss of cultural identity due to commodification of biological diversity	Loss of biodiversity Loss of cultural diversity "Biopiracy" and the patenting of genetic material from indigenous lands & waters	Hirudin (anticoagulant derived from leeches)

link between old and new doesn't end there. To produce sufficient quantities of heparin for therapeutic use requires recombinant technology. This is done using bacteria, eukaryotes and yeasts to produce recombinant forms of hirudin (r-hirudin) (Sohn et al. 2001). Taq polymerase, widely used in polymerase chain reaction (PCR) technology, including DNA sequencing into the genetic material of another organism, is from DNA polymerase of *Thermus aquaticus*, a bacterial "extremophile" which occurs in the geysers of Yellowstone National Park, where its ability to survive extreme heat enables its DNA polymerase to survive the successive heating cycles of PCR. Aside from the direct health benefits from hirudin, there is great economic value in the contribution to PCR technology from *Thermus aquaticus.* Not only did this win its inventor, Karry Mullis, the Nobel Prize in 1993, but in 1991, the Swiss pharmaceutical company Hoffmann-La Roche bought the exclusive world rights to the PCR process for $300 million from Cetus Corporation, for whom Karry Mullis worked at the time (Doremus 1999). In 2005, worldwide sales of PCR enzymes were reported to be in the range of $50-100 million (Lohan & Johnston 2005) and may be more today, given growth in the biotechnology field.

This example illustrates several points relevant to the confluence between wetlands, the Ramsar Convention, natural products and human health. First, the medicinal qualities of leeches are a good example of the continued value of traditional knowledge to health care today. Second, new technologies, such as rapid throughput screening (White 2000) and PCR, are changing the face of new natural product development. Third, links between wetland biodiversity and human health need to focus less on the obvious (such as birds, large mammals or plants) and more on the "hidden biodiversity" (such as fungi and bacteria). Fourth, the case of biodiversity prospecting for *Thermus aquaticus* illustrates how controversial this can be, with claims and counter-claims of ownership (for instance, local peoples claim knowledge of some medicinal properties; scientific developers claim discoveries, with ensuing disputes over patent rights and payment benefits), and this matter has important policy implications and links to the Convention on Biological Diversity (CBD). Finally, the most likely places for promising leads are wetland species from extreme environments, such as hot springs, alpine wetlands, particularly in high diversity montane systems such as the Andes or Himalaya, desert salt-pans, soda lakes, highly alkaline or acid streams, and high diversity tropical rivers. All such ecosystems are defined as wetlands by the Ramsar Convention, and some are listed as Ramsar Sites under the Convention such as the hot springs and soda lakes of East Africa's Rift Valley (Lake Bogoria and Lake Elementeita), but it does raise the question of the Convention being used to protect cultural knowledge and biodiversity where traditional medicines and new product potential exist together.

Traditional medicines

The uneven worldwide distribution of medical doctors is a weakness in public healthcare. Typically, high numbers of medical doctors practice in large cities of developed countries and low numbers in rural areas of developing countries (Wibulpolprasert & Pengpaibon 2003). As a result, traditional medicines continue to serve as the main form of health care for an estimated 80% of people in developing countries (WHO 2002). Across the world, diverse local health care systems have developed over hundreds or thousands of years through complex and dynamic interactions between people and their environment, commonly treating parasitic diseases, diarrhea, and oral hygiene. The use of medicinal plants is also widespread in developed countries. In Australia, for example, 48% of people use complementary and alternative medicine (CAM), and 42% of the population in the United States reportedly do the same (Eisenberg et al. 1998), with use levels increasing significantly in recent years (Pagan & Pauly 2005).

It is estimated that of the 422,000 known species of flowering plants 12.5% (52,000) are used medicinally, with 8% (4,160 species) of these being threatened species (Schippmann et al. 2003). Global exports of medicinal and aromatic plants to China, India and Germany is vast. China is the single largest exporter (chiefly from the mainland to Hong Kong, 140,500 tonnes) and importer (80,550 tonnes)(Lange 1998). The medicinal properties of plants are commonly concentrated within plant families, reflecting their evolutionary history and ecological adaptations, such chemical defenses against herbivores, fungi or pathogens. Although common wetland plants such as cattail or bullrush (*Typha*), common reeds (*Phragmites*) and lotus (*Nelumbo nucifera*) seeds are widely used in traditional medical systems, wetlands dominated by monocotyledons (Cyperaceae, Juncaceae, Typhaceae, Poaceae) are a far less important source of medicinal plants than flooded forests, swamp forests and mountain wetlands and seepage areas. Many of China and India's most important medicinal plants, for example, are from montane bogs, seepage areas and alpine pastures of the Himalaya rather than from the coastal systems better represented by Ramsar Sites. Similarly, Nepal exports between 7,000 – 27,000 tonnes of medicinal plants a year, most of them to India, worth between US$ 7 – 30 million/year (Olsen 2005). Many of these are montane medicinal plants, including threatened species in the Families Ranunculaceae (*Aconitum*), Papaveraceae (*Meconopsis*), Scrophulariaceae (*Picrorhiza*) and Valerianceae (*Nardostachys*) (Cunningham, personal observations). Exceptions to the limited number of medicinal plants in lowland systems are the flooded forests and swamp forests of the African, Asian and South American lowland tropics, which contain a high diversity of medicinal trees and shrubs in the Apocynaceae (*Rauvolfia, Tabernaemontana*), Clusiaceae (*Clusia, Garcinia*), Rubiaceae (*Genipa*), and Euphorbiaceae (*Phyllanthus*) families (Cunningham, personal observations).

In Asia, particularly China, India, Pakistan and Vietnam, government support for the development and modernization of traditional medical systems is likely to increase harvest levels from wild stocks. In India, where the Ayurvedic industry is worth an estimated US$ 1 billion per year, 7,500 factories produce thousands of Ayurvedic and Unani formulae (Bode 2006). In China, clinical trials for Traditional Chinese Medicines (TCM) preparations are now frequent (Qiong et al. 2005) and the plan is to establish a series of standards for modern TCM products and a competitive modern TCM industry through new technology and standardization. In Africa and South America, production is less formal and branding less sophisticated, yet the scale of the trade is quite large. In South Africa, for example, 1.5 million informal sector traders sell about 50,000 tonnes of medicinal plants annually in a region with an estimated 450,000 traditional healers (Mander 2004). As with China, India and Nepal, relatively few medicinal species in African and Madagascar trade are from wetlands, but notable exceptions include the massive trade in the medicinal endemic sundew *Drosera madagascariensis* (Drosearaceae) from Madagascar to Europe (Paper et al. 2005), and in southern Africa, several species come from montane marshes and seepages, *Allepidea amatymbica* (Apiaceae) used for coughs and *Gunnera perpensa* (Gunneraceae), which is used in herbal preparations prior to childbirth. Many wild species supplying medicinal plant markets are undergoing decline in availability, with important implications for primary health care (Cunningham 1993).

New natural products

The process of discovery of new natural products has been radically changed due to the availability of molecular biology, PCR technology (thanks to *Thermus aquaticus* and innovative research), and genomic sciences (Drews 2000). In many ways, biotechnology has become a major tool of the industry. Although the focus of this section is on human health, new natural products have a wide range of other applications, from agriculture to cosmetics, including some with direct links to habitat conservation. The fungal infection *Phytophthora*, for example, poses the major conservation threat to southwestern Australia's unique flora. One of the active ingredients used to treat *Phytophtora*, known as oocydin A, which has applications in agriculture and forestry and conservation restoration, was developed from *Rhyncholacis penicillata* (Podostemaceae), a plant from rivers in southwest Venezuela associated with an endophytes *Serratia marcescens* which produces oocydin A, a novel anti-oomycetous compound (Strobel et al. 1999).

New antibiotics are a good example of health links to new natural products, with 5,000-10,000 new antibiotics discovered from bacteria and fungi since the 1950s and 1960s when well known drugs such as tetracycline were developed (Challis & Hopwood 2003). The bulk of these have come from *Streptomyces* species, which are saprophytes found in soil, marine sediments and plant tissues. Endophytic microorganisms, which are commonly found on plants, including many wetland species, produce a diverse range of compounds with potential use in medicine, agriculture and industry, including new antibiotics, anti-mycotics, immuno-suppressants, and anti-cancer compounds (Strobel & Daisy 2003). The most promising wetlands in which to search for endophytes with commercial potential seem to be the high diversity systems of tropical lowlands, montane and boreal systems rather than mono-dominant wetlands, and recent studies in Canadian wetlands support this conclusion (Goss 2000).

In addition to *Thermus aquaticus*, as the best known extremophile, there is great interest in other extremophiles. Wetland examples include the green algae *Dunaliella acidophila*, which survives at pH <1, and *Gloeochrysis* which lives on stones in acidic (pH 2) streams running out of active volcanoes in Patagonia, Argentina (Baffico et al. 2004). They have industrial applications including waste treatment, the production of liposomes for drug delivery and cosmetics, and the food industry. For wetlands and human health this can have both positive outcomes (such as waste treatment) and negative outcomes (such as their use as protein-degrading additives in detergents, made possible because of their ability to withstand high temperatures).

Valuation of Benefits Derived from Ecosystem Services

Wetland ecosystem services contribute to the material well-being of individuals and populations, satisfying a human need for income, improving socio-economic status, which mediates a health benefit[5]. They can be valued in economic terms.

Given an increased emphasis on market-based mechanisms for assessing and managing ecosystem services, an overview of economic valuation is provided as a prelude to describing examples of the benefits for human health, with some being expressed in economic terms or capable of being economically valued.

Economic valuation comprises a set of tools for quantifying the benefits (both marketed and non-marketed) that people obtain from wetland ecosystem services and enables decision-makers to weigh the economic costs and benefits of any proposed change in a wetland. The broadest framework of these is the Total Economic Value approach (see Box 3.1).

Economic valuation, adopting a utilitarian approach, enables conversion of the exchange values in terms of money and thereby permits comparison with other tangible benefits that emerge through alternate uses of wetlands. While the amount of information on the economic value of wetlands is growing and advances have been made in calculating and expressing the value of wetland services, a major challenge remains in ensuring that the results are fed into decision-making processes and used to influence conservation, health, and development agendas. This may require a further shift and realisation that wetland conservation and management can benefit from a closer association of economic and ecological perspectives – a key message from the Millennium Ecosystem Assessment water and wetland synthesis (Finlayson et al. 2005). This highlights the exchange value of ecosystem services and the importance of maintaining an ecosystem condition in order for it to provide its ecosystem services (Bingham et al. 1995). An example is provided by Tapsuwan et al. (2009)(Box 3.2).

A range of valuation techniques exist for assessing the economic value of ecosystem services of wetlands (see de Groot et al. 2006 for a summary of the methods and constraints). Application of these market and non-market valuation techniques present policy makers with useful economic estimates of the contribution of wetlands towards sustaining health and guiding sound decision making. A summary of some of wetland specific economic valuation studies is presented in Table 3.3.

Though economic values of wetlands are site-specific and contingent upon the provision of services that are perceived as valuable by a particular society, attempts have also been made to assess the global values of these services based on meta-data analyses. Woodward & Wui (2001), using results from 39 studies, came up with estimates of various ecosystem services ranging from US$ 7–2,993 per hectare per year at 1990 prices. Brander et al. (2003) analyzed 190 valuation studies drawn from various regions for five wetland types and suggested the value of ecosystem services to be US$ 2,800 per hectare. De Groot et al. (2008) provide an estimate of US$ 3,300 per hectare per year, although it is an under-estimate as values for several services could not be included.

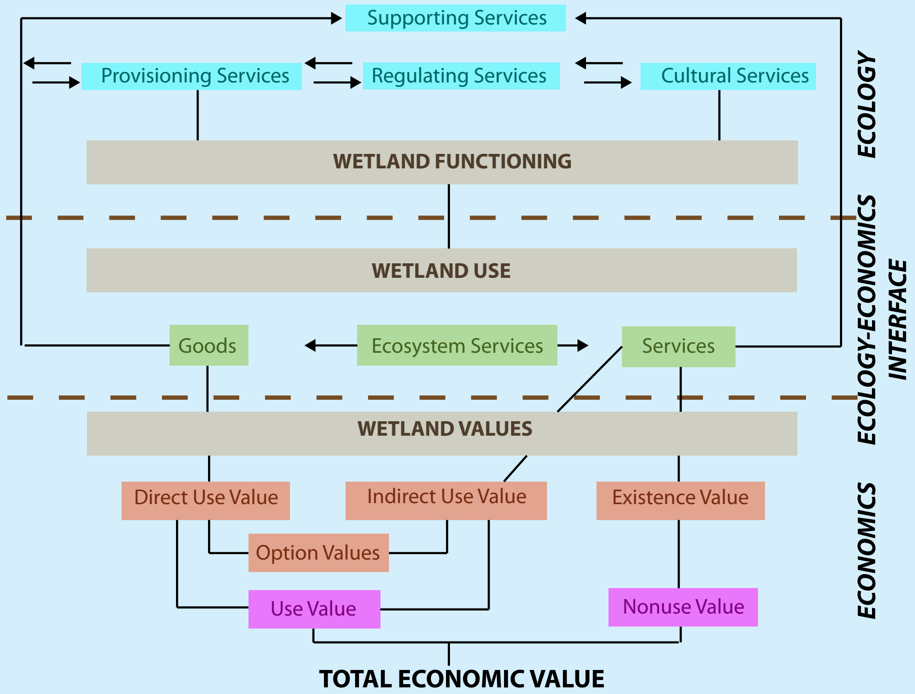
In general, the valuation studies highlight the significant contribution of wetlands to local, national, regional and global economies. Several of these studies also indicate that when both marketed and non-marketed economic benefits are included, the total economic value of an unconverted wetland is often greater than that of a converted wetland. Burke et al. (2002), in an assessment of coral reefs in Indonesia, demonstrated that a healthy coral reef could provide an average sustainable fisheries yield of 20 tonnes per year as compared to 5 tonnes per year for a reef damaged by destructive fishing practices. Similarly, sustainable fishing within the reefs could generate as much as US$ 63,000 per km^2 more over a twenty year period than over-fishing on healthy reefs. Economic assessments carried in Ream National Park, Cambodia, indicated that mangroves provided subsistence support to nearly all of the resident population of Sihanoukville province (Emerton 2005). The net value of park resources was estimated to be US$ 1.2 million a year, averaging to US$ 220 for every household living in and near the national park. These values far exceed the benefit yielded by alternative uses: clear cutting the mangroves could generate just half of these benefits. Even prawn farming under the best conditions could realize only a fragment of the economic benefits provided by the intact system.

An understanding of the pattern of sharing and accrual of economic benefits across various stakeholder groups provides an important insight into wetlands and poverty linkages. In several circum-

5 A derivation of this exists: the opportunity costs of managing wetland ecosystems for public health and medicine. Since there will be costs associated with health outcomes due to the degradation and disruption of wetland ecosystem services, acting to prevent them will bring economic advantages This remains a fruitful area of research that might provide a way of resolving some of the tradeoffs mentioned in Section 3.1; it is discussed in more detail later in Section 5.4.

Box 3.1: Total Economic Value (TEV) Framework

TEV is based on the presumption that individuals can hold multiple values for ecosystems and it presents a useful framework for ensuring that all values are considered in empirical analyses and decision making. This framework is widely used for assessing the utilitarian value of ecosystems and it disaggregates TEV into use and non-use values. Use values are those that arise from the *in-situ* use of a resource and can be further classified into direct use and indirect use values. The direct use values arise from commercial as well as non-commercial uses of wetland services. Direct use values include products that are used by local communities and harvested directly, such as reeds, or fuel wood etc. Indirect use values include the support and protection provided by wetlands to the economic activity and property, such as the value created through flood protection or groundwater recharge.



Framework for TEV of wetland ecosystem services (adapted from Turner et al. 2000).

The non-use values are unrelated to the current use of the resource and can be further classified into option value, bequest value, and existence value. Option values occur due to uncertainty over the outcome of a particular use of a natural resource, given that decisions about these resources are generally irreversible. Due to this uncertainty an individual associates some value to the right to take a decision at a future time when the uncertainties have largely been resolved due to better information about the consequences of a particular decision. Bequest values are related to altruist tendencies, the value generated by the motivation of bequeathing the resource to future generations. This basically represents the value that would be lost if a resource were degraded in quality or quantity, but continued to exist. While the basis for determining a bequest value is the direct consumption of the services generated from a resource, it does not accrue as a consumption benefit to the person to whom this value is imputed. Existence values reflect what would be lost if a resource ceased to exist, that is, the value generated by the existence of a resource.

stances, wetlands are inhabited by extremely poor and marginalized sections of society whose subsistence is linked with the wetlands' resources. Household surveys in areas adjoining Ream National Park indicated that the wetlands contributed more than 65% of the household incomes of the families living in and around them. A study on Hadejia-Nguru wetlands examined the value of wild resources used for food, raw material and firewood and concluded that returns from harvesting and selling palm fronds provided returns three times the average agricultural wage (Eaton & Sarch 1997).

Table 3.3: Examples of economic valuation of wetland ecosystem services

Wetland ecosystem service	Site / Location	Wetland Type	Year	Value Imputed (US$)	Reference
Provisioning Services					
Fisheries	Louisiana, USA	Coastal	1989	2,100 / ha	Costanza et al. (1989)
Fisheries	Bintuni Bay, Indonesia	Mangroves	1994	583.5 million/ year	Ruitenbeek (1994)
Groundwater recharge	Hadejia–Nguru Wetlands, Nigeria	Floodplains	2000	13,000 / day	Acharya et al. (2000)
Regulating Services					
Water purification	USA		1995	15,400/ ha	Breaux et al. (1995)
Nutrient cycling	That Luang Marsh, Laos	Freshwater Marshes	2003	71,000/ year	Gerrard (2004)
Flood control, flood storage	Waza Logone , Cameroon	Floodplains		3,000/sq km	IUCN (2001)
Coastal shoreline and river bank stabilization and storm protection	Fiji	Mangroves		5,820/ha/ year	Lal (1990)
Storm protection	Koh Province, Cambodia	Mangroves		32 /ha	Bann (1997)
Flood protection	That Luang Marsh, Laos	Freshwater Marshes	2003	2.8 million/ year	Gerrard (2004)
Cultural Services					
Recreation	USA	Assorted	1986-87	360 / user	Bergstrom et al. (990)
Ecotourism	Kenya	Assorted	1993	450 million / year	Moran (1994)
Supporting Services					
Primary Production	Louisiana, USA	Brackishwater marshes	1979	42 ,000 – 69,800 / ha	Costanza et al. (1989)

Some wetland services such as flood protection and storm buffering could be of particular value to the poor, who have no access or means to otherwise protect themselves (FAO 2001). Under such circumstances, a decline in the resource base due to the loss of wetlands or their particular services could critically affect the livelihoods of these communities, exacerbate poverty and health conditions, and result in emigration. Loss of wetlands was identified as one of the major reasons behind the catastrophic floods in China in 1998, which left 20 million people displaced and economic losses exceeding US$ 32 billion (Eftec 2005). Iftihkar (2002) showed that the decline of mangroves in the Indus Delta as a consequence of water allocation decisions had seriously jeopardized the livelihoods of more than 135,000 people who relied on mangrove products with an economic value of US$ 1.8 million, as well as damaging the coastal and marine fisheries sector that was generating domestic and export earnings of almost US$ 125 million. Riopelle (1995) cites information about a hotel in West Lombok, Indonesia, which had spent US$ 880,000 over a seven-year period to restore a 250m stretch of beach allegedly damaged by past coral mining.

Despite significant advances in the field of economic valuation of wetlands, there are several issues which need further attention to be able to sufficiently encapsulate the contribution of wetlands to human health and well-being. Most valuation attempts represent a partial approach within a particular policy context without sufficiently addressing the substitute or complementary relationships within the services.

Box 3.2: Valuing urban wetlands in Perth, Western Australia, using hedonic property pricing methods

"Up to 60 per cent of potable water supplied to Perth, Western Australia, is extracted from the groundwater system that lies below the northern part of the metropolitan area. Many of the urban wetlands are groundwater dependent and excessive groundwater extraction and climate change have resulted in a decline in water levels in the wetlands. In order to inform decisions on conserving existing urban wetlands, it is beneficial to be able to estimate the economic value of the urban wetlands. Applying the Hedonic Property Price approach to value urban wetlands, we found that distance to the nearest wetland and the number of wetlands within 1.5 km of a property significantly influence house sales price. For a property that is 943 m away from the nearest wetland, which is the average distance to the wetland in this study, reducing the wetland distance by 1 m will increase the property price by AU$42.40. Similarly, the existence of an additional wetland within 1.5 km of the property will increase the sales price by AU$6976. For a randomly selected wetland, assuming a 20 ha isolated circular wetland surrounded by uniform density housing, the total sales premium to surrounding properties was estimated to be around AU$140 million (AU$40 million and AU$230 million)."

The authors define 'hedonic property pricing' in the following way: "The hedonic pricing method is based on the idea that properties are not homogenous; they differ in respect to a variety of characteristics . . . [so] property prices can be affected by all these location-specific environmental, structural and neighbourhood characteristics. The method relies on observable market transactions, for instance, property sales data, to place values upon the various characteristics that make up a heterogeneous product . . . [and] prices of properties near wetlands contain a capitalized amenity value for wetland proximity, so that when the properties are sold, the new buyers have to pay for this amenity value in the form of higher house prices".

-- Tapsuwan et al. 2009, p. 527

The inability to address the non-linearity of ecosystem functions and values often leads to uni-polar solutions of "either all or none" choices between conservation and development (Barbier et al. 2008). Rigorous assessment of the affects of ecosystem changes on ecosystem services calls for the application of integrated ecological-economic modeling which can capture various systemic attributes and their socioeconomic linkages and can lead to solutions that can balance conservation-health development tradeoffs.

An example of complex and long-term benefits provided by wetlands for human health and well-being is the Lagoon and City of Venice along the Adriatic Sea (Box 3.3).

A further example of complex linkages is seen in the strategies used in Bangladesh to reach tradeoffs between increasing rice production on the floodplain versus maintaining the natural wetland for fish production, when both are important to the diet of local populations (Shankar et al. 2004). Similarly, important tradeoffs exist between the benefits of major infrastructure development projects such as large dams and the unintended consequences of increased infectious disease risks (such as schistosomiasis), or the negative impacts on previously sustainable fisheries based on fish whose spawning or migrations were dependent upon natural river flows (see Corvalan et al. 2005b; Finlayson et al. 2005; Vorosmarty et al. 2005). Even the increased recreational uses of a wetland, with the positive health and tourism benefits they provide, may require conservation tradeoffs, such as acceptance of the continued presence of exotic fish in rivers in places like Chile and New Zealand (Dudgeon et al. 2005).

3.3 Conclusions

Ecosystem services provided by wetlands form the basis of a range of human health and well-being benefits. Effective recognition and communication of these benefits could lead to meaningful cooperation between wetland managers and health service providers, leading to the development of more effective holistic management strategies.

Wetlands are one of the most productive sources of traditional medicines and new natural products. Traditional community medicines derived from wetlands are commonly used to treat parasitic diseases, diarrhea, and oral hygiene in developing and underdeveloped economies, thus forming important parts of the health infrastructure. Wetland-based medicinal and aromatic plant species form a significant segment of global trade in these materials. New natural

Box 3.3: The Lagoon and City of Venice and human well-being

The Lagoon of Venice is a huge coastal wetland of more than 50,000 hectares located along the northwestern shore of the Adriatic Sea. It has immense social and ecological importance for the city of Venice and much more widely as well. The benefits provided by the Lagoon and City transcend health and incorporate many aspects of human well-being, and the maintenance of the Lagoon is seen as evidence that the city authorities have long realised that it was an essential element in the Venetian way of life.

The Lagoon contains a diversity of wetland types including saltmarshes, tidal mudflats, marshes, tidal canals and channels, outlets to the sea, and fishponds. It is one of the most important feeding stations where birds rest and refuel on their journeys along international flyways. It has been likened to a "major service station" on an inter-European motorway for some 130,000 migrating waterbirds.

The cultural heritage of the Lagoon and City was recognized as a World Heritage site by UNESCO in 1987. In addition to the heritage value of the built environment, there is a vibrant informal or intangible heritage, namely the fiestas, folklore, popular knowledge, myths, legends, gastronomy, etc. These are often under-rated in many modern societies, but in the Lagoon of Venice they constitute an essential part of its history. The ancient origins of the cultural heritage are also evident in unique institutions, such as the Magistrature for Waters (*Magistrato alle Acque*) which has manage the waters of the Lagoon since the start of the 16th Century.

An immense amount of research, legislation, and funding has gone into the conservation and management of the City and Lagoon of Venice over the centuries, and more especially over the past few decades as the threats to this unique site have become more evident. The principal problems facing the Lagoon include subsidence and erosion, but there are others, too.

Subsidence occurs naturally in the Lagoon, but it has been accentuated by the convergence of various human activities causing the lowering of the water table (over-exploitation of the aquifers, dredging of canals, fishery practices which have an impact on the bottom of the Lagoon, insufficient inflow of sediments of fluvial origin, etc.) with repercussions both on the natural ecosystem and on the normal life of the City through the frequency of extraordinary high tides that flood a considerable part of Venice at certain periods of the year.

Rapid erosion of the sediments of the Lagoon is leading to a loss of its coastal wetland characteristics and replacement by a marine environment. The causes are many, with some being natural and others related to human activities, both historically and more recently by the greater use of motor boats.

Pollution. Lagoon bottom-sediments and water pollution largely from the industrial area around Porto Marghera has led to high levels of chemical pollution in the waters and the substrate, often with heavy metals. Furthermore, many of the rivers coming from the Alps, which formerly provided sediments for the lagoon, now carry a heavy load of pollutants.

Fishing has always been a major part of the culture of the Venetians, both in the open Lagoon and in the fish farms ("valli"). The shellfish production in the Lagoon is one of the most productive in Europe, chiefly because of the tidal influence. Fishing of both types, traditional and commercial, must continue, but some regulation and control will be needed to prevent over-fishing and to avoid fishing in polluted areas. The appearance in the past fifteen years of the Philippine Clam (*Tapes philippinarum*) has caused new and unfamiliar problems. The unregulated and illegal catching of these very profitable molluscs, using dragnets which scrape the bottom of the Lagoon, has exacerbated the erosion problem.

Tourism. Increasing numbers of tourists have placed heavy pressures on the City, resulting in changes in use of the buildings, in saturation of urban spaces, and in the generation of a vast quantity of solid and liquid waste – and, in short, in a loss of cultural identity. In recent years there has been a decrease in services being made available for local residents and an increase in services for tourism, including an increase in car parks, road and port facilities, etc., which has led to the loss of the essential character of certain parts of the City.

The Lagoon is, and always has been, an area of high biodiversity, and these attractions can be perfectly well utilized for recreational and eco-tourism activities. There is a strong local hunting culture that has grown up over the centuries in the Lagoon, and this activity, carried out for sporting purposes, is fully compatible with the conservation of the ecosystem. Some measures have been taken to establish nature reserves, but further protection measures are required, and above all educational measures on developing reserves for the public and for schools.

As Venice is a city "built on water", it needs to maintain its water – its rich natural and cultural heritage is built around the lagoon and its water. *-- adapted from Smart & Vinal 2005.*

products derived from wetlands have a wide range of applications ranging from medicine to agriculture.

By reducing human vulnerability to disasters and extreme events, many wetlands provide "insurance" value through the formation of natural buffers. By storing water and slowing movement, wetlands buffer surrounding areas from storms and floods. In several countries, conversion of wetlands has been cited as one of the primary reasons for increased vulnerability to disasters. Efforts to contain them, on the other hand, through structural and hard engineering measures have often proven to be costly and ineffective. This has prompted several governments to integrate wetlands into their disaster reduction strategies.

The scarcity of some ecosystem services and the need to choose between alternatives poses the unavoidable question of relative values. Quantification and valuation of wetland ecosystem services in a way that makes them comparable with the returns derived from alternative uses can facilitate improved policy and decision making. The application of economic valuation techniques has yielded useful economic estimates of the contribution of wetlands towards health objectives to guide sound decision making. Case studies from across the globe have yielded region-specific and global economic estimates that demonstrate the significant contribution of wetlands to local, national, regional and global economies and local livelihoods. Several assessments also indicate that when both marketed and non-marketed economic benefits are included, the total economic value of an unconverted wetland is often greater than a converted wetland. However, further research needs to be directed at integrating tradeoffs that emerge at various scales and across a multitude of stakeholders. Recent advances in ecological-economic modeling show interesting applications for addressing these issues in line with the principles of wise use.

Disruption and/or loss of wetland ecosystem functions impose huge economic costs. Staggering economic estimates of damages due to the destruction of wetlands, particularly emerging from recent well-publicized disasters, and of restoration costs, indicate the relative cost effectiveness of investments in the conservation and wise use of wetlands.

4. Wetland ecosystem settings: core requirements for humans, their livelihoods and lifestyles

4.1 Introduction

Health issues of concern with respect to wetland ecosystems have been placed in nine classes in Table 2.3 above. Here we develop a more comprehensive treatment of four of them: two are core requirements for human health and well-being, namely sufficient and safe water, and adequate nutritious food provided by wetlands, and two are the settings for social determinants of health in wetlands, namely livelihoods and lifestyles. This section builds on previous material presented in Section 3 above, to the effect that wetlands can be fundamental for human health and well-being through provisioning ecosystem services, and in Section 2, that wetlands can be regarded as the settings for human health where we learn, work, play, and love.

Table 4.1: Ecosystem services that are of principal interest for sufficient and safe water

Health: core requirement	Relevant wetland ecosystem services	Health effects, health outcomes from ecosystem services		Examples of disruptions to wetland ecosystems	Examples or case studies
		Benefits if services are maintained or enhanced	Consequences of disruption to the services		
Access to sufficient water	Drinking water for humans /livestock Groundwater replenishment Water purification/ waste treatment or dilution Flood control, flood storage	Adequate water availability to meet human needs Good hygiene	Dehydration (inequality, conflict, immigration) Poor hygiene Physical hazards (land subsidence, flood damage, etc.)	Depletion of water from drainage or over-extraction Loss of access to water (contamination) Non-renewal of water due to decline in rainfall.	*Box 4.1.* Waste water treatment – the East Kolkata wetlands, India

4.2 Sufficient and safe water

Adequate access to safe freshwater supplies continues to be one of the major factors contributing to poor human health. It is underpinned by several discrete ecosystem services that regulate and supply water.

The principal supply of renewable fresh water for human use comes from inland wetlands, including lakes, rivers, swamps, and shallow groundwater aquifers. The global renewable resource base has been estimated at around 44,000 cubic kilometres of fresh water per year, with global water withdrawals of over 3 800 cubic kilometres per year (Molden et al. 2007; Table 4.2). Asia accounts for over half of the total withdrawals, with OECD countries next, using about one third, and the remaining continents each representing less than 10% of global use. Agricultural withdrawals account for 70% of all use, followed by industrial and then domestic applications.

is invaluable for human well-being through the provision of energy and food and for transport, as well as water for irrigation and human consumption; the balance of benefits obtained from reservoirs has been widely articulated, but possibly less widely agreed (see World Commission on Dams 2000; Vorosmarty et al. 2005).

Globally, though, some 2.8 billion people live in river basins where water scarcity occurs (Molden et al. 2007). About 1.6 billion of these live in areas of *economic* water scarcity where human, institutional, and financial capital limit people's access to water even though water in nature is available locally to meet human demands. Another 1.2 billion people live under conditions of *physical* water scarcity in river basins where water resources development has exceeded sustainable limits. At the same time further water development is often seen as being necessary to ease problems of poverty and inequality (Molden et al. 2007). Given the importance of fresh water

Table 4.2: Water resources and withdrawals, 2000
(cubic kilometres per year unless otherwise indicated).

Region	**Renewable water resources**	**Total water with-drawals**	**Water withdrawals**						**With-drawals: as % of renewable resources**
			Agriculture		Industry		Domestic (urban)		
			Amount	Percent	Amount	Percent	Amount	Percent	
Africa	3,936	217	186	86	9	4	22	10	5.5
Asia	11,594	2,378	1,936	81	270	11	172	7	20.5
Latin America	13,477	252	178	71	26	10	47	19	1.9
Caribbean	93	13	9	69	1	8	3	23	14.0
North America	6,253	525	203	39	252	48	70	13	8.4
Oceania	1,703	26	18	73	3	12	5	19	1.5
Europe	6,603	418	132	32	223	53	63	15	6.3
World	43,659	3,829	2,663	70	784	20	382	10	8.8

Source: based on Molden et al. 2007

Groundwater, often recharged through wetlands, plays an important role in water supply, providing drinking water to an estimated 1.5–3 billion people, but despite its importance, sustainable use of groundwater has seldom been sufficiently supported through appropriate pricing and management action. Another important water supply is represented by the widespread construction of artificial impoundments that stabilize river flow and now hold back an estimated 6-7,000 cubic kilometres of fresh water that

for people, it seems inevitable that with increasing human populations and their demands for water, further water development will occur – the manner in which this is done will determine if further adverse environmental consequences can be limited, if not avoided (Falkenmark et al. 2007; Finlayson et al. 2005; Vorosmarty et al. 2005).

Adverse health outcomes from insufficient water are direct in terms of human water requirements for survival, and indirect in terms of lack of access to drinkable water and water suitable for sanitation and hygiene. Poor quality water contributes to a range of human health problems such as diarrhea, internal parasites, and trachoma. Unsafe water, inadequate sanitation, and insufficient hygiene are the major risk factors for diarrheal disease, which is the second leading contributor to the global burden of disease (WHO 2010). Lack of access to safe drinking water and poor sanitation usually affects the poorest sector of society, with follow-on affects for food security.

According to Pruss-Usten et al. (2008) in an important publication from the World Health Organization, an major share of the total burden of disease worldwide – around 10% – could be prevented by improvements related to drinking-water, sanitation, hygiene, and water resource management. For the Millennium Development Goal 7 (Environmental Sustainability), one target is to reduce by half the proportion of people who lack sustainable access to safe drinking water and basic sanitation. By far the largest burden of disease associated with water is found in developing economies (Table 4.3), and these countries are usually those with economic or physical scarcity of water.

Global assessments track progress towards meeting the MDG target by 2008 and show nearly 900 million people still without improved sources of drinking water, and over 2.6 million people not using improved sanitation facilities (WHO & UNICEF 2010). Large differences exist between urban and rural populations for both of these, with the rural populations more disadvantaged, and this is true in most developing countries; here women shoulder the largest burden for collecting drinking water (WHO & UNICEF 2010). These global trends need to be considered in wetland management processes.

Wetland ecosystems provide water treatment services in different but inter-related ways. A wetland combination of depositional environments, aerobic water columns, anaerobic sediments, and microbial suites can ensure that nutrients, other inorganic compounds including those containing metals and metalloids, and organic molecules, remain bound within sediments.

Wetland vegetation plays an important role in improving water quality through extraction and/or filtering of pollutants (e.g., nitrates) and amelioration of pathogens including coliform bacteria and faecal streptococci (Ghermandy et al. 2007; Verhoeven et

Table 4.3: Summary statistics on deaths and disabilities (in DALYs: disasbility-adjusted life years) related to water, sanitation and hygiene in 2002

DISEASE OR INJURY	DEATHS						DALYS[a]					
	Total		Children 0–14 years		Developed countries	Developing countries	Total		Children 0–14 years		Developed countries	Developing countries
Population ('000)	6 224 985		1 830 140		1 366 867	4 858 118	6 224 985		1 830 140		1 366 867	4 858 118
	('000)	%[b]	('000)	%[b]	('000)	('000)	('000)	%[b]	('000)	%[b]	('000)	('000)
Total deaths or DALYs	57 029		11 945		13 430	43 599	1 490 126		544 534		213 574	1 276 552
Total WSH-related	3 575		3 011		73	3 503	135 748		117 789		1 861	133 887
% of total deaths or DALYs	6.3%		25%		0.5%	8.0%	9.1%		22%		0.9%	10%
Diarrhoeal diseases[c]	1 523	42.6	1 370	45.5	15	1 507	52 460	38.6	48 830	41.5	648	51 812
Intestinal nematode infections[d]	12	0.3	8	0.3	0	12	2 948	2.2	2 884	2.4	3	2 945
Malnutrition (only PEM)[c,e]	71	2.0	71	2.4	0	71	7 104	5.2	7 104	6.0	83	7 021
Consequences of malnutrition[c,e]	792	22.1	792	26.3	9	783	28 475	21.0	28 475	24.2	181	28 294
Trachoma[d]	0	0.0	0	0.0	0	0	2 320	1.7	13	0.0	0	2 319
Schistosomiasis[d]	15	0.4	0	0.0	0	15	1 698	1.3	560	0.5	1	1 697
Lymphatic filariasis[d]	0	0.0	0	0.0	0	0	3 784	2.8	1 211	1.0	1	3 783
Subtotal water supply, sanitation and hygiene	2 413	67.5	2 241	74.4	24	2 389	98 789	72.8	89 077	75.6	918	97 871
Malaria[e]	526	14.7	482	16.0	0	526	19 241	14.2	17 984	15.3	11	19 230
Onchocerciasis[e]	0	0.0	0	0.0	0	0	51	0.0	10	0.0	0	51
Dengue[e]	18	0.5	14	0.5	0	18	586	0.4	512	0.4	0	586
Japanese encephalitis[e]	13	0.4	7	0.2	0	13	671	0.5	459	0.4	0	671
Subtotal water resource management	557	15.6	502	16.7	0	557	20 550	15.1	18 965	16.1	12	20 539
Drownings[e]	277	7.7	106	3.5	33	244	7 871	5.8	3 845	3.3	736	7 135
Subtotal safety of water environments	277	7.7	106	3.5	33	244	7 871	5. 8	3 845	3.3	736	7 135
Other infectious diseases[e,f]	328	9.2	162	5.4	15	312	8 538	6.3	5 902	5.0	196	8 343

Source: Pruss-Usten et al. 2008

Box 4.1: Waste water treatment – the East Kolkata wetlands, India

The East Kolkata Wetlands (EKW), located on the eastern fringes of Kolkata city, is an assemblage of sewage-fed fish ponds spread over an area of 12,500 hectares. They are part of the Gangetic delta and sustain one of the world's largest and oldest integrated resource recovery practices, based on a combination of agriculture and aquaculture providing livelihood to a large, economically underprivileged population of around 20,000 families that depend upon the wetland.

The East Kolkata Wetlands were salt lakes prior to the 18th century when they comprised the backwater spill of the Bidydhuree River which carried the tidal flows from the Bay of Bengal. Kolkata city, which grew on the levees of River Hooghly in the 16th century, presented the picture of an undrained swamp in the immediate vicinity of a malarious jungle – the salt lakes. Most of the sewage and solid waste of the city used to be dumped in the river and the low-lying areas, giving rise to frequent outbreaks of malaria, plague, and other diseases. Committees constituted to find solutions for waste management recommended construction of canals to carry all the sewage to the low-lying salt lakes on the eastern periphery of the city. Since the mid-19th century, the city has grown without any waste treatment facility, draining all its sewage and dumping all its garbage into the wetlands – and surviving on the nutrient retention service provided by those ecosystems.

Changes in deltaic processes in the Gangetic Delta aggravated by channelization led to rapid decline in the wetlands' connectivity with the Bay, mainly marked by the cessation of all flows in the Bidyadhuree River. Discharge of sewage carried through the canals from the city resulted in brackish lagoons becoming less saline, and this was soon converted as an opportunity to establish a system of sewage-fed fisheries, horticulture and agriculture, thereby adding/transforming nutrient retention to augmentation of food production. Reduction in salinity created a conducive environment for colonization of freshwater fish in these wetlands; it is also likely that some informal stocking of fish was undertaken. The first attempt to develop freshwater aquaculture is reported in 1918. Subsequent construction of wastewater channels in the city increased the access of farmers in the area to wastewater, which in turn encouraged others to adopt wastewater aquaculture. The wetland system presently has 264 functioning aquaculture ponds (locally called bheries), which produce annually more than 15,000 MT of fish. The solid waste dumping on the western periphery of the wetlands have been converted to horticulture since 1876, and this productive vegetable growing area became known as Dhapa, producing on average 150 MT of vegetables daily. These wetlands thereby have become central to the food security of the city, and the whole area has come to be recognized officially as a Waste Recycling Region.

As the city expanded, the demand for land increased, leading to the conversion of large areas of wetlands for creating new settlements. During the 1950s, the government of West Bengal conceived the first large-scale project of building up Salt Lake City in eastern Calcutta. This involved the development of about 1,000 ha and the filling of some hundred ha of water bodies between 1962 and 1967. In 1969, redistribution of land through land reforms led to further filling of approximately 2,500 ha of water bodies for conversion into paddy fields. However, the attempt by the government to reclaim and develop more than 300 ha of land adjacent to the city for construction of a trade center alarmed the environmentalists of the city, who filed a petition for conservation of wetlands. The state High Court, recognizing the values and functions of wetlands, restrained any further wetland conversion, and it also banned any further change in land use within the waste recycling region. The state government mooted a proposal to designate the site as a Wetland of International Importance under the Ramsar Convention, subsequently listed as a Ramsar Site in 2002. The East Kolkata Wetlands (Conservation and Management) Act was notified in 2006 to lay the foundation of the East Kolkata Wetland Management Authority and systematic implementation of wise use principles for management of the Ramsar Site.

The Management Authority presently grapples with the challenges of rapid sedimentation due to alteration of flow regimes, sewage allocation between various production systems, the changing quality of sewage from organic to non-organic attributed to industrialization, continuing high levels of poverty, a decline in biodiversity, and the need to improve the effectiveness of institutions and governance systems. A management plan has been formulated to identify specific strategies and actions.

-- Case study contributors: Ritesh Kumar and Chaman Trisal, Wetlands International – South Asia

al. 2006; WWDR 2006). Fisher & Acreman (2004) collated data from 57 wetlands globally and found that at most of them the presence of vegetation reduced incoming nutrient concentration.

In some cases, wetland ecosystems near large cities have become an important if not critical part of water treatment of effluents of various types, with the East Kolkata wetlands in India being an outstanding example (Box 4.1) In fact, this role is so useful that artificial wetlands have been purposely created for this purpose in many countries (Molle et al. 2005; Verhoeven et al. 2006).

Finally, wetland landforms and to a certain extent vegetation are *adjusted hydrologically*, meaning that they have been defined by the floods they received in past centuries or millennia. A failure to recognize these ecosystem services, by for example inappropriate drainage, habitation and infrastructure in flood-prone environments, will have profound consequences for access to drinkable water and sanitation (see section 4.6).

4.3 Nutrition

A core contribution of wetlands to human health is through the provision of food security. The three main components, each linked to ecosystem services provided by wetlands, are: i) food availability; ii) buying power or social capital to access food with cash or through barter; and iii) sufficient nutrients from the available food (Boko et al. 2007). In addition, food security in the future may also depend on the genetic material contained within wetland plants. Wetland degradation and loss can impact on all of these components. For example, important food crops like rice (*Oryza* species), taro (*Colocasia* species), and cowpeas (*Vigna* species) are the basis of diets in different parts of the world, where they play an important role on local and political economies and have significant wild relatives that might be important in the future.

Significant wetland foods for human well-being: rice and fish

Rice, a staple food item for almost half the world's population, is grown in a wide range of environments (irrigated fields, rainfed flooded fields, and rainfed non-flooded fields) and in 2005 covered an estimated 127 million hectares (see Figure 4.1), almost 90% of this is Asia, with Africa and the Americas each having around 5%. Worldwide, some 79 million ha of irrigated lowland rice provides 75% of the world's rice production and receives 35-45% of the world's irrigation water and some 24-30% of developed freshwater resources (see Bouman et al. 2006). In the 1960s the combination of new high-yielding rice varieties and increased use of water, fertilizer, and pesticides led to a rapid increase in productivity that, along with an increase in cropped area, enabled total rice production over the past 40 years to keep pace with the tremendous growth in population in Asia (Bouman 2007).

Table 4.4: Food security as a determinant of health in a wetland setting

Health: core requirement	Relevant wetland ecosystem services	Health effects, health outcomes from ecosystem services		Disruptions to wetland ecosystems (examples)	Examples or case studies
		Benefits if services are maintained or enhanced	Consequences of disruption to the services		
Access to sufficient nutrition	Water for irrigated agriculture Food for humans Food for livestock Biological control agents for pests/ diseases Other products and resources, including genetic material Soil, sediment & nutrient retention	Good nutrition, growth & development Appropriate diet (including essential vitamins & trace elements) & appropriate behaviour associated with a healthy diet (i.e., physical exercise)	Malnutrition, Starvation, Stunting Inappropriate diet: obesity, diabetes, vitamin deficiency, eating disorders	Overextraction of water for irrigation Overharvesting of wetland produce Over application of pesticides Loss of genetic diversity/ variety & simplification of wetland trophic webs as a result)	Rice Fish (& aquaculture) Reduction or simplification of diet Agricultural subsidies

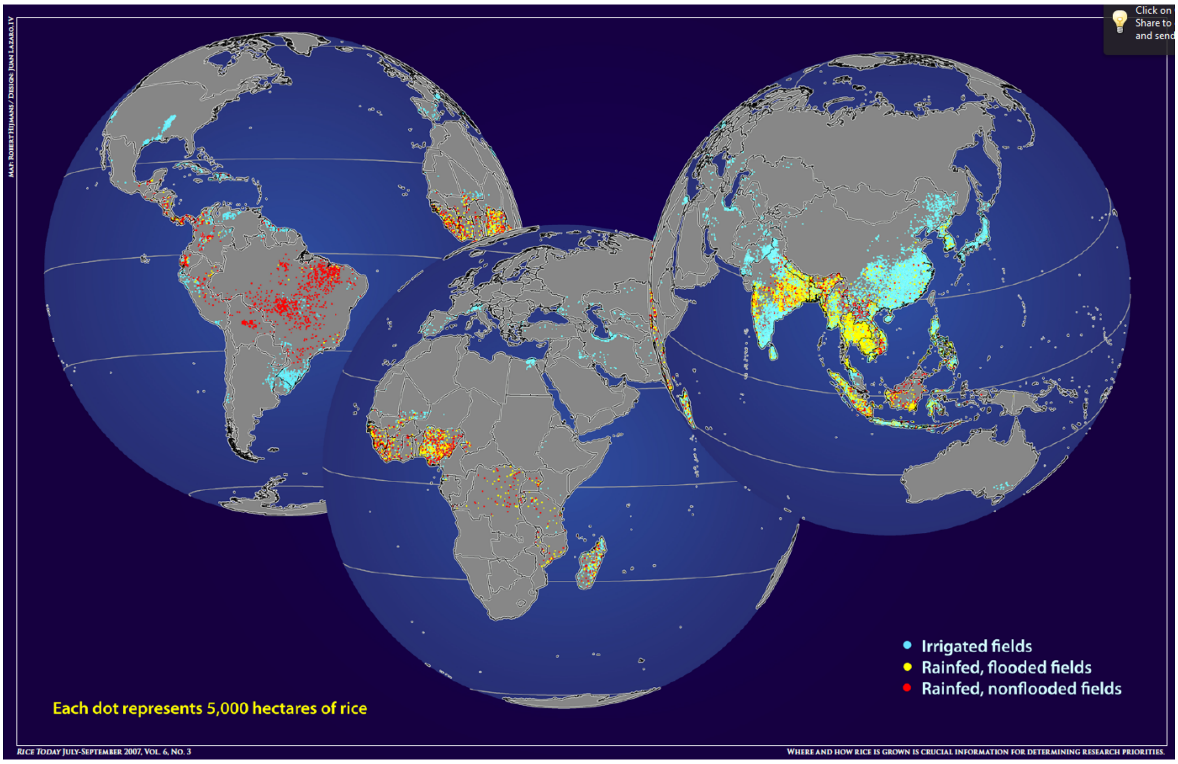


Figure 4.1: Global map of irrigated, rainfed and flooded and non-flooded rice fields (from Hijmans 2007)

Fish are particularly important to people's diet and health in developing countries where they often form the main source of animal protein. Fisheries can be either oceanic or wetland (from coastal, estuarine, and inland wetlands): the latter is the focus here. The importance of wetland fisheries economically should not be underestimated (Kura et al. 2004) – for example, inland fisheries and aquaculture contribute about 25% of the world's production of fish and are often critical to local food security, with the value of freshwater production to human nutrition and incomes being much greater than gross national production figures suggest (Dugan 2005). Wood & Ehui (2005) reported that approximately 10% of wild harvested fish are caught from inland waters; however, as it is difficult to measure freshwater fisheries catches, these may be underreported.

The bulk of inland fish production is generated by small-scale activities, with high levels of participation in catching and farming as well as in processing and marketing (Kura et al. 2004; Wood & Ehui, 2005; Dugan, 2005). At the regional level the main increases in inland fish catches have been in Africa and Asia, with those in the former reflecting increased yield from lakes, especially of Nile perch (*Lates niloticus*) from Lake Victoria. The Mekong river sustains one of the world's largest freshwater fisheries, with an annual yield of 1 million tonnes of fish, most of which are harvested by small-scale artisanal fisheries (Valbo-Jorgensen & Poulsen 2000). In Cambodia, local people get about 60-80% of their total animal protein from the fishery in Tonle Sap and associated floodplains. Floodplain fisheries are often very productive, although fish production is highly variable due to seasonal floods and longer-term climatic trends that threaten fisheries such as those around Lake Chad and from increased fishing pressure (Jul-Larsen et al. 2004). In addition to their nutritional value, the socio-economic value of freshwater fishery is especially high as they often support the livelihoods and food security for low-income and vulnerable groups, including women and children.

Fisheries have been augmented through the development of aquaculture in many countries, predominantly in wetland settings, which in 2002 contributed approximately 27% of fish harvested and 40% (by weight) of all fish consumed as food (Wood & Ehui 2005). In Asia and Europe aquaculture has been developed over centuries and has not only provided a staple food item, but has also changed the landscape, as best shown by the 6,000 ha Trebon fishponds in southern Bohemia. Although the development of extensive aquaculture in many parts of the world has increased output (particularly for shrimp), at least for a limited time period, it has also brought about many social and environmental problems. Despite these problems and the apparent lack of success of some countries in managing coastal aquaculture, the

Box 4.2: Aquaculture and human health

Aquaculture is intimately associated with wetlands. It relies on two types of production systems: land-based (ponds, rice fields, tanks, etc.) and water-based (cages, pens, shellfish rafts, and long-lines). Irrigated rice fields apart, most land-based aquaculture systems make new wetlands by creating ponds and harvesting rainwater and/or extracting water from rivers or coastal seas. The increase in wetland areas and increased physical contact with water from routine pond management and the deterioration of quality of those water bodies receiving aquaculture wastes can all pose problems for human health.

As aquaculture relies on the environment for a range of ecosystem services, it can result in decreases in biodiversity and environmental quality and indirectly impact on human health (Beveridge et al. 1994, 1997; Naylor et al. 1998). For example, pumping seawater into coastal shrimp ponds can lead to salinization of groundwater, compromising its use for domestic purposes, while intensive cage aquaculture discharges its wastes directly into the environment, resulting in eutrophication and environmental deterioration that impacts most directly on the poor (Beveridge 2004).

Aquaculture impacts on human health both directly and indirectly and in both positive and negative ways. Fish are an excellent source of protein, fats, minerals (calcium), and vitamins A and D and represent one of the most important sources of dietary lipids for humans and are generally rich in Omega 3 fatty acids, which are known to reduce coronary vascular disease and inflammatory and autoimmune disorders such as rheumatoid arthritis. Adequate intake is essential during pregnancy, lactation and infancy to ensure proper development of brain and retinal tissues. However, contaminants in the aquatic food chain (organochlorines, such as DDT, PCBs, endocrine disruptors and metals) may put fishing communities that rely heavily on seafood in their diets at particular risk (UN 2007).

In contrast to capture fisheries, it is possible to minimise pollution risks in aquaculture through careful sourcing of dietary ingredients. However, intensively reared fish are usually fed on diets containing fishmeal and fish oil, which, depending on dietary inclusion rates and whether they are sourced from oily fish, can contain elevated levels of contaminants (Easton et al. 2002; Moreau et al. 2007).

A recent household consumption study among urban households in Cameroon has shown that fish is most important in the diets of the poor and that poor households spend more on fish (39% of the total) than other animal protein sources (R. Brummett, pers. comm.). Results from nationwide studies in Malawi have shown that fish farming households consume more fresh fish and animal protein and were more food secure than non-fish farmers (Ruddle 1996; Dey et al. 2007). Moreover, WorldFish, in partnership with World Vision, has recently demonstrated that women and child-led households in some 1,200 HIV/AIDS-affected families doubled their income and greatly increased fish and vegetable consumption, critical in helping to survive the infection. Studies in Bangladesh and Cambodia have also shown that small indigenous wild fish species captured from fish ponds during harvest are an important source of Vitamin A, Ca, Fe and Zn for women and children in the locality (Roos et al. 2007).

-- Information supplied by M. Beveridge, World Fish Centre, Egypt

development of improved codes of practice and integrated coastal zone management has ensured that shrimp culture is still a major economic activity for many people (Kura et al. 2004). While the value of aquaculture has been steadily increasing (Box 4.2), the manner in which it has been practised has raised concerns and conflicts with other water users, including agriculture, and in some instances can undermine efforts to support the poorer members of society who rely on open access to fisheries (Kura et al. 2004; Atapattu & Molden 2006).

Wetlands, nutritional deficiencies and supplementation

An additional dimension concerns wetlands and food quality. Over-harvesting from some wetland ecosystems can result in the loss or erosion of nutrients and a decline in the nutritional quality and volume of food produced. These situations are reversible, but only with the import of nutrients from elsewhere, requiring regular energetic and financial inputs that may be unsustainable in the long term. An example is the Mekong delta in Vietnam, where it has been reported that extensive clearing of the natural vegetation for growing rice led to the development of acid sulfate soils and a need to add fertiliser in order to sustain the production of rice (Minh 2001).

In the developing world, increased food production across broad areas has come in the form of starch and oils, diminishing the variety of foods and resulting in deficiencies in micronutrients and attendant health consequences (Box 4.3), a phenomenon that has been termed "hidden hunger". The simplification of diets, especially of the poor, is sometimes regarded as a particularly urban phenomenon, but it also occurs in rural areas. Agricultural subsidies have played a role in the development of hidden hunger: high-input agriculture, reduced transportation costs and other subsidies have combined to make refined carbohydrates (wheat, rice, sugar) cheaper than ever in the cities of the developing world, where fried 'street foods' are often the most important dietary item for many poor people (Frison et al. 2004).

Addressing dietary diversity requires a multi-dimensional approach focusing on nutritional and health status, socio-cultural traditions, income generation, and biodiversity conservation. Referring to the "nutrition transition" (the non-communicable disease consequences of malnutrition linked to a large extent to a shift in diet), Frison et al. (2004) concluded that:

> "A more diverse diet is one key to combat this trend and to healthier lives, with biodiversity, nutrition and conservation coming together in mutually reinforcing virtuous circles to the ultimate benefit of all people. Small-scale farmers, especially women, who grow and use diverse crops improve their own health and that of their families, and at the same time improve their incomes by supplying diversity to the market. As healthier, well-nourished people growing a range of appropriate crops, they will better conserve the natural landscapes around them. And when people perceive that agricultural biodiversity has greater value through positive impacts on both income and health, they are more likely to maintain and protect it."

Wetlands, food security and sustainable livelihoods

Wetlands also provide opportunities for balancing food security and human health aspects within the framework of sustainable livelihoods. Rice-fish culture is one option which has been identified as an extremely efficient way of using the same resource base to produce both carbohydrate and animal protein. In rice-fish farming systems, fish help control weeds as well as insects and snails with less need for pesticides, including insecticides that are otherwise used heavily in rice cultivation systems. This is beneficial to the farmer, the environment, and arguably the consumer as well. Fish also play an important role in the nutrient cycle of rice fields, increasing the fertility while reducing the requirements of fertilizer input, resulting in better grain yields. In China, this system of agriculture has been shown to be three times more profitable than growing rice alone (Halwart & Gupta 2004).

Starchy staple diets (rice, cassava, maize) are frequently deficient in nicotinic acid, vitamin C, calcium, riboflavin, and protein. Harvested wild foods are known to be a valuable source of these nutrients, particularly in protein from edible fish and shellfish, nicotinic acid (niacin) from wild edible greens, and vitamin C from wild fruits. Although many edible wild plants are harvested from forests or woodlands rather than wetlands, a wide diversity of wetland plants provide these supplementary food sources. Popular food species are also traded, for example, watercress (*Rorippa nasturtium-aquaticum*) in Europe, *Maritia* fruits and *Euterpe* palm hearts from South American floodplain forests, lotus (*Nelumbo nucifera*)

Box 4.3: The importance of micronutrient deficiency in human diets

"Micronutrients are the essential vitamins and minerals required by human beings to stimulate cellular growth and metabolism. Nineteen vitamins and minerals are considered essential for physical and mental development, immune system functioning and various metabolic processes. Deficiencies of iron, iodine and vitamin A are the most widespread forms of micronutrient malnutrition with public health consequences. Other micronutrients have been shown to play a role in preventing specific disease conditions (e.g., folic acid, calcium) or in promoting growth (e.g., zinc). The global prevalence of zinc and folate deficiency has not yet been established, but it is predicted to be significant, as micronutrient deficiencies rarely occur in isolation. One reason is that deficiencies usually occur when the habitual diet lacks diversity or is overly dependent on a single staple food, as is the case with monotonous cereal- or tuber-based diets. Situations of food insecurity, where populations do not have enough to eat, will also inevitably result in micro nutrient deficiency."

-- quoted from Kennedy et al. (2003)

seeds and water-chestnut (*Eleocharis* species) tubers in Asia, and wild rice (*Zizania aquatica*) and cranberries (*Vaccinium oxycoccos*) collected for food and trade by indigenous people in North America**.** Further investigation is necessary before we can really articulate the value of these items, especially when they are consumed or traded in local or remote communities.

In their literature review of the burden of long-term community ill-health following natural disaster events, Cook et al. (2008) described the spectrum of malnutrition as highly variable and occurring as a consequence of devastated production areas, general calorie- or protein-deficiencies, inadequate intake of micronutrients, or excessive ingestion of trace elements (Box 4.4).

largely influence the types of food that are available and what is ultimately chosen to eat. Closer to individuals but still largely outside of their control are the conditions in which they live and work: safe, healthy environments are critical to the level of population health. For example, an unsafe work environment in the agricultural, fishing and mining industries results in the highest rates of injury-related mortality in rural and remote regions of developed countries. At the perimeter is the national and regional environment that sets limits on the social infrastructure available to support health or governance in general. Opportunities for education, housing, and nutrition, all influential factors for human health, are constrained by, for example, global and national distribution of wealth.

Box 4.4: An outline some of the consequences of natural disasters for malnutrition

Flooding disasters provide a dramatic example as they can directly decrease the quantity of food supplies (such as crop yields and fish stocks) or access to such supplies. Impaired nutritional intake is also a risk factor for mortality from infectious diseases, such as gastroenteritis and measles, which are often also more common immediately after such disasters. In refugee populations, a range of nutrition-mediated outcomes, including the relationship between vitamin deficiencies and increased childhood mortality, have been described.

Populations already vulnerable to poverty and food insecurity, such as some of those in Sub-Saharan Africa, are particularly likely to succumb to superimposed crises. Droughts over many years (which are likely to become more prolonged and widespread if climate change predictions are correct) are associated with increased risk of disease and malnutrition, and monsoonal floods in Bangladesh have resulted in adverse long-term outcomes for a range of developmental and nutritional indicators.

The May 2008 tropical cyclone in Myanmar (Burma) is a further example whereby the local population was exposed to the after-effects of severe flooding and loss of rice production, resulting in an ongoing humanitarian crisis (on top of over 133,000 fatalities).

-- Adapted from Cook et al. (2008)

4.4 Social determinants of health

The multiple layers of influence on health show the relative influence of livelihood on human health and well-being (Whitehead & Dahlgren 1991). Core determinants are the age, sex and hereditary factors that an individual possesses, and there are particular health characteristics depending on each of these. Individual behaviours are imposed upon these factors, and they too exert a direct influence on health: risk taking, sedentary lifestyles, over- or under-eating, and so on. These behaviours are themselves influenced by socio-economic, cultural and other social factors, reflecting a range of norms and practices that affect health. Consumption patterns are a good example of this: in some countries, cultural values, amplified through sophisticated marketing,

All these determinants can play out in a ‘healthy setting’, which is relevant to this report when that setting is a wetland.

Livelihoods

As described above, the way people make a living is an important determinant of their health. Livelihoods comprise the capabilities, assets (stores, resources, claims, and access), and activities required to make a living. When these capabilities, assets, and activities are conducted in a wetland setting, wetland management seeks to achieve goals of both sustainable livelihoods and human health (Table 4.5).

A livelihood is sustainable if it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, provide opportunities for the next generation, and provide net benefits to other

Table 4.5: Livelihoods as a determinant of health in a wetland setting

Social determinant of health	Examples of wetland ecosystem services	Health effects, health outcomes from ecosystem services		Examples of disruptions to wetland ecosystems	Examples or case studies
		Benefits if services are maintained or enhanced	**Consequences of disruption to the services**		
Livelihoods	Water purification/waste treatment or dilution Most provisioning services All cultural services	Reduced workplace, occupational exposures Sufficient water & food Sustained living made from wetland assets	Work-place, occupational exposures Insufficient water, insufficient nutrition, exposure to toxics, diseases and psychological stresses associated with loss of livelihoods from change to a wetland ecosystem	Overextraction of water Overharvesting of foods Both impacting on individuals dependent on them for their livelihoods.	The rice paddy – places of production & conservation The Aral Sea – loss of water, food & livelihoods.

livelihoods at the local and global levels in the short and long term (Chambers and Conway 1992, cited in Friend 2007).

As Box 4.5 shows, the livelihoods frameworks and approaches (like the social determinants of health framework) are *people-centered*. The common principles provide the approach by which wetlands can be managed so that the wetland ecosystem services that underpin livelihoods and the social determinants of health can be maintained.

These sustainable livelihood principles can be illustrated when considering wetland livelihoods. A family draws much of its livelihood from a rice-paddy. Members of the family can have individual circumstances that might make them more susceptible to ill-health (or wellness), such as a genetic factor, advanced age, or pregnancy. Their health might also

Box 4.5: Common principles across 'livelihoods' frameworks and approaches

People are the priority concern: their values and aspirations need to be the starting point of inquiry, emphasizing how people themselves understand and talk about their livelihoods, vulnerabilities, values, and strengths.

Approaches should be empowering for, responsive to, and participatory with those who have diminished voice, opportunities, and well-being – both as a means and an end to good development.

Household and individual strategies are based on the use of a wide range of assets (or 'capital') – natural, human, infrastructural, financial, socio-cultural, political.

The viability of livelihood strategies requires the managing of these assets to achieve livelihood outcomes such as income, food security, health, and well-being.

People, including poor people, have significant knowledge of, and are capable managers of, their resources even in conditions of extreme hardship; their activities and outcomes should inform policy and effective governance.

To achieve livelihood outcomes, macro and meso scale structures and processes (dealing with socio-economic forces, household and community dynamics of wealth and power, the influence of the markets, state institutions and policy, regional and global economic and development trends) should support people to build on their strengths.

Securing sustainable livelihoods requires interventions at numerous levels – individual, households, community, etc. – and requires an integrated approach.

-- *(derived from Carney (2002), Friend (2007), and Senaratna Sellamuttu et al. (2008)*

be determined by lifestyle factors like their diet, their alcohol consumption, or the amount of sleep they get each night. Social and community influences might determine when in the day, or during the week, in what type of weather, they may be working in the fields, and the length of time they can work for. This might then expose them differentially to living and working conditions such as pesticide applications, mosquitoes (and potentially arboviral diseases), or machinery accidents. The likelihood of exposure will change according to socio-economic conditions (the need to cultivate to sustain a community's livelihood), cultural conditions (observance of religious festivals, planting and harvesting customs), and environmental conditions (such as climate change, migratory birds, etc.), and knowledge systems for all of these. And the ability of the family to earn its living will also be influenced by government constraints and market conditions. A wetland manager, or an environmental health service provider, will therefore need to be aware of these different influences and, most importantly, of how they constantly interact. The principles in Box 4.5 provide the guidance for the approach the wetland manager or health service provider should take to sustain the family and community livelihood, by understanding the family and community situations by listening to their stories, hopes and wishes, and by acting according to them, within the context of local and traditional knowledge, government requirements, and market forces.

A concrete example comes from the Aral Sea, where ecosystem disruption (again through alteration of the water regime and associated effects) has had significant and well documented effects on livelihood and health for the local and regional population (Box 4.6). A livelihoods approach, applied at the regional level, provides a way of regaining ecosystem services through socio-cultural re-invigoration and ecological restoration programmes, albeit on a local and regional scale.

Finally, there is also a good example in Hurricane Katrina, where the loss of resilience in the social ecological system, seen in the inability or failure of many people to evacuate; the 28 breaches of the New Orleans levees, caused by under-engineering and insufficient maintenance; and the slow and inadequate emergency response (WWDR 2006), caused a broad range of health-related issues. Particular difficulties were experienced by the elderly. For others, stress and disenchantment resulted from an expectation of more appropriate emergency relief. Evacuees were placed at increased risk of depression and post-traumatic stress disorder, domestic violence, and domestic abuse. There was a displacement of hundreds of thousands of residents, with attendant loss of livelihoods, and considerable financial hardship was felt most keenly in lower income households, who because of limited resources often take longer to pass through the transition to recovery. In all, it was a classic example of wide-scale interruption of established community, cultural and social ties.

Lifestyles

Proximal determinants of health can frequently include lifestyle factors, that is, abilities, behaviours and activities such as diet, level of physical activity, drug misuse, and ability to cope with stress. While the potential health benefits of using natural environments as a site for physical activity are commonly recognized (see for example Pretty et al. 2005), the non-material psychological health benefits of contact with nature (such as mental restoration, connection to cultural heritage, creating a sense of place) are often taken for granted in materially comfortable societies (Millennium Ecosystem Assessment 2005).

Nevertheless, the literature is beginning to demonstrate the health benefits of contact with nature beyond physical activity, as the following three examples show. Stronger feelings of reflection, relaxation, and emotional attachment, all associated with better mental health, have been recorded by visitors to green spaces with greater biodiversity and species richness, suggesting that bushland conservation and consideration of the quality and complexity of urban green spaces may significantly enhance human well-being (Fuller et al. 2007). Recent research (Collins et al. 2009) also suggests that residents in lower income neighbourhoods are more likely to rate their health as fair or poor if they perceive their neighbourhood environment to be of poor quality. And some evidence is emerging that people involved in local conservation projects report better general health and a greater sense of belonging in their community than those people who were not involved (Moore et al. 2006).

Lifestyle factors in a healthy wetland setting are related to the ecosystem services provided in the setting, particularly leisure and recreation, water sports, nature study pursuits, and associated cultural heritage for both physical and mental health (see table below). Little empirical evidence exists for wetlands in particular because researchers have tended to focus on 'green spaces' generally; nevertheless, green spaces within urban settings are more often than not also wetland settings (streamside walks and rides, promenades along watercourses, lake-based play grounds, etc.), given human affinities for wetlands and watercourses. Indigenous expressions of the cul-

Box 4.6: The Aral Sea – livelihoods and human health effects of hydrological change

The Aral Sea in Central Asia was once the fourth largest lake in the world. The lake borders Tajikistan, Uzbekistan, and parts of Turkmenistan, Kyrgyz Republic, and Kazakhstan. The AmuDarya and the SyrDarya are the two main river systems that feed into the sea.

Water and irrigation have always been the basis of life in this region and by the beginning of the 20th century irrigated lands accounted for 3.5 million hectares with irrigation networks of different levels. At this stage the population was around 7 to 8 million and over time it has boomed to exceed 50 million people, and along with this increase, irrigated lands also doubled to around 7.5-7.9 million ha. With this increase in water withdrawals to about 120 km3, of which 90% was for irrigation, the flow of water to the sea through the two river systems have almost completely stopped. Between 1960 and 1995 the sea underwent reduction of the sea level by 17m (at a rate of 80-90cm per year) and the volume by 75%. With the reduction in water volume in the sea and the increasing evaporation, the salinity has also increased sharply from 9.94g/l in 1965 to 15g/l in 1996. The main crops grown in the area are cotton and rice amongst other export products.

Effects on agriculture and fisheries. The reduction in the sea area had many implications for agriculture. Desertification took over, resulting in vast wastelands with fine white sand which started to blow and pollute the agricultural lands, reducing the productivity and output. As a result, the farmers had to compensate by applying more fertilizers and pesticides to the soil, making the situation worse. With climate changes associated with the reduction of the sea, things have become harder for the farmers – the climate has become more continental, reducing the growing period to 170 days, less than the 200 frost free days required for harvesting cotton.

As the water situation deteriorated, the river deltas were also converted to agricultural lands with heavy pesticide use. Over-irrigation also led to areas of heavy salt build-up. The overuse of the pesticides and fertilizers have led to the pollution of surface and groundwater bodies, and the delta ecosystems had disappeared by 1990. More than 95% of the marsh wetlands had turned into sand deserts – more than 50 delta lakes, covering 60,000 ha, had completely dried up.

Local fisheries were also important for livelihoods and provided annual catches of 40,000 tonnes. High mineral levels (40g/l) prevent the survival of most of the sea fish and wildlife that was present. All commercial fishing came to an end in 1982 and current catches remain negligible. Fishing communities in the region now remain unemployed.

Implications for livelihoods and well-being. Farming and fishing were the two main sources of livelihood for the people of the area, and with the disappearance of the fish and the agricultural lands becoming completely depleted of nutrients and polluted, unemployment is a raging problem. The people have no way of feeding their families and have little access to safe drinking water, as the sea water is heavily polluted. In Karakalpakstan the drinking water is saline and polluted with high contents of strontium, zinc and manganese

Health problems are also a concern as local people are highly susceptible to disease due to malnutrition added to the poor quality drinking water. Curable tuberculosis is considered to be epidemic in the region (with around 250 to 370 out of every 100,000 being infected). Other common health issues include throat problems, lung cancer, kidney disease, hepatitis, asthma, bronchitis, gastrointestinal disorders, infant mortality, birth defects and anemia. More than 20 million people in the region suffer from poor health due to the hazardous conditions. It is said that very little work has been done to address the health problems in the region because it involves not only the need for medication, but also for nutrition and education.

-- Sources: www.american.edu/ted/aral.htm, www.redcross.org/news/in/asia/020410aral.html, www.fao.org/ag/magazine/9809/spot2.htm

Table 4.6: Lifestyles as a determinant of health in a wetland setting

Social determinants of health	Examples of wetland ecosystem services	Health effects, health outcomes from ecosystem services		Examples of disruptions to wetland ecosystems	Examples or case studies
		Benefits if services are maintained or enhanced	**Consequences of disruption to the services**		
Lifestyles (& personal behaviours)	Recreational hunting & fishing Water sports Nature study pursuits Educational values Understanding ecosystem behaviour Cultural heritage Contemporary cultural significance, including for arts & creative inspiration, & including existence	Maintenance of recreational opportunities in wetland ecosystems (benefits derived from physical exercise) Educational opportunities; better understandings of wetland ecosystems (improved ability to respond to life threatening events) Health benefits associated with opportunities to be creative & productive	Loss of recreational opportunities (decline in physical fitness) Loss of educational opportunities (decline in ability to respond to life-threatening events) Mental health issues associated with alienation from culturally significance elements of wetland ecosystems	Loss of access to wetland ecosystem preventing health gaining activities and behaviours (i.e., destruction, contamination, drainage, infilling, conversion).	The importance of parks in urban design for physical health Inappropriate behaviours in the face of, or in response to the potential for, hurricanes, tsunamis, fire, flood, etc. Indigenous concepts of water in wetlands as the life spirit

tural significance of water in its setting also have a strong health and well-being component. Exploring lifestyle factors for health specifically in wetland settings, and how to promote them, are required areas of research (see also Section 5).

4.5 Conclusions

Addressing wetland management as if people's lives, their livelihoods and their lifestyles depended upon it will undoubtedly contribute to human health. Wetlands play an important role in ensuring water security and are fundamental to human health and well-being. The role played by wetlands within the hydrological cycle provides an important opportunity for linking local public health concerns to wetland conservation. The fundamental importance of the supply of high quality fresh water for people is well recognized.

Food security is one of the most significant contributions of wetlands to human health. Wetlands contribute to all three elements of food security, i.e., availability, access, and nutrient sufficiency, and they directly support the health and livelihood of many people worldwide through the provision of important food items such as rice and fish. Future food security is also dependent on the genetic materials contained in plants, including those in wetlands. Wetlands also provide products that form the basis of subsistence incomes for local communities. For rural people desiring to enter the cash economy, exploiting wild resources from wetlands (salt, fish, shellfish, useful plants) is an important option, as local knowledge and skills can be used to harvest products for trade to form an important part of their subsistence incomes. Complex trade networks commonly characterise this hidden economy, and the income received provides some buying power, which is an important component of food security. In many developing countries where there are limited government social security systems, these resources often provide a form of "green social security".

But people's health around wetland ecosystems can be determined by their lifestyles as well as by their livelihoods. Wetlands through their spiritual, recreational, inspirational and educational values contribute to the psychological and social well-being of human communities. Many religions attach spiritual and religious values to aspects of wetland ecosystems. The contributions made by wetland ecosystems to well-being by recreational use are best represented by the health benefits of physical activity, although some literature now documents substantial mental health benefits as well.

5. Wetland ecosystems and human exposures to health risks: the role of disruption to ecosystem services

5.1 Introduction

Humans can be exposed to health risks in wetland ecosystems. While steps can be taken to ameliorate these risks, this report argues that the risks can increase (sometimes dramatically) if disruption to ecosystems, and the services they provide, is profound.

In this section, the different forms of human exposures in wetland settings are illustrated by examples that show the ecosystem services that are involved and the services required to ensure that any necessary interventions are effective.

Four distinct forms of exposure are identified.

Exposure to pollution. Human health can be affected by acute or chronic exposure to toxicants, through the media of water, wetland sediments, or even air when sediments become desiccated and airborne or burnt. The nature of these exposures is greatly exacerbated by human activities where pollution is involved (Section 5.2).

Infection. Wetlands are the loci for communicable disease – microorganisms (the pathogens) are transmitted through water, people, animals, surfaces, foods, sediments or air, any or all of which can be associated with wetlands. Infectious diseases associated with wetlands have profoundly influenced the discipline of public health, and this is probably the source of the erroneous oversimplification that wetlands are always bad for human health. Two major and significant classes of communicable diseases are covered in this section: water-borne and vector-borne diseases. Again, the case is made that human exposures to these diseases can be exacerbated by disruption to ecosystem services (Section 5.3).

Psycho-social well-being. Wetlands, in their myriad forms, also provide the physical foundation for a location and, as such, become embedded in the human psyche in formulations of “sense of place”. Changes to wetlands, their products, or their ability to deliver a livelihood, or when they become a source of toxic exposure or disease, can influence a person’s mental health. These potentialities are increasingly recognized as being part of the wetland manager’s and public health practitioner’s spheres of prevention and intervention (Section 5.4).

Physical hazards. Finally, physical hazards, externalities like floods, earthquakes, hurricanes/ typhoons/ cyclones and drought, can magnify any of these exposures mentioned above (Section 5.5).

5.2 Exposure to pollution

Wetlands are settings where ecosystem services can be provided and exposure to toxicants can be prevented, or the reverse, where exposure occurs in conditions of disruption to the services (as described in the table below).

The pressures on inland ecosystems and their resultant degradation have considerable public health implications. In the 19th century the main wetland-related health problems arose from faecal and organic pollution related to untreated human wastewater, but in more developed countries such contamination has largely been eliminated. However, as described in Section 4.2, improved sanitation or access to a secure supply of safe drinking water – together a highly desirable combination if the objective is to prevent exposures to water pollution – is still required for significant part of the world population.

Despite the capacity of wetlands to purify water, they do have their limits (Verhoeven et al. 2006). They can only process and assimilate a certain amount of agricultural runoff, and only so much inflow from domestic and industrial wastes. As more toxic chemicals (such as PCBs, DDT and dioxins), antibiotics from animal husbandry, untreated human sewage, and pesticides that act as ‘endocrine disrupters’ are added to these wetland systems, the sources of the food they supply, and the water itself, can be rendered unfit for consumption and pose a danger to human health. This section recognizes three categories of toxicants to which humans might be exposed in wetland settings under such circumstances: i) soil or water-borne inorganic chemicals; ii) soil or water-borne microbial toxins; and iii) atmospheric particles or chemicals from wetlands.

Table 5.1: Pollution as a determinant of health risks in a wetland setting

Health risk	Relevant wetland ecosystem services	Health effects, health outcomes from ecosystem services		Disruptions to wetland ecosystems (examples)	Examples or case studies
		Benefits if services are maintained or enhanced	Consequences of disruption to the services		
Exposure to pollution	Water purification/waste treatment or dilution Other hydrological services: hydrological maintenance of biogeochemical processes Soil, sediment & nutrient retention	Prevention of exposure to environmental contaminants Enhanced abilities to interact with wetland ecosystems to derive other benefits, like those that accrue from provisioning and cultural services, or to derive an income	Exposure to: Soil or water-borne inorganic chemicals Soil or water-borne microbial toxins Atmospheric particles or chemicals	Sewage contamination Industrial contamination Eutrophication Salinisation Acidification Depletion (drainage or over-extraction)	Food chain bio-accumulation (e.g., DDT) Acute or chronic poisoning (e.g., arsenic or mercury) Nitrate as a human health issue Blooms of toxic cyanobacteria Respiratory diseases from peat fires

Soil or water-borne organic or inorganic chemicals

Chemical contamination of wetland ecosystems has occurred over a number of years as a result of both human activities and natural processes. At common concentrations, most chemicals are likely to cause adverse health effects only after prolonged periods of exposure. However, there are many cases worldwide where chemical pollution of wetlands have occurred and where such pollution may be detrimental to human health either through direct ingestion of water (particularly where the wetland is a source of drinking water) or through incorporation and subsequent accumulation of toxic chemicals in the food chain (components of which are then ingested).

Nutrients (principally nitrogen and phosphorus), in organic and inorganic forms, are arguably the chemical pollutants that have caused the most concern globally, and received the most attention (Box 5.1). While these nutrients occur naturally, one of the signatures of anthropogenic stresses are elevated nutrient levels from human wastes, or as byproducts of human activities such as fertilisation, and particularly in wetland ecosystems that have undergone some form of hydrological change. An important and highly charged issue in many countries is the debate concerning farming and grazing and the degradation of waterways and groundwater aquifers (Falkenmark et al. 2007; Peden et al. 2007; Shah et al. 2007). This is a concern globally, as increasing stock levels, poor management practices and the clearing of riparian vegetation for further grazing allows high volumes of farm effluent, excess nutrients and chemicals to enter waterways. Eutrophication (and associated algal blooms, see below) is being reported more frequently; continental river basins in North America, Europe and Africa have elevated concentrations of organic matter (Revenga et al. 2000).

Increased nitrogen fluxes are partly due to a dramatic and rapid global increase in nitrate fertilizer application, as well as indirect sources of nitrate (where organically bound N can be mineralised by soil bacteria into ammonia (slow), then nitrification to nitrate (rapid)(Gray 2008). Nitrate can leach into surface or groundwater, and nitrate pollution of groundwater is presently getting worse in northern China, India and Europe (Revenga et al. 2000; Vorosmarty et al. 2005; Shah et al. 2007). Nitrate is an important consideration for human health in three ways:

i) as a contributor to eutrophication and the problematic consequences due to prolific algal growth (see above);

ii) as a common component of food, nitrate is itself relatively harmless, but nitrate can be reduced to nitrite (either by the acidic conditions found in the stomach or by commensal bacteria in the saliva, small intestine and colon). Acidic production of N-nitroso-compounds might be problem-

Box 5.1: Nutrient enrichment in inland waters

Over the past four decades, excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems. While the introduction of nutrients into ecosystems can have both beneficial effects and adverse effects, the beneficial effects will eventually reach a plateau as more nutrients are added (that is, additional inputs will not lead to further increases in crop yield), while the harmful effects will continue to grow.

Increase in nitrogen fluxes in rivers to coastal waters due to human activities, relative to fluxes prior to the industrial and agricultural revolutions, have been shown for many areas (Howarth & Ramakrishna 2005). Synthetic production of nitrogen fertilizer has been an important driver for the remarkable increase in food production that has occurred during the past 50 years; world consumption of nitrogenous fertilizers grew nearly eightfold between 1960 and 2003. As much as 50% of the nitrogen fertilizer applied may be lost to the environment, depending on how well the application is managed. Phosphorus application has increased threefold since 1960, with a steady increase until 1990 followed by a leveling off at a level approximately equal to applications in the 1980s.

Since excessive nutrient loading is largely the result of applying more nutrients than crops can use, it harms both farm incomes and the environment.

Many ecosystem services are reduced when inland waters and coastal ecosystems become eutrophic. Water from lakes that experience algal blooms is more expensive to purify for drinking or other industrial uses. Eutrophication can reduce or eliminate fish populations. Possibly the most apparent impact upon services is the loss of many of the cultural services provided by lakes – foul odours of rotting algae, slime-covered lakes, and toxic chemicals produced by some blue-green algae during blooms keep people from swimming, boating, and otherwise enjoying the aesthetic value of lakes.

-- sourced from Millennium Ecosystem Assessment 2005 unless otherwise stated

atic for human health: the compounds are known to be animal carcinogens (although epidemiological evidence is lacking concerning a link between nitrates and cancer in humans)(Gray 2008); and

iii) when nitrite combines with haemoglobin, debilitating its oxygen-carrying function. Methaemoglobinaemia is the syndrome associated with acute expressions, and it can be fatal, particularly for infants less than 3 months old, who are especially susceptible due to different respiratory pigments. Co-factors like the presence of microbial contamination, diarrhea or respiratory diseases, may be implicated in acute cases (Gray 2008).

The chemical quality of drinking water on a global level is poor, particularly in developed and rapidly industrialising countries. In the 1970s the US Environmental Protection Agency found hundreds of organic chemicals in drinking water sources, many of which were believed to be carcinogenic and teratogenic, i.e., tending to cause birth defects (Okun 1996). Epidemiological studies in New Orleans at that time revealed higher levels of cancer in individuals using the treated water supply versus those using untreated groundwater (Talbot & Harris 1974). These results led to the passage of the Safe Drinking Water Act in the US in 1974. At the same time on the other side of the world, Rook (1974) showed that the common chemical used for water treatment – chlorine – created disinfection byproducts (DBPs) which were carcinogenic in rodents. Thus far, epidemiological data indicate potential developmental, reproductive, or carcinogenic health effects in humans exposed to DBPs (Malcolm et al. 1999; Anderson et al. 2002), but the data are inconclusive and there is need for further research.

A further controversial topic is the occurrence of endocrine disrupting chemicals (EDCs) in aquatic ecosystems, particularly those used for human drinking water. Pollutants that contain EDCs include pesticides, dioxins, excreted drugs, alkylphenols, and furans, which enter the environment directly via agricultural or industrial activities or from treated sewage effluent. Although EDCs currently occur in low concentrations, they may cause significant health effects on aquatic organisms and humans (Melnick et al. 2002).

Another matter of great concern is the growing number of cases around the world of groundwater and surface waters contaminated by metal ions from natural and anthropogenic sources. Humans can be exposed to heavy metals in a wetland setting by:

Box 5.2: Common metal ions and their health effects

Common metal ions associated with wetlands and human infrastructure:

Iron, Fe, predominantly from infrastructure, groundwater
Zinc, Zn is used in galvanising, roofing, infrastructure
Copper, Cu is used in pipes, cooking appliances
Cadmium, Cd is found in fertilizers
Mercury, Hg enters water from batteries, atmospheric deposition, or gold processing
Lead, Pb is found in old pipes, and is distributed by atmospheric deposition
Arsenic, As, most often associated with acidic groundwater
Aluminium, Al in water from water treatment, infrastructure, cooking appliances
Chromium, Cr used in wood treatment

Most of these metals can be found in effluents from mining activities, which invariably find their way into wetlands.

The health effects of metal ions (adapted from Hinwood et al. 2008)

The metals cadmium, lead, arsenic and aluminium are well known for their health impacts in exposed populations. Cadmium exposure has been associated with renal disease and studies have also suggested that it may impact the skeleton, whilst lead is well known for such health impacts as memory deterioration, cognitive difficulties, neurological impacts, and kidney damage. Concerns have been expressed by several authors on the impacts of lower levels of cadmium on bone density. Inorganic arsenic is also associated with a range of health effects including vascular disease, skin lesions at high concentrations, and cancer of the bladder and kidney. Aluminium has the potential to affect the central nervous, skeletal, and haemapoietic systems of humans. Copper is an essential element for people, but some are susceptible to the effects of increased copper exposure, such as those with Wilson's disease, renal and liver disease, and infants.

i) ingesting water, either directly from a source or through potable water from corroded piping systems or other metallic infrastructure; ii) being exposed to dust particles; or iii) ingesting foods where it has been bioaccumulated.

The health effects of heavy metals are relatively well known (Box 5.2). Numerous examples exist of such contamination, probably none more graphic than the almost inconceivably vast scale of arsenic poisoning on the Indian subcontinent (Frisbie et al. 2002). Similarly, the use of groundwater affected by oxidized acid sulfate soils to irrigate produce has the potential to expose humans to heavy metals (Hinwood et al. 2008). Base-metal mining in Te Aroha, North Island, New Zealand, has resulted in concentrations of arsenic, cadmium, lead and zinc above the levels recommended for drinking, in the Tui and Tunakohoia streams (Sabti et al. 2000).

Soil or water-borne microbial toxins

Some forms of pollution emanate from the metabolic byproducts or breakdown products of microbes, particularly in ecosystems suffering anthropogenic stress. Probably the most relevant examples are toxins associated with blooms of cyanobacteria (sometimes called "blue green algae") that occur in freshwater, estuarine, and near-shore marine wetland ecosystems. Harmful algal blooms, attributed partly to nutrient loads, have increased in freshwater and coastal systems over the past 20 years (UNEP 2007). Toxigenic cyanobacteria (those species that have toxic strains or populations) are capable of producing neurotoxins (acting specifically on nerve cells of vertebrates), hepatotoxins (damaging the metabolic processes in the liver), dermatotoxins (skin irritants), and endotoxins (gastrointestinal irritants) (Carmichael 2002). In addition to the production of toxins, cyanobacteria have often been associated with the production of taste and odour compounds, particularly where drinking water is sourced direct from a wetland ecosystem. Fristachi et al. (2008) suggest that these more obvious, often acute, impacts on human health need to be supplemented with a consideration of less well-known chronic, subtle or insidious impacts, and potential impacts where hazards exist in remote areas where health impacts have not yet been sustained. Most commentators on the occurrence of cyanobacterial blooms suggest that nutrient enrichment is an important causal agent, but beyond that many other biophysical parameters are involved, including temperature, light availability, meteorological conditions, alteration of water flow,

Box 5.3: Contamination of drinking water by cyanobacterial toxins

"The earliest demonstration of this was in 1983, when the population of a rural town in Australia was supplied with drinking water from a reservoir carrying a dense water bloom of a toxic species of cyanobacterium, *Microcystis aeruginosa*. The toxicity of this water bloom was being monitored in the reservoir. The controlling authority dosed the reservoir with copper sulphate to destroy the cyanobacteria, which caused the cells to lyse and release toxin into the water. Epidemiological data for liver injury in the affected population, a control population and comparison of the time periods before the bloom, during the bloom and lysis, and afterwards, showed clearly that liver damage had occurred only in the exposed population and only at the time of the water bloom."

-- quoted from Falconer & Humpage 2005

turbidity, vertical mixing, pH changes, and trace metals such as copper, iron and zinc (Fristachi et al. 2008). Exposure to cyanobacterial toxins through consumption of contaminated drinking water has however also resulted in poisoning (see Box 5.3).

Atmospheric particles or chemicals

Hydrological change to wetland ecosystems that results in aerosol production has also been demonstrated to have impacts on human health. A graphic example of this is the Indonesian peat fires of 1997 (see Box 5.4), from which a significant number of cases of asthma, bronchitis and acute respiratory infection were reported. Sensitive subgroups such as the elderly and those with pre-existing illness reported a greater severity in symptoms (Kunii et al. 2002). In Singapore, impacts from the Indonesian fires were also observed in increases in outpatient attendance for respiratory illnesses including asthma (Emmanuel 2000). Mott et al. (2005) investigated readmission of older patients associated with smoke exposure from the 1997 fires specifically in Malaysia, and they reported short-term increases in re-admission of patients with cardio-respiratory and respiratory diseases. Frankenberg et al. (2005), using data from an Indonesian population-based longitudinal survey combined with satellite measures of aerosol levels, assessed the impact of smoke from the fires on human health. Their results indicated that exposure to the smoke from fires has a negative and significant (but mostly transitory) impact on the health of older adults and prime age women.

5.3 Infection

This section deals with two main classes of communicable diseases (see the table below). Waterborne diseases (mostly but not only associated with the faecal-oral cycle), and vector-borne diseases (again mostly but not only associated with biting insects). Both classes are heterogeneous in nature and this section will not attempt to be comprehensive in its coverage, rather highlight the more significant diseases and where wetland ecosystem disruption plays a role in disease prevalence and incidence. Two special cases are explained in this context: emerging infectious diseases, and antimicrobial resistance.

Diseases and wetland management

Human health is directly dependent on wetlands, but wetlands can also be associated with an increased incidence of particular human diseases. The draining of swamps is a well-known example of human modification of wetlands to improve health, which has contributed to the eradication of malaria in many parts of Europe. However, the degree to which wetlands can be modified because of the infectious diseases they harbor, or might harbor, or the degree to which wetlands can be managed without *causing* disease-related issues, remain critical but often neglected questions in wetland management. Could management activities in a wetland feed back through ecological or systemic processes to worsen health outcomes? (See Box 5.5).

Malaria (because of host mosquitoes) and diarrheal infections including cholera (because of sewage and other contamination) are globally the worst wetland-associated diseases in terms of their human impact, accounting for 1.3 and 1.8 million deaths respectively in 2002 (WWDR 2006), and causing disability and suffering in many millions more. A serious disease burden also results from other infections such as schistosomiases (see Box 5.7 below), Japanese encephalitis, filariases, onchocerciasis and others that affect millions, each of these with a wetland connection. The vast majority of these diseases are seen in children under five years old, particularly in Africa, Asia, and parts of the Americas.

On the other hand, diseases resulting from the absence or removal of wetlands also need to be considered: controlling malaria was one of the driving forces for wetland destruction in the past (Stapleton 2004), but such destruction has led to the loss of vital

Box 5.4: Peat fires in Indonesia

Tropical peatlands are one of the largest carbon stores on earth, the release of which has implications for climate change (Page et al. 2002). The vast majority of these peatlands are lowland, rain-fed ecosystems with a natural vegetation cover of peat swamp forest. In a natural state, lowland tropical peatlands support a luxuriant growth of rainforest trees up to 40m tall, overlying peat deposits up to 20 metres thick, but any persistent environmental change, particularly decrease in wetness, threatens their stability and makes them susceptible to fire. At the present time, the peatlands of Southeast Asia represent a globally important carbon store which has accumulated over 26,000 years or more. In recent decades, however, an increasing proportion of this store has been converted to a carbon source through a combination of deforestation, land-use change, and fire.

Fires were widespread on the extensive peatlands of Indonesia during the 1997 El Niño and recurred in 2002, 2004 and 2006. By using satellite imagery and ground measurements within a 2.5 million hectare study area in Central Kalimantan, it was determined that 32% (0.79 M ha) of the area burned in 1997, of which peatland accounted for 91.5% (0.73 M ha), releasing 0.19-0.23 Gt of carbon to the atmosphere through peat combustion. It was estimated that between 0.81-2.57 Gt of carbon were released to the atmosphere from Indonesia's peatlands in 1997 as a result of burning peat and vegetation.

Many of these fires spread into forest areas where they burned with great intensity. In Kalimantan, South Sumatra, and West Papua, fires were started on or reached areas of peatland, burning both the vegetation and the underlying peat. In Central Kalimantan, the situation was exacerbated by a massive peatland conversion project – the so-called Mega Rice Project (MRP), a scheme initiated in 1995 with the aim of converting 1 M ha of wetland, mostly peatland, to agricultural use. Throughout the MRP area extensive, deep drainage and irrigation canals were excavated and much of the peat swamp forest was logged, and during 1997 fire was being used as a rapid land clearance tool. Initial estimates indicated that approximately 4.5 M ha of land had been damaged by the 1997 fires, but more detailed assessments doubled this figure to 9 M ha. Of this latter area, as much as 1.45 M ha was believed to be peat and swamp forest, although no one made credible estimates of the area of peatland affected by fire at the time.

The two most intensive sources of smoke and particulate matter were the fires centered on the peatlands of Central Kalimantan and the Riau area of South Sumatra. Here both vegetation and underlying peat caught fire, contributing greatly to the so-called haze (particulate-laden smog), which blew northwestwards to affect Singapore and Malaysia. During this time solar radiation in Central Kalimantan was reduced to 40% of normal levels, whilst visibility was reduced to 25 metres.

It has been estimated that the financial consequences of the fires were over US$ 3 billion from losses in timber, agriculture, non-timber forest products, hydrological and soil conservation services, and biodiversity benefits, whilst the haze cost an additional US$ 1.4 billion, most of which was borne by Indonesians for health treatment and lost tourism revenues.

The peatland fires of 1997 resulted in the combustion of stored carbon that took between 1,000 and 2,000 years to accumulate (Page et al. 2002). At the current estimated rate of carbon accumulation in Central Kalimantan peatlands of 85 g m^{-2} yr, this single fire event represents an approximate loss of between 70-200 years of carbon sink function. The Southeast Asian region is currently subject to increasing climatic variability, and seasonal precipitation extremes associated with future El Niño events are predicted to become more pronounced (Goldammer and Price 1998; Siegert et al. 2001). This may lead to reduced water supply to and retention by peatlands, resulting in a lowering of water tables. This will limit the rate of peat accumulation where it is still taking place, enhance degradation and oxidation on peatlands that are no longer actively forming peat, and greatly increase the likelihood of peatland fires, with consequent rapid loss of stored carbon. Increased climatic seasonality and variability has the potential to switch the tropical peatland ecosystems of Southeast Asia from carbon sinks to carbon sources.

Unless land use policies are changed to control logging and the drainage and clearing of peatland for plantations, recurring fires will lead to a complete loss of Indonesia's peat swamp forests and continued, high emissions of CO_2 to the atmosphere.

-- adapted from Rieley undated

Table 5.2: Infection as a determinant of health risks in a wetland setting

Health risk	Relevant wetland ecosystem services	Health effects, health outcomes from ecosystem services		Disruptions to wetland ecosystems (examples)	Examples or case studies
		Benefits if services are maintained or enhanced	Consequences of disruption to the services		
Exposure to Infection	Drinking water for humans and/or livestock Water purification/waste treatment or dilution Biological control agents for pests/diseases Soil, sediment and nutrient retention	Enhanced abilities to interact with wetland ecosystems to derive other benefits, like those that accrue from provisioning or cultural services, or to derive an income.	Water-borne diseases Vector-borne diseases Emerging infectious diseases Antimicrobial resistance	Creation of artificial wetlands (all sizes) Contamination from sewage and agricultural runoff Loss of biodiversity (loss of specialisation, simplification of wetland ecosystems, loss of capacity to suppress disease)	Table Cryptosporidium, Campylobacter, Giardia Malaria, Dengue, Schistosomiasis Highly pathogenic avian influenza

ecosystem services such as the provision of clean water, flood protection, and supply of food (see Buening et al. 2007).

The fact that a significant proportion of the world's population lacks sufficient clean water for drinking, personal hygiene and cooking might be seen from another perspective: human populations have exceeded the capacity of the wetlands to provide our basic water supplies or assimilate our wastes. Significant disruption to water regimes in wetlands can be just as problematic and can carry a heavy disease burden: over-irrigation can result in standing water in which disease-carrying mosquitoes and snails can breed, and water used by industry can often allow toxins to enter the human food chain (WWDR 2006). Altered water regimes and reconfigured vegetation communities can lead to human hardship and global environmental change. More recently, a range of 'emerging' infectious diseases have also been linked to water and/or wetland (mis) management, and have in some cases resulted in epidemics (as described below).

The removal of wetlands, or altering their water regimes, is therefore not generally the only disease management option that should be considered. The incidence of many of these diseases can instead be reduced through more integrated approaches: provision of clean water, improved sanitation, and

Box 5.5: Wetland management: friend or foe for minimising the burden of infectious diseases?

Malan et al. (2009) report on the considerable effort now being directed towards rehabilitation of degraded wetlands and the construction of artificial systems to treat effluent and stormwater. They focus on the potential habitat that wetlands provide for vectors or intermediate hosts implicated in diseases. For the two major invertebrate disease hosts (mosquitoes for malaria and schistosome-transmitting snails for the disease bilharzia) in South Africa, the authors document the type of habitat required by the water-dependent life stage and the ways in which wetland degradation, rehabilitation and creation may affect the availability of suitable habitat. Notwithstanding the general practical measures for minimising pest species, particularly mosquitoes, they conclude that in regions of the country where the diseases are prevalent, there is the likelihood that wetland rehabilitation and creation could inadvertently encourage the hosts responsible for transmitting malaria and schistosomiasis. They recommend that assessment of the potential risks and benefits of a proposed wetland modification need to be undertaken in a holistic manner using an adaptive framework that recognizes the critical need to balance human health with the needs of wetland management.

– importantly – good management of wetlands. Sustainable approaches to the management of wetlands includes, for example, the use of fish that have been demonstrated to consume mosquito larvae without significantly affecting other parts of the food chain, or bacterial larvicides that target mosquito larvae without affecting other organisms. Better design, management, and improved regulation of dams and irrigation schemes and water drainage systems are other examples of such practices, and significant disease reduction can be achieved by combining different approaches (WWDR 2006; Kibret et al. 2009).

A significant but desirable challenge therefore will be to find wetland management solutions that benefit both ecosystem health and human health concurrently.

Water-borne diseases

Present in human and other vertebrate faeces there are numerous classes of pathogens that cause infections including bacteria (enteric and aquatic), enteric protozoa, and enteric viruses, whose transmission is aided by water. Other pathogens are not associated with faeces, but still occur in aquatic ecosystems. Most of these pathogens have helped define a public health agenda. Other forms of contamination can exacerbate these forms of infection. For instance, agricultural effluent contributes excess nutrient loadings, a consequence of which can be an associated outbreak of microbiological contamination.

Waterborne diseases continue to be a major cause of mortality and morbidity across the world. In 2000, waterborne and water-washed diseases killed 2.2 million people (most of them children) and affected more than 2 billion people (United Nations & World Water Assessment Programme 2003). Corvalan et al. (2005b) reported that water-associated infectious diseases claim up to 3.2 million lives each year, approximately 6% of all deaths globally. The burden of disease from inadequate water, sanitation and hygiene totals 1.7 million deaths and the loss of more than 54 million healthy life years. It is likely that the reported numbers, although high, greatly underestimate the real incidence of waterborne diseases. The large burden of disease is a direct result of water scarcity and poor water quality, and here the links to wetland ecosystems and their services are clear.

Bacterial Infections

A variety of waterborne bacterial pathogens are of concern to public health authorities, and therefore to wetland managers as well. Some of them, like *Salmonella* spp. (causing typhoid and paratyphoid, acute gastroenteritis), are perceived to have been largely eliminated from the developed world, and at least controllable in the developing world due to the high numbers that need to be ingested for infection to take hold and the fact that disinfection (i.e., chlorination) appears to be highly effective (Gray 2008).

Of principal interest in the context of this report, however, are the bacteria that cause severe illness in humans (or domesticated animals) and for which there are significant aquatic ecosystem factors involved in their transmission or multiplication. For instance, infections of *Mycobacterium ulcerans* (Buruli ulcer disease) is a debilitating skin affliction, recently recognized as a rapidly emerging disease of tropical and subtropical regions, where nearly all epidemiological studies have suggested an association between disease outbreaks and proximity to human-disturbed freshwater habitats (Merritt et al. 2005). Two good examples have established this relationship much more clearly, namely for cholera (*Vibrio cholera)* and campylobacteriosis (*Campylobacter)*.

For cholera, the latest cholera pandemic swept the globe only last decade. The re-emergence of this severe form of gastrointestinal disease occurred across the Western Hemisphere in the early 1990s (Colwell 1996).

> "The history of cholera reveals a remarkably strong association with the sea. The great pandemics followed coastlines of the world oceans. As with acute communicable diseases in general, endemicity of cholera carries the potential of epidemic flare-ups, and pandemicity is always a threat, especially in developing countries having poor sanitation, lack of hygiene, and crowded living conditions. These factors have long been recognized as characteristic of environments in which diarrheal diseases flourish." (Colwell 1996).

Our understanding of cholera as an emerging infectious disease has evolved "from a linear reductionist model focused on oral–faecal transmission of a waterborne bacterium and a human host, to a vastly more complex, yet accurate ecological model of an infectious disease. This model includes global weather patterns, aquatic reservoirs, bacteriophages, zooplankton, the collective behaviour of surface attached cells, an adaptable genome, and the deep sea, together with the bacterium and its host [with] a causal chain involving regional climatic patterns, river basin rainfall variability, river discharge and flooding, and transmission variability" (Wilcox & Colwell 2005).

Campylobacteriosis was first recognized as an 'emerging' human gastrointestinal disease in the late

1970s and is now the most commonly notified disease in the western world. It accounts for about 10% of all diarrhea worldwide. *Campylobacter jejuni* is a bacterium that invades the intestinal lining. The consequences range from asymptomatic infection, through diarrhea, to rare but severe complications that include arthritis and nerve inflammation. The characteristic acute diarrhea arises 2-5 days after exposure (ingestion), and is usually associated with abdominal pain, malaise, fever and nausea. Campylobacteriosis is a food and water-borne disease whose transmission is a matter of 'survival trajectories' between excretion by the reservoir (domesticated animals including poultry, sheep and cattle) and ingestion by the case (Skelly & Weinstein 2003). The survival of this organism in the environment is subject to the influence of a variety of ecosystem-related factors. The interventions for this disease, therefore, need to focus on water management and the management of stock associated with it.

These examples emphasize that to understand the variety of independent variables acting at different levels of organization, and the interactions between host agent and aquatic environment factors, it is necessary to broaden the traditional perspectives of public health and their epidemiological approaches into one more closely aligned with the science of ecology (Aron & Patz 2001), an area where wetland managers have a significant contribution to make.

Waterborne protozoan infections

The infection dose of protozoan and viral agents is lower than bacteria, in the range of one to ten infectious units or oocysts (Leclerc et al. 2002). One of the most common protozoan agents that cause gastrointestinal disease in humans is *Cryptosporidium.* Oocysts of this protozoan have been identified in human faecal samples from more than 50 countries on six continents (Leclerc et al. 2002). One of the modes of transmission is via water, and outbreaks have been associated with drinking water and recreational water contact including rivers and lakes. Oocysts are highly resistant to chemical disinfectants used to purify drinking water, and advanced filtration systems are required to remove them (Gray 2008).

A second common protozoan agent, distributed worldwide with a high burden of disease, is *Giardia*. The prevalence of infection for this protozoan ranges from 1% to 30% in different parts of the world, with the highest levels occurring in countries with poor sanitation. This enteric disease is similar to cryptosporidiosis but is milder and treatable, generally self-limiting and less resistant to chemical disinfectants such as chlorine; over the past 30 years, giardiasis has become the most common cause of human waterborne disease in the USA (Gray 1994). It is associated with drinking water from unfiltered surface water sources or shallow wells and with recreational contact in bodies of fresh water. In addition to *Giardia* and *Cryptosporidium*, some species of genera *Cyclospora*, *Isospora*, and of family Microsporidia are emerging as opportunistic pathogens and may have waterborne routes of transmission (Leclerc et al. 2002). Interventions for these diseases must involve ecosystem approaches (see Table 5.3).

Waterborne viral pathogens

A further group of pathogens that are responsible for numerous cases of gastroenteritis worldwide are viruses, specifically Norwalk-like viruses (NLVs). In 2002 these viruses were reclassified into a new genus *Norovirus* in the Caliciviridae family. Molecular detection methods indicate that NLVs are the major culprits for food and waterborne nonbacterial gastroenteritis. In the USA, it is estimated that more than 60% of the population have antibodies to NLVs by their fifties (Chin 2000), while in developing countries antibodies are acquired at a much earlier age. Cases of gastroenteritis from NLVs most often occur in outbreaks rather than sporadically (Table 5.3).

Other viruses that are frequently transmitted via contaminated water are Hepatitis A (HAV) and Hepatitis E (HEV). Hepatitis A occurs worldwide and is sporadic and epidemic, with a tendency to cyclic recurrences. In developing countries, adults are usually immune and epidemics of HAV are uncommon (Chin 2000). Ironically, improved sanitation has resulted in individuals lacking immunity, and the frequency of outbreaks is increasing. In contrast, HEV has a more limited distribution, mostly confined to tropical and subtropical areas, primarily in areas with inadequate sanitation. However, recently it is becoming an issue in countries where it was not traditionally endemic, such as in Europe (Worm et al. 2002). Outbreaks of HAV and HEV typically follow heavy rains, when water sources become contaminated by sewage, or during dry periods when viruses are concentrated in contaminated water sources. As for other waterborne diseases, interventions must involve ecosystem approaches.

Non-faecal waterborne diseases

As mentioned above, waterborne diseases without a faecal reservoir can occur, with new pathogens including environmental bacteria that are capable of surviving and proliferating in water distribution and plumbing systems. For example, *Legionella* and

Table 5.3: Examples of ecosystem disruption and/or diminished ecosystem services resulting in outbreaks of disease resulting from waterborne pathogens

Causative agents (pathogens)	Outbreak	Ecosystem disruption/diminished ecosystem services	Intervention undertaken or required	Key reference
Bacteria				
Escherichia coli O157:H7 and *Campylobacter jejuni*	In May 2000, seven people died & over 2,000 people were ill as a result of a contaminated drinking water supply in Walkerton, Ontario, Canada.	Investigation of the outbreak traced the source of the disease to a contaminated well supplying the municipal water system. Altered hydrological services. Disrupted water purification services.	Evidence from molecular subtyping suggested that the pathogens originated from cattle manure on an adjacent farm. Take contaminated well out of water supply system.	Hrudey et al. 2003
Viruses				
Norwalk-Like Virus	An outbreak of gastroenteritis occurred in a Swedish ski resort during February-March 2002, affecting approximately 500 people.	Altered hydrological services. Disrupted water purification services.	A crack in a sewage pipe 10 meters from the well was discovered as the source of the contamination	Carrique-mas et al. 2003
Hepatitis E	Between December 1992 & April 1993, 3,682 individuals were affected by a large water-borne epidemic in the city of Saharanpur, Uttar Pradesh, India	Altered hydrological services. Disrupted water purification services.	The source of the contamination was traced to a leak in the municipal water supply pipes, which passed through sewerage holes	Singh et al.1998
Protozoa				
Cryptosporidium	In 1993, an estimated 403,000 residents of greater Milwaukee, Wisconsin, USA (population, approximately 1.61 million) became ill, & some 100 died	Ineffective filtration process led to the inadequate removal of oocysts in one of two municipal water treatment plants	The documentation on the Milwaukee outbreak highlighted the need for better drinking water treatment, & the quality of public water systems have improved significantly since 1993 in the US & internationally, but there is still need for improvement.	MacKenzie 1994
Bacteria and Protozoa				
A variety of zoonotic pathogens, including *Campylobacter*, *Cryptosporidium*, and *Giardia*.	New Zealand's lakes, major rivers, & thousands of streams provide about 60% of the water consumed by the human population of 3.8 million. Pastoral farming has a major impact on both water flow & quality. Much of the farming land is heavily stocked with millions of heads sheep and cattle. Some of their excrement is washed into waterways with heavy rains, where it may come into contact with humans both directly (drinking, recreation) & indirectly (by 'seeding' secondary cases).	Over the past 150 years, deep-rooted vegetation has been removed from hillsides & riverbanks, increasing the volume & speed of runoff during heavy rains. The natural self-purification of water percolating through soil & vegetation is reduced as a result, exposing both stock & humans downstream to pathogens. Agricultural development directly influences biodiversity, ecosystem health, & hence the risk of disease transmission in freshwater ecosystems	Recent surveys have found over 50% of New Zealand's surface waters appear to be contaminated with *Giardia* & in undeveloped catchments, *Campylobacter* occurs in over 50% of samples. The unusual ecology of the causative organism in New Zealand's uniquely modified ecosystem suggests that the required intervention in this case is dramatically improved land- & water-care & better understandings by the health sector of the ecosystem-health relationship.	Eyles et al. 2003

Mycobacterium avium complex (MAC) are environmental pathogens that have found an ecological niche in drinking and hot water supplies. *Mycobacterium avium* complex frequently causes disseminated infections in AIDS patients and drinking water has been suggested as a source of infection; in some cases the relationship has been proven (Leclerc et al. 2002).

Antimicrobial resistance

Because of the widespread use of antibiotics, some human and animal pathogens that have in the past been controlled successfully are now resistant in the water environment and to most disinfectants and/or antibiotics. This resistance has been mediated principally by point-source discharge from sewage treatment plants (thereby originating from human use and overuse of antibiotics) and non-point source (i.e., land runoff) discharge from animal production areas (where the use is veterinary). Both result in drug residues and the presence of antibiotic resistant isolates in the receiving environment. It appears that there are now an enlarged variety of waterborne pathogens, many with low infectious dose and moderate to high resistance to disinfectants and/or antibiotics.

Important examples include antibiotic-resistant *E. Coli*, which have been isolated from rivers and coastal areas, surface water and sediments, lakes, seawater, drinking water, domestic sewage, and hospital environments (Parveen et al. 1997), and *Listeria monocytogenes*, an intracellular pathogen responsible for severe food-borne infections, which has been isolated from surface waters in a Canadian watershed dominated by urban and rural development, livestock and crop production, and wildlife habitats, where many isolates showed resistance to multiple antibiotics (Lyautey et al. 2007); and iii) *Aeromonas* (see Box 5.6).

Ensuring that agricultural runoff is treated or prevented from discharge into wetland areas is an important management consideration, particularly for intensive production lots where antibiotics are likely to form part of the waste stream. The agricultural use of antibiotics in animal feed can result in the selection and transmission of antibiotic-resistant bacteria which move through the environment by different routes (see Figure 5.1). A significant one is via surface water, suggesting an obvious role for wetland managers in ensuring that waste does not enter surface waters untreated.

Vector-borne diseases

As discussed above, wetland managers can make a significant contribution to avoiding adverse health outcomes by ensuring that they consider the potential for their management regimes to influence vectors of human disease. Most of the vectors of major disease and their ecologies are known regionally (see for example Table 5.4).

Again, health gains might come at the expense of some wetland ecosystem services, or management for control of one vector might suit the proliferation of another:

> "[D]ue to recent urbanization of Macau, which geographically consists of two small islands and a peninsula of land connected to a larger island area of mainland China, . . . there has occurred a decline to zero in populations of several anopheline vectors of malaria. However, optimal habitat has increased for culicine mosquitos including among the most abundant, *Culex quinquefasciatus*, *Cx. sitiens* and *Ae. albopictus*. Such nuisance species and potential disease vectors present the threat of transmission of other vector-borne diseases" (Knudsen & Behbehani 1996).

The key point to be noted is that the creation of urban wetlands, restoration of urban or rural wetlands, or construction of wetlands for water resource develop-

Box 5.6: Antimicrobial resistance of *Aeromonas* in urban playa lakes

Bacteria belonging to the genus *Aeromonas* are indigenous to aquatic environments. Once regarded as unimportant human pathogens, reports of opportunistic infections caused by these organisms have appeared increasingly in the medical literature. The potential for human infection by *Aeromonas* would be expected where limited water resources are being used intensively. Warren et al. (2004) studied the spatial and temporal variation and incidence of antimicrobial resistance among environmental isolates of *Aeromonas* from two urban playa lakes in Lubbock, Texas. *Aeromonas* population densities varied seasonally and with water depth. One hundred fifty-one *Aeromonas* isolates were divided into 10 species or subspecies groups; nine isolates displayed resistance to co-trimoxazole, tetracycline, and cefuroxime, and none was resistant to more than one of these antimicrobial agents. Their results showed that the densities of *Aeromonas* peak in the late spring and again in late summer, times when human activity around the playa lakes is also high, and that human exposure to these potential pathogens varies seasonally. Other published studies have showed a higher incidence of antimicrobial-resistant *Aeromonas*.

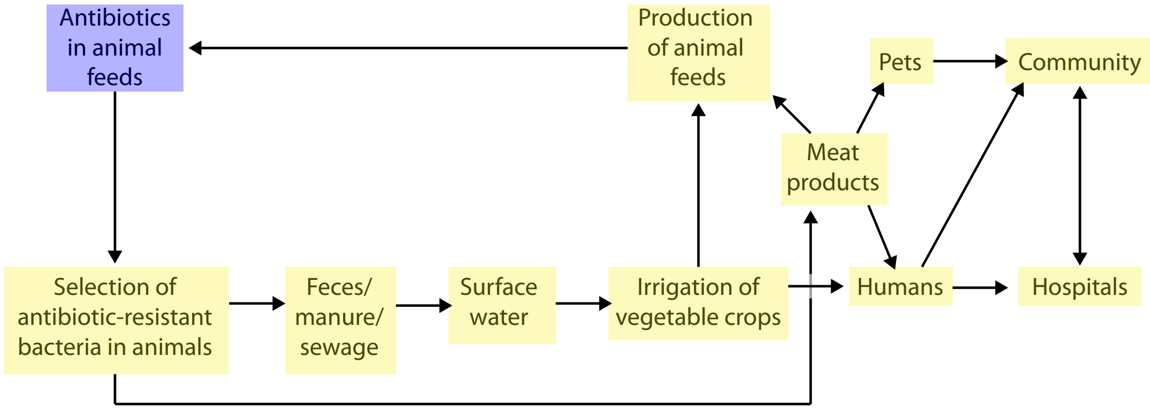


Figure 5.1: The agricultural use of antibiotics in animal feed
(from Khachatourians (1998))

ment, in particular dams and irrigation schemes, can equally facilitate the transmission of vector-borne diseases. If so, further wetland management will be required, by paying attention to water regimes, water quality, pest control and so on, to minimize the potential for vectors to spread diseases.

Mosquito-borne diseases are re-emerging as a significant threat to public health worldwide (Gubler 2002; Molyneux 2003). Malaria, dengue and other mosquito-borne diseases are increasing in incidence in areas where they were previously thought to be under control, and expanding into new geographic regions. Changes in vector density and distribution following ecological and environmental disruption are major factors responsible for increasing mosquito-borne disease transmission worldwide (Gubler 2002; Molyneux 2003). Anthropogenic changes in water regimes, land use and land cover are primary drivers of such ecological disruption and have the potential to strongly influence human vulnerability to vector-borne diseases, particularly those carried by mosquitoes (Sutherst 2004). Such anthropogenic changes diminish some ecosystem services, usually by trying to enhance other ecosystem services, and can be broadly classified into the following non-mutually exclusive categories: water resource development, deforestation (see Box 5.8); agricultural development, and urbanisation (Norris 2004). Water resource developments such as dam construction and agricultural irrigation are important examples of such changes that may support mosquito breeding and adversely impact upon associated disease transmission, and careful attention to water regimes can help minimise mosquito breeding (Kibret et al. 2009). Soil and surface water salinization that follow land clearing (Horwitz et al. 2001; Jardine et al. 2007; Dale & Knight 2008), and acidification of surface waters from the exposure of acid sulphate soils (Ljung et al. 2009), may also enhance vector mosquito breeding. In all cases, anthropogenic changes to water regimes are implicated in disruptions to ecosystem services that lead to the potential for increased vector breeding.

The complex nature of mosquito-borne disease transmission means that the exact impact on health is variable and difficult to predict. For instance, ecological changes following development of agricultural irrigation schemes do not necessarily increase the overall number of mosquitoes present. In some cases, the species composition of the mosquitoes present changes significantly with no increase in absolute numbers, as irrigation development favours the breeding of some species but not others (Coosemans & Mouchet 1990; Amerasinghe & Indrajith 1994; Hearnden & Kay 1995). While water resource developments generally create the potential for increased disease transmission, the actual effects on health are a product of many factors and the subtle interactions among them. These factors include the pathogen itself, the mosquito vector population (including vector survival longevities), any vertebrate host population, the human populations and the environment/climate.

Another good example of a disease that has an aquatic vector is schistosomiasis, which depends on an intermediary snail host (Box 5.7).

Emerging infectious diseases

A range of infectious diseases and the ecological mechanisms that result in a change in the incidence of the disease (through vector or pathogen expansion, or host susceptibilities) are shown in Table 5.5. These mechanisms have, in turn, been driven by human activities that have led to ecosystem disruptions that have allowed these mechanisms to emerge. Emerging infections are those whose incidence in humans or other organisms have increased within the past two

Table 5.4: Major diseases, with their invertebrate hosts, linked to wetlands in Africa

Disease	Parasite causing disease	Invertebrate host	Geographical distribution	General comments
Malaria	*Plasmodium* spp. In South Africa: *P. falciparum* (90% of cases)	Anopheline mosquitoes.	Most of Africa	
Schistosomiasis (bilharzia)	*Schistosoma* spp. In South Africa: *S. haematobium* *S. mansoni*	In South Africa: *Bulinus globosus & B. africanus* *Biomphalaria pfeifferi*	Most of Africa	*S. haematobium* causes urinary bilharzia. *S. mansoni* causes intestinal bilharzia
Fascioliasis (liver fluke)	*Fasciola hepatica* *Fasciola gigantica* Both of above species	*Lymnaea truncatula* *L. natalensis* *L. columella* (an exotic species)	Some parts of Africa, especially Egypt.	Human infection not common, but is increasing worldwide
Paragonimiasis (lung fluke)	Possibly *Paragonimus kellicotti*	Host species not definitively identified in South Africa. Snail host followed by a crustacean host.	Only a few reports from South Africa.	Transmission to humans through eating insufficiently-cooked freshwater crustaceans.
Rift Valley Fever	'arbovirus'	Mosquitoes (several spp. including *Aedes spp.*)	Central and Northern Africa. Parts of Southern Africa.	Zoonosis – usually infects cattle, goats, sheep, buffalo
West Nile and Sindbis Fever	'arboviruses'	Mosquitoes: *Culex univittatus* & *C. neavei*	Central Africa. Occasionally in South Africa.	Zoonoses. Birds = reservoir host. The ecology of the 2 diseases is very similar in South Africa.
Chikungunya	'arbovirus'	Mosquitoes (*Aedes aegypti* and other *Aedes* spp.)	West, central & Southern Africa, Asia. Occasionally in South Africa.	Zoonosis – usually infects monkeys & baboons
Dengue	an 'arbovirus'	Mosquitoes (*A. aegypti*)	Most tropical & subtropical areas of world, Mozambique.	Increasing global threat. Potential to be imported from Asia.
Yellow fever	an 'arbovirus'	Mosquitoes (*Aedes simpsaloni, A. africanus, A. aegypti*)	Central Africa (not Southern or South Africa)	Rare form is a Zoonosis. Primates = reservoir host. Urban form is most common.
Filariasis (elephantiasis)	Nematodes:*Wuchereria bancrofti* *Onchocerca volvulus*	*Culex* spp. mosquitoes	Central Africa (not Southern or South Africa)	
Onchocerciasis (River blindness)	Nematode: *Onchocerca volvulus*	Black flies (*Simulium damnosum)*	Central Africa (not Southern or South Africa)	Found near rapidly-flowing rivers. Can also lead to elephantiasis.
Dracunculiasis (Guinea worm)	Nematode: *Dracunculus medinensis*	Copepods (*Cyclops* sp.)	Central Africa, (not Southern or South Africa)	

Source: adapted from Malan et al. (2009)

Box 5.7: Schistosomiasis and wetland management

Wetland managers should be aware of the complexities of specific diseases, the ecology of the diseases, and the roles of water resource development in their establishment and spread. In doing so, wetland management can be involved in the prevention of the introduction of new diseases to an area, and control of the spread of diseases in the future. Schistosomiasis is a good example.

"Schistosomiasis is a chronic, debilitating parasitic disease caused by blood flukes of the genus *Schistosoma*. Freshwater snails, after being infected by schistosome "miracidiae"" (larvae that emerge by the hatching of eggs found in human excreta, deposited in the water) act as intermediate hosts. The infected snails produce other larvae called "cercariae," which infect humans by entering the body through the skin during water contact. The disease, also known as "bilharzia", is endemic in 74 countries in Africa, South America, and Asia. Worldwide, an estimated 200 million people are infected, of which 20 million are assumed to suffer from more or less a severe form of the disease creating 4.5 million DALYs lost. Schistosomiasis is endemic in 46 out of the 54 countries in the African continent. The disease may cause damage to various tissues (the bladder, liver or the intestines) depending on the species, and lower the resistance of the infected person to other diseases. There are 16 different known species of *Schistosoma*, of which 5 are infective to humans – *S. mansoni*, *S. haematobium*, *S. intercalatum*, *S. japonicum* and *S. mekongi*. The species differ according to their snail intermediate hosts, egg morphology, final location of the adult worms in the human body, resulting symptoms, and their geographical distribution. The most common forms of the disease in Africa are: intestinal schistosomiasis, which is caused by *S. mansoni*, and urinary schistosomiasis, which is caused by *S. haematobium*. In sub-Saharan Africa, approximately 393 million people are at risk of infection from *S. mansoni*, of which 54 million are infected. Those numbers for *S. haematobium* are estimated to be as high as 436 million at risk, of which 112 million are infected."

The spread of schistosomiasis is intimately related to the intermediate hosts that are involved. These are therefore a critical point of intervention for wetland managers.

"The intermediate hosts of schistosomes in Africa are freshwater pulmonate snails. There are numerous examples that substantiate the fact that the establishment of irrigation projects and other water resources development projects have increased transmission of schistosomiasis and other water-related diseases. Schistosomiasis and other water-related diseases, while expected to remain public health problems of significance, may become more acute as a result of the growing human population and the ensuing demands on energy and food that will lead to expanded and intensified exploitation of water resources in Africa. It is, therefore, important that health considerations are addressed when evaluating potential benefits of new irrigation schemes, and that measures are taken to minimize health problems related to the new ecological settings. Clearly, the potential health risks of water resources development are related to problems already present in the area. However, the possibility of new diseases being introduced or existing diseases reaching epidemic proportions cannot be ruled out."

-- quoted text is from Boelee & Madsen, 2006

decades or threaten to increase in the near future (definition adapted from Lederberg et al. 1992). Avian Influenza is an excellent example of a newly emergent disease (Box 5.9) where the ecosystem service of disease control has been disrupted in high density poultry production systems. Re-emerging infectious diseases are also considered: ones whose vector or pathogen have adapted in such a way that previously-thought prevention approaches are no longer working (i.e., where pathogens have become resistant to antibiotics, see above, or where ecological conditions have changed, see Table 5.5).

5.4 Mental health and psycho-social well-being

Distress and trauma can be associated with exposures to environmental change. Sometimes the changes are acute (like devastating natural disasters that can occur without warning); at other times the changes can be more insidious, with gradual and relentless onset. These exposures can produce a variety of psycho-social effects, including financial hardship, family breakdown, anxiety and depression, alcoholism, road trauma and suicide. People's attachment to the cultural and economic services that wetlands provide, and due to the propensity of wetlands

Box 5.8: Vector borne diseases and disruption to ecosystem services in the Amazon Basin

The work of Foley et al. 2007 demonstrates that the extent and pattern of deforestation may degrade the disease regulation services of the rainforest ecosystems, making diseases more prevalent.

"Rainforests may provide a valuable ecosystem service, moderating the risk of infectious disease by regulating the populations of disease organisms (viruses, bacteria, and other parasites), their animal hosts, or the intermediary disease vectors (most often insects or rodents). For example, the loss of forest cover may affect the abundance and behaviour of mosquitoes – a common disease vector in the tropics – through changes in local habitat conditions.

"Individual mosquito species occupy unique ecological niches and can react rapidly to changes in habitat. A recent project in the Peruvian Amazon examined the links between deforestation and the principle mosquito vector for malaria in South America, *Anopheles darlingi* (Vittor et al. 2006). This analysis suggests a direct relationship between the extent of deforested land and increasing biting rates of *A darlingi*. In fact, heavily deforested areas can see up to a 300-fold increase in the risk of malaria infection, compared to areas of intact forest, controlling for changes in human population density. Furthermore, there appears to be a threshold effect in these data: when the landscape is about 20% deforested, mosquito biting activity increases substantially. In short, deforestation appears to greatly magnify mosquito biting rates and the risk of spreading malaria by increasing habitat available for *A darlingi*.

"Specifically, links between deforestation, changes in local habitat conditions and biodiversity, and the ecology of *A darlingi* resulted in greatly increased risk of malaria. However, this result could be even more general; deforestation may also amplify other disease risks as well . . . changes in forest cover (and associated changes in rivers and regional climate) could affect human health through changes in food and freshwater availability, or in water and air quality."

Table 5.5: Wetland-related infectious disease and mechanisms changing incidence as related to ecosystem changes

Disease	DALYs *(thousand)*	(Proximate) Emergence Mechanism	(Ultimate) Emergence driver	Geographical distribution	Sensitivity to ecological change	Confidence level
Malaria	46,486	niche invasion, vector expansion	Deforestation, water projects	tropical (America Asia and Africa)	++++	+++
Dengue fever	616	vector expansion	Urbanization, poor housing	tropical	+ + +	+ +
Japanese encephalitis	709	vector expansion	irrigated rice fields	southeast Asia	+++	+++
West Nile virus and other encephalitides	na	na	na	Americas, Eurasia	++	+
Schistosomiasis	1,702	intermediate host expansion	dam building irrigation	America, Africa, Asia	+ + + +	+ + + +
Cholera	b	sea surface temperature rising	climate variability & change	global (tropical)	++	+ + +
Cryptosporidiosis	b	contamination by oocytes	poor watershed management where livestock exist	global	+ + +	+ + + +
Rift Valley fever	na	heavy rains	climate variability & change	Africa	na	na

a) Disability-adjusted life years. B) Both cholera and cryptosporidiosis contribute to the loss of nearly 62 million DALY's annually from diarrheal diseases. Key: + = low; + + = moderate; + + + = high; + + + + = very high.

-- *adapted from Corvalan et al. 2005b*

Table 5.6: Psycho-social stresses as determinants of health risks in a wetland setting

Health risk	Relevant wetland ecosystem services	Health effects, health outcomes from ecosystem services		Disruptions to wetland ecosystems (examples)	Examples or case studies
		Benefits if services are maintained or enhanced	Consequences of disruption to the services		
Exposure to psycho-social stresses	Contemporary cultural significance, including for arts, creative inspiration, & existence values Aesthetic & "sense of place" values Spiritual & religious values Important knowledge systems, & importance for research	Meaningful interactions with wetland ecosystems as places; enhanced abilities to derive benefits from cultural services	Depression, suicide (associated with hopelessness and helplessness of wetland degradation & other environmental change; & their social consequences) Grieving over loss of place ("Solastalgia")	Environmental change (to a wetland system) that brings with it a sense of hopelessness and/ or helplessness Loss of productivity or livelihood associated with an ecosystem	Drought, salinity, extensive mining activity, deforestation, climate change

to flood and to be subjected to prolonged drought or coastal erosion, can be the context for such mental health exposures, and for their prevention.

Sense of place and psycho-social well-being

In the social sciences, the concept of 'sense of place' can improve understanding about the relationship between well-being and human-environment relationships. Tucker et al (2006) have summarized the work of others to define its characteristics:

> "Sense of place may broadly be described as the meanings which people assign to a landscape through the process of living in it, and comprises the cognitive, emotional and behavioural dimensions of place identity, place attachment and place dependence. . . . Place identity involves 'those dimensions of self that define the individual's personal identity in relation to the physical environment by means of a complex pattern of conscious and unconscious ideas, beliefs, preferences, feelings, values, goals and behavioural tendencies and skills relevant to this environment'. . . . Place attachment is a positive bond that develops between groups or individuals and their environment. . . . Place dependence is an occupant's perceived strength of association between him or herself and specific places . . . and [it] incorporates the manner in which environments facilitate the achievement of valued behavioural goals."

To determine the relationship between sense of place and a preparedness to invest in protecting ecosystems and the water services they provide, Tucker et al (2006) carried out a questionnaire-based survey of residents in the Hawkesbury river area (eastern Australia). They found that

> "in terms of intentions for performing protective behaviour or being willing to pay for protective measures, these are clearly linked to a number of threats that are directly associated with the urban water system, specifically: sewage/wastewater disposal; algal blooms; and litter. Further, it was evident that all Sydneysiders were concerned for the health of the river system, regardless of where they lived, and that it was the river system as a whole that was of interest, rather than any specific location." (Tucker et al. 2006).

Changes to wetland ecosystems are particularly relevant here. Rogan et al. (2005) demonstrated that environmental changes, manifesting as degradation to biophysical components, were salient influences on the way participants structured their relationship with their surroundings. They argued that managers of natural resources need to acknowledge people's awareness and perception of change as mediating variables when examining the effects of their decisions on local environmental quality. Albrecht (2005) has suggested that this awareness and perception of change can have a pathological extension. He described the term 'solastalgia' for the pain or sickness caused by the loss of, or inability to derive, solace connected to the present state of one's home environment.

Box 5.9: Avian influenza and wetlands: complex interactions

Since it was first recognized in 1997, highly pathogenic avian influenza (HPAI) H5N1 has infected domestic and wild birds in more than 60 countries across Asia, Africa and Europe. By November 2005, over 150 million domestic birds had died from disease or been slaughtered in attempts to control its spread; the economies of the worst affected countries in southeast Asia have suffered greatly, with lost revenue estimated at over $10 billion (Diouf 2005), and there have been serious human health consequences. By December 2008, 934 human cases have been confirmed by the World Health Organization, over 60% of these fatal.

Prior to HPAI H5N1, reports of HPAI in wild birds were very rare. The broad geographical scale and extent of the disease in wild birds is both extraordinary and unprecedented, and the conservation impacts of H5N1 have been significant. It is estimated that between 5-10% of the world population of Bar-headed Goose *Anser indicus* died at Lake Qinghai, China, in spring 2005. At least two globally threatened species have been affected: Black-necked Crane *Grus nigricollis* in China and Red-breasted Goose *Branta ruficollis* in Greece. During winter, approximately 90% of the world population of Red-breasted Goose is usually confined to just five roost sites in Romania and Bulgaria, countries that have both reported outbreaks, as also have Russia and Ukraine where they also over-winter. However, the total number of wild birds affected has been small in contrast to the number of domestic birds affected, and many more wild birds die of more common avian diseases each year. Perhaps a greater threat than direct mortality is the development of possible paranoia about waterbirds and misguided attempts to control the disease by disturbing or destroying wild birds and their habitats. Such responses are often encouraged by inflammatory and misleading messages in the media.

Highly pathogenic avian influenza H5N1 is a contagious viral disease caused by influenza A virus. There are many different influenza A viruses, and while some are capable of causing severe disease most cause infections that produce few, if any, symptoms. Avian influenza viruses are characterised as either of low or high pathogenicity (LPAI or HPAI). The natural reservoir of LPAI viruses is in wild waterbirds – most commonly in ducks, geese, swans, waders and gulls (Hinshaw & Webster 1982; Webster et al. 1992; Stallknecht & Brown 2007).

Given the ecology of the natural hosts, it is unsurprising that wetlands play a major role in the natural epidemiology of avian influenza. As with many other viruses, particules survive longer in colder water (Lu et al. 2003; Stallknecht et al. 1990), and the virus is strongly suggested to survive over winter in frozen lakes in Arctic and sub-Arctic breeding areas. Thus, as well as the waterbird hosts, these wetlands are probably a permanent reservoir of LPAI virus (Rogers et al. 2004; Smith et al. 2004) (re)infecting waterbirds arriving from southerly areas to breed (shown in Siberia by Okazaki et al. 2000 and Alaska by Ito et al. 1995). Indeed, in some wetlands used as staging grounds by large numbers of migratory ducks, avian influenza viral particles can be readily isolated from lake water (Hinshaw et al. 1980).

In these wetlands, LPAI viruses are a natural part of the ecosystem. They have been isolated from over 90 species of wild bird and are thought to have existed alongside wild birds for millennia in balanced systems. In their natural hosts, avian influenza viruses generally do not cause disease; instead, the viruses remain in evolutionary stasis as indicated by low genetic mutation rates (Gorman et al. 1992, Taubenberger et al. 2005). When LPAI viruses are transmitted to vulnerable poultry species, only mild symptoms are induced, such as a transient decline in egg production or reduction in weight gain (Capua & Mutinelli 2001). However, where a dense poultry environment supports several cycles of infection, the viruses may mutate, adapting to their new hosts, and for the H5 and H7 subtypes these mutations can lead to generation of a highly pathogenic form. Thus, HPAI viruses are essentially products of intensively farmed poultry (GRAIN 2006; Greger 2006), and they should be viewed as being made possible by human modification of a naturally balanced system.

After an HPAI virus has arisen in poultry, it has the potential both to re-infect wild birds and to cause disease in other non-avian taxa, with different subtypes showing varying predilection for horses, pigs, humans, mustelids, felids, and even seals and whales. If influenza A viruses adapt inside these new hosts to become highly transmissible, there can be devastating consequences, such as the human influenza pandemics of the 20th century (Kilbourne 2006). The conditions necessary for cross-infection are provided by agricultural practices that bring together humans, poultry and other species in high densities in areas where there is also the potential for viral transmission from wild birds to domestic ducks on shared wetlands and in 'wet' (i.e., live animal) markets (Shortridge 1977; Shortridge et al., 1977).

An agricultural practice that provides ideal conditions for cross-infection and thus genetic change is used on fish-farms in Asia: battery cages of poultry are placed directly over troughs in pig-pens, which in turn are positioned over fish farms. The poultry waste feeds the pigs, the pig waste is either eaten by the fish or acts as a fertiliser for aquatic fish food, and the pond water is sometimes recycled as drinking water for the pigs and poultry (Greger 2006). These kinds of agricultural practices afford avian influenza viruses, which are spread via the faecal-oral route, a perfect opportunity to cycle through a mammalian species, accumulating the mutations necessary to adapt to mammalian hosts. Thus, as the use of such practices increases, so does the likelihood that new influenza strains lethal to humans will emerge (Culliton 1990; Greger 2006).

-- text provided by Rebecca Lee, David Stroud and Ruth Cromie

> "Solastalgia exists when there is recognition that the place where one resides and that one loves is under assault (physical desolation) . . . the 'lived experience' of the loss of the value of the present as manifest in a feeling of dislocation; of being undermined by forces that destroy the potential for solace to be derived from the immediate and given." (Albrecht 2005).

Any context where place identity is challenged by pervasive change to the existing order has the potential to deliver this pathology. In the context of wetland ecosystems, natural disasters such as drought, fire and flood can be a cause of solastalgia. Human-induced change such as war, terrorism, land clearing, mass poisoning of fish, significant hydrological change (over-extraction, drainage or infilling of wetlands), mining, and rapid institutional change might also be causal agents. The concept of solastalgia has relevance in any context where there is the direct experience of negative transformation or desolation of the physical environment (home) by forces that undermine a personal and community sense of identity, belonging and control.

Examples include prolonged drought: research undertaken on the mental health aspects of drought have concluded that it is not just large-scale landscape change (loss of vegetation, dust storms, dead animals, starving animals, etc.), even smaller scale events might induce depression and illness, like the loss of a much loved part of a wetland used by farmers (Sartore et al. 2008). Alston and Kent (2008) describe the effects of the recent long-running Australian drought and in particular the social consequences affecting the farm families and communities reliant on agricultural production, focusing on the mental health outcomes for farm men, whom they find are more vulnerable to extreme measures such as suicide; they argue that this emanates from a stoicism so typical of normative rural masculinity that it prevents men from seeking help when their health is severely compromised (in this case, when there is a sense of helplessness and hopelessness caused by lack of rain).

Similar situations occur when citizens and communities experience dust, noise, machines, explosions and pollution generated from mining activity: clear connections have been found between the loss of ecosystem health and declines in both physical and mental health of those affected by large scale industrial activity (Connor et al. 2004).

The critical point of realization for a wetland manager, therefore, is that wetland ecosystems, and their changes, including their degradation, will have consequences for the mental health of populations who live in a wetland setting. The significant challenge for wetland management will be to intervene to prevent poor mental health outcomes.

5.5 Exposure to physical hazards

Natural disasters are extreme environmental events that may cause substantial morbidity and mortality in the population. Some disasters are discrete, relatively infrequent and largely unpredictable events (such as earthquakes), whereas others may follow an intermittent or cyclical pattern, including monsoonal floods, bushfires, and cyclones. At the other extreme, disasters may occur as a long-term and ongoing process: it may be argued that climate change increasingly falls into this category and that this global phenomenon drives the frequency and intensity of other wetlands-relevant disaster events.

Although each of these natural disasters may produce serious health consequences for victims, it is

Table 5.7: Exposure to physical hazards as a determinantsof health risks in a wetland setting

Health risk	Relevant wetland ecosystem services	Health effects, health outcomes from ecosystem services		Disruptions to wetland ecosystems (examples)	Examples or case studies
		Benefits if services are maintained or enhanced	**Consequences of disruption to the services**		
Exposure to physical hazards	Climate regulation Flood control, flood storage Soil, sediment & nutrient retention Coastal shoreline & river bank stabilization and storm protection Local climate regulation/buffering of change	People are not forced to migrate, or not forced to invest in protection from temperature extremes or physical forces Any of the benefits described in Sections 3 and 4, associated with enhanced livelihoods from wetland ecosystems	Exposure to extremes of temperature Exposure to floods and droughts, cyclones, hurricanes, tsunamis, etc. Any risk of exposure where change to a wetland ecosystem has been implicated	Clearing of native (deep-rooted) vegetation Loss of shade, soil organics and soil moisture Over-harvesting of fuels	Disasters like Hurricane Katrina, South Asian tsunami, Haiti earthquake

often the identification and management of *short-term* ill-health that captures most of the attention and resources. In contrast, *long-term* health impacts in communities that have experienced natural disasters are often overlooked. Recovery from disasters such as flooding, mudslides, or hurricanes is often a long, drawn-out process. Ongoing assistance is often required for long-term physical needs, and adverse impacts on psycho-social well-being can be protracted. In addition to defined clinical entities such as post-traumatic stress disorders (PTSD), many families suffer considerable financial hardship and social displacement following a disaster event. Recovery plans need to address these interruptions in the return to pre-disaster functioning and make provisions for addressing ongoing health problems. It is therefore relevant to examine illness patterns that may arise, directly or indirectly, in the months and years following a wetlands-related disaster event. In the context of this report, most attention will focus on the longer-term effects of failing to allow wetland ecosystems to regulate natural hazards: "not all health problems recede with the floodwaters".

The disease burden following major disaster events ranges from psychopathology (e.g., depression and generalized anxiety; substance abuse) to physical injury and systemic illness. The pathways to such disease events may be direct or indirect and, as Galea (2007) notes, such illness may become apparent across a spectrum of community members following a catastrophic event, including people injured during the mass trauma; rescuers; people who have lost property, belongings or capacity to sustain a livelihood; families of those injured; and the more general population who may lie outside the 'disaster zone' but are nonetheless affected in indirect ways by the event. The principal health outcomes, as well as possible pathways to community health impact, and relevance to wetland management, are summarized in Table 5.8.

The principal injuries reported after flooding include lacerations, blunt trauma, and puncture wounds, often in the feet and lower extremities (Shultz et al. 2005). Ahern's 2005 review of flood-related conditions reported sprains/strains (34%), lacerations (24%), ''other injuries'' (11%), and abrasions/contusions (11%).

There is ample evidence that disasters are linked to increased rates of infectious disease, but this is not an inevitable consequence. The majority of infections of concern occur during or shortly after the acute disaster phase. Post-injury complications are an immediate concern, however: after the 2004 tsunami in the Indian Ocean, for example, polymicrobial wound infections were common and contained pathogens from sea water, fresh water, and soil (Ivers & Ryan 2006). Tetanus is an associated risk; 106 cases (including 20 deaths) were described in the early weeks in Aceh after the Asian tsunami.

Following cyclonic events and flooding, infections transmitted by the faecal-oral route are a risk in

Table 5.8: Summary and review of post-disaster community health indicators

Category	Pathways to community health impact	Relevance for wetland managers(examples)
Chronic disability/ pain following physical injury	Initiation of injuries & their sequelae attributable to disaster event (directly or indirectly, e.g., from road accidents from infrastructure damage), both in the general population & in vulnerable groups	Identify flood extent of wetland systems & need to adjust built infrastructure accordingly in planning processes.
Infectious disease risk	Delayed biological contamination of water or food sources. Rodent, arthropod or other vector proliferation of disease-causing organisms or disease vectors in disrupted environments. Collapse of public health services, including immunization programmes	Identify routes of exposure of humans, stock & wildlife to wetland flooding extent. Plan measures to mitigate and/or restore wetlands.
Chronic systemic illness	Exacerbation of pre-existing chronic disease. Cardiorespiratory sequelae to psychological illness (e.g., depression/ post-traumatic stress disorder). Chronic exposure to toxic agents (e.g., air-borne particulates/air toxic/release of material from contaminated sites). Collapse of public health services.	Identify contaminated sites that may be inundated by flood waters or other natural hazards. Plan measures to mitigate exposure to contamination, and/or restore wetlands. Wetland managers provide important support for public health services.
Effects of malnutrition & trace element toxicity	Contamination or loss of food sources. Modification of dietary practice. Suboptimal micronutrient intake, especially in vulnerable populations	Wetland managers will be involved in the identification & treatment of contamination sources. Plan measures to mitigate exposure to contamination and/or restore wetlands.
Mental health outcomes	Post-traumatic stress disorder/depression/ anxiety from psychological or physical trauma/ regional economic insecurity/decline in social capital. Exacerbation of pre-existing mental health illness	Plan measures to restore wetlands, involving local people where necessary and appropriate.

-- adapted from Cook et al. 2008

the short to intermediate term. The 2004 floods in Bangladesh resulted in more than 17,000 confirmed cases in one treatment centre of enterotoxigenic *Escherichia coli*, *Vibrio cholerae*, *Shigella* spp and other enteric pathogens (Waring & Brown 2005), with those affected by milder diarrhea in the general population estimated to be far greater. Other faecally transmitted pathogens, such as hepatitis A and E, *Salmonella typhi* and *enterica* (typhoid and paratyphoid fever), and *Cryptosporidium parvum* have all been documented in the wake of disasters (Beinin 1985; Watson et al. 2007).

Although most of these events are relatively short-lived, the potential for a more protracted risk of communicable disease may arise if these post-disaster problems are not resolved. In general, the main risks arise as a result of population displacement (Watson et al. 2007), which creates situations in which poor sanitation, overcrowding, and contamination of food or water sources arise. Full-scale epidemics are more likely in communities experiencing associated conflict, poor underlying health status (including immunity to vaccine preventable diseases), and limited availability of health care (Griffin 2007; Mims & Mims 2004). If the disaster is sufficiently severe, community destruction and dislocation may force populations to remain in camp accommodation for months or years. Communicable diseases usually present at lower levels in the community may display epidemicity in the disrupted setting after a disaster. Delayed increases in a number of infectious diseases, including typhoid and paratyphoid fever, infectious hepatitis, gastroenteritis, and measles, were reported five months after Hurricanes David and Fredrick in the Dominican Republic in 1979 – these deferred outbreaks were attributed to extended residence in crowded shelters coupled with insufficient sanitary facilities, disruption and contamination of food and water supplies, and suboptimal immunization rates (Shultz et al. 2005).

Displacement may also favour malaria transmission. Non-immune refugees may contract the disease by passing through or settling in high-risk areas, or – conversely – infectious cases may disseminate disease to other areas (Anon 1990). Environmental changes caused by a major catastrophe may act as an ongoing driver of infectious disease. Inundation or disruption of water services, such as damaged or overwhelmed sewerage or drainage systems, provide ideal conditions for proliferation of disease vectors. In the aftermath of giant waves and local subsidence following the massive 2004 South Asian earthquake, the problem of saltwater intrusion became more acute for the Andaman Islands (Kondo et al. 2002). Paddy fields and fallow land which once contained mainly fresh water turned increasingly brackish, resulting in profuse breeding of a salt-tolerant malaria vector, *Anopheles sundaicus:* the authors note that vector abundance and increased malaria transmission potential are likely to remain a permanent feature of the islands, given the extent of the tsunami-created breeding grounds and their continued flooding from land subsidence.

Following a disaster, chronic physical illnesses in the intermediate to long term often arise because of the disruptions in medical care and management. The increased strain on, or collapse of, existing medical facilities following such events may destabilize normal patterns of care. The failure of the health infrastructure to care for displaced (and often impoverished) people has profound implications for those who require medications, ongoing procedures (for example, dialysis; pain management), or a high level of care (including those with diabetes, epilepsy, heart disease and respiratory illnesses; those with disabilities; the elderly).

Disasters also have the capacity to exert ongoing health effects by dispersal of toxic agents, including petrochemicals, human and agricultural wastes, and asbestos, which may persist for long periods in wetland ecosystems. The disease process and the risks posed by such hazards may not be apparent until many years after the event, and they are likely to be subsumed by more immediate concerns in the immediate disaster aftermath. Considerable concern has been expressed about the potential toxicity of the floodwaters in post-Katrina New Orleans. A systematic study indicated that levels of lead, arsenic, and chromium exceeded drinking water standards; although contamination levels were not notably high, the extent of their dispersal and the potential population affected was considerable (Young et al. 2004). The receding waters also left sediments at risk of eventually becoming desiccated and windborne. These dusts, which are potentially respirable and contain toxicants such petrochemical residues and asbestos, may continue to pose a hazard for many years into the future. This process of dust mobilization is occurring in combination with a serious mold hazard (Euripidou & Murray 2004); a study of water-damaged homes in New Orleans and surrounding parishes estimated that 63% of homes are experiencing mold contamination. It has recently been hypothesized that the combination of exposure to mold and the contaminated dusts is likely to result in increased susceptibility to allergies and respiratory illness in New Orleans residents who are trying to return to their lives and businesses (Plumlee et al. 2006).

Mental health issues following disasters including flooding are well-documented, and it is common for individuals to experience acute distress in the face of such overwhelming events. Although the majority do not continue to be adversely affected in the long term, a significant proportion of disaster victims experience persistent mental ill-health, including posttraumatic stress disorder (PTSD), major depression, or other psychiatric outcomes (Brennan & Waldman 2006).

It is a key point to be noted that these consequences of disasters, and their relevance for wetland management, will not exist independently of wetland ecosystems or their services. The water and the wetlands themselves could become the medium for the spread of disease, or the source of the contamination, requiring intensive treatment, and such events will dominate the wetland management imperatives well beyond the disaster itself. Planning to cope with hazards like floods, hurricanes and tsunamis will invariably involve wetland managers and wetland scientists in the identification of extent of flooding, identification of contaminants, mitigation of potential exposures to contaminated sources, and in some cases active wetland restoration.

5.6 Conclusion

There is a need to broaden the traditional perspectives of public health and their epidemiological approaches into an approach more closely aligned with the science of ecology, an area where wetland managers have a significant contribution to make. Infectious diseases include water-borne and vector-borne pathogens and come from a diverse range of biotic groups, all requiring an ecological understanding of the conditions that allow proliferation, resurgence, or emergence of the pathogen.

Wetland managers need to acknowledge people's awareness and perceptions of change as mediating variables when examining the effects of their decisions on local environmental quality. This awareness and perception of change can have a pathological extension, for instance the pain or sickness caused by the inability to derive solace from the present state of one's home environment.

The consequences for human health may persist or arise over the long term, so interventions must operate with all relevant temporal scales rather than just the short or medium term. For instance, communities that have experienced disasters can suffer from physical injury, exposure to microbial and chemical contaminants, increased disease vector activity, over the shorter term, but the mental health effects can be persistent and enduring and potentially affect several generations.

Since many of these matters operate at the global scale, the attention of wetland managers must also be focused beyond local and regional concerns. Freshwater ecosystem disruptions at the global scale will affect both developed and developing countries, and the same holds true for the consequences of climate change on human health.

Climate change has exacerbated, and is expected to continue to exacerbate, health impacts in relation to wetlands and water, both by affecting the wetlands themselves, for which it is projected that there will be more adverse than beneficial impacts (particularly affecting reefs, atolls, mangroves, wetlands in prairies, tropical and boreal forests, and arctic (including permafrost) and alpine ecosystems), and by affecting disease burdens through increased death and disease from climate extremes, as climate change and variability alters distributions of vector-borne disease and contributes to more widespread drought, decreasing food production in low latitudes, and thus increasing the number of undernourished people in the low-income world.

6. Interventions required to enhance human well-being by addressing the erosion of ecosystem services in wetlands

6.1 Introduction

This report has so far emphasised the strong interdependence of wetland ecosystems and human health as a key component of human well-being. An understanding of this interdependence has been constructed from a) the linkages between ecological character and ecosystems services, b) an elaboration of the way ecosystem services benefit human well-being, c) a recognition of drivers of ecosystem change that diminish the contributions of those ecosystem services, and d) a documentation of the human health effects and outcomes of such changes. Arising from this is a response imperative: *what interventions are required to enhance human well-being by addressing the erosion of ecosystem services in wetlands?*

Both wetland ecosystem health and human health are being affected, often adversely, by the broad spectrum of direct and indirect drivers of change to ecosystems. Ultimately only the very challenging resolution of these global issues will facilitate improving both human and ecosystem health. These global issues are set out in, for example, the Millennium Ecosystem Assessment and the Global Environment Outlook, and require increasingly urgent and major changes in societal attitudes and governmental policies and responses. Within this, there are a range of available or promising response options, particularly at the smaller scales of wetlands, which may help.

There are critical points here that determine the structure of this section. For all interested stakeholders, and for reasons argued throughout this report, it is clear that a business-as-usual model will not deliver the changes required to address the magnitude of challenges faced. The first section of this section deals with *attitudinal shifts and reorientation of perspectives to enable those with a wetland and human health question to construct their problem statements*.

The reformulation of the water and wetland management agenda will require changes within governments at all levels. Such changes will seek to develop cross-sectoral approaches to societal matters such as ecosystem management, public health, agriculture, and public infrastructure. Without such policy initiatives and governance considerations, the task of addressing on-site wetland management and public health issues together will be very difficult. The second section of this chapter will attempt to *explain how particular interventions at a higher level of policy development will enable on-the-ground action*.

Wetland managers will therefore be encouraged to consider the positive or negative consequences of their actions for human health. Conversely, by attending only to matters of human health and well-being, societal actions may directly or indirectly result in ecosystem disruption. Wetland managers will therefore need to respond and act appropriately in both cases, and the last part of this section will *provide some instruments and approaches that will allow wetland managers to assess the possible implications of their actions on human health and well-being.*

Policy and practice interventions are derived from previous and recent international investigations of these topics. Four international investigations have been of particular use in this regard:

- the Millennium Ecosystem Assessment in 2005;
- the Global Environment Outlook (UNEP 2007);
- the 2nd UN World Water Development Report of 2006;
- Comprehensive Assessment of Water Manage-ment in Agriculture (Molden 2007).
- The Health in All Policy (Kickbusch 2008; Adelaide Statement on Health in all Policies 2010) was also examined to demonstrate the locus of some of these issues within the health sector at large.

6.2 Thinking big – changing attitudes and perspectives

These five compendia and policy agendas repeatedly emphasise two important points related to ecosystem change and human well-being: *proposed response and intervention themes are often common across different sectors*, yet many of the possible *response options to human health and ecosystem change lie primarily outside the direct control of the wetland sector and the health sector,* for they are embedded as attitudes and perceptions in areas such as sanitation and water supply, education, agriculture, trade, tourism, transport, development, and housing. Because of this, the importance of identifying principal partners and responsible stakeholder groups required to achieve appropriate outcomes cannot be overemphasized. To be most effective, wetland policy-makers should recognize that integrating across these partners and groups, by 'creating a space' for them, is essential to reducing the potential health impacts of ecosystem change. These integrated approaches, and spaces, will necessarily address existing social values and cultural norms, existing infrastructure, and the social, economic, and demographic driving forces that result in ecosystem change. These driving forces do not just produce ecosystem changes – they are also a product of them in true reciprocal and interdependent style.

Using systems thinking, wetland managers realize that there are consequences of their actions, and they undertake these actions *knowing* about them, notwithstanding the fact that we live in a complex and uncertain world. We suggest that four attitudinal changes will assist this process for wetland managers (as shown in Figure 6.1).

Figure 6.1: Attitudes and perspective shifts required for wetland managers to ensure that human health consequences are adequately considered in policy and practice

I) When tradeoffs are being made, they need to be considered and valued according to principles of sustainability and equity rather than ignored or dealt with on financial terms only.

II) It is not acceptable to reason that we can manage wetlands for biodiversity alone; in fact to do so, as argued in this report, will be counterproductive. A people-centred approach in wetland management, which does not diminish the importance of biodiversity, will help achieve co-benefits of sustainable ecosystem management and the Millennium Development Goals.

III) Resolving matters of tradeoffs across levels of human involvement from the personal to the global is achievable with dialogue, using a deliberative rather than hierarchical approach, to ensure that the local interests of people are not marginalized by more powerful forces.

IV) Identifying principal partners and responsible stakeholder groups, often across disciplines and between sectors where barriers and boundaries exist, requires a particular form of engagement that wetland managers need to develop as part of their skill set: patience, tolerance of these 'others', and a willingness to reciprocate.

Thinking differently about tradeoffs

The Comprehensive Assessment (Molden 2007) dealing with agriculture identified the *big* tradeoffs. One of the major tradeoffs will be controversial: the need to address human health issues where solving such matters might lead to local population increases and further pressures on local resources which might then lead to other forms of human suffering(a *human population* tradeoff). Tradeoffs are invariably part of a social ecological system[6], where patterns of tradeoffs result in either virtuous cycles (where societal benefits reinforce decision-making) or vicious cycles (where decision-making boomerangs to make conditions in the system worse). These are not resolved through simple formulae – rather they require flexible and adaptive approaches of awareness and response.

Another tradeoff occurs when promoting productive and efficient agriculture tends to favour the wealthy, while promoting more equitable, nutritious and/or environmentally benign agriculture is not necessarily productive (an *equity-productivity* tradeoff). A tension can exist between providing for quality of life for this generation at the expense of quality of life for the next, or vice versa (an *intergenerational* tradeoff).

High on the list of tradeoffs identified was the need to address whether to provide water storage for agriculture or water for the environment (*water for allocation/environment*), and how much should go to either. Similarly, to what extent will a reallocation of water actually mean an overallocation of water (*reallocation or overallocation of water*), and to what degree should we address upstream causes or downstream effects (*upstream-downstream*).

A key category of tradeoff of particular interest for this report is where ecosystem services for particular health or well-being gains are disrupted because another set of ecosystem services are enhanced to produce different health or well-being gains. A conspicuous example is where a provisioning service (e.g., using water from a wetland to benefit human well-being) is enhanced at the expense of regulating services which might have negative consequences for human health. Rodriguez et al. (2006) classify such ecosystem service tradeoffs along three axes: a spatial scale concerns the degree to which the effects of the tradeoff are felt locally or at a distant location; a temporal scale refers to whether the effects take place relatively rapidly or slowly; and the degree of reversibility expresses the likelihood that an ecosystem service might be extinguished and unable to return to its original state if management regimes prioritise other ecosystem services.

Where there are tradeoffs, it is important for politicians, regulators, and the public to understand the consequences of taking one path in preference to another (Rodriguez et al. 2006). Recognizing the potential for tradeoffs is an important step in this understanding, and modeling consequences under different scenarios, for each of the axes outlined by Rodriguez et al. (2006), will be the first significant step. But beyond that, undertaking a *process* by which the tradeoffs and their consequences are negotiated becomes the central concern: representation of marginalised stakeholders, increased transparency of information, and engaging with the core pursuits of other sectors will be key components of such a process.

Wetland management contributions to MDGs

One of these complementarities is achievable when wetland policy-makers and wetland managers make a contribution towards the Millennium Development Goals (Table 6.1) when the close relationship between food production, hunger and poverty, climate change, water use and extraction, and wetland management are concerned. A review report on water management in agriculture, specifically with the MDGs in mind, was conducted by Molden (2007). The analysis pointed to the critical need to focus on rainfed agriculture in poverty-stricken areas for poverty reduction and increasing productivity, accompanied by increased human and institutional capacity to reduce risk. Also important for the stability of food production will be enhancing the performance and productivity of existing irrigation. While trade will be an important factor in the global water supply and demand equation, it cannot be relied upon to address issues of environment, poverty, and individual food security, underscoring the need to focus on food production in those areas vulnerable to the uncertainty of trade. It concluded that whatever strategy is chosen, there will be difficult tradeoffs among productivity, ecosystems, poverty reduction, and so on.

Seeking to achieve MDGs, improve human health, and enhance wetland ecosystem services may not necessarily be mutually beneficial, indeed systemic effects like cross-scale interactions and feedback consequences may prove to undermine originally intended objectives in this regard. Table 6.1 provides some examples of where intervening in the disrup-

6 "Social ecological systems" make explicit the complex linkages between human behaviour and organization and the biophysical world. In fact, the linkages are so intertwined that the system becomes 'self organized' to deal with the phenomena that emerge from the relationships.

tion to wetland ecosystem services may help to improve human health and address the MDGs, and where addressing MDGs need to be more cognisant of the systemic nature of the relationship between human health and wetland health. For the latter, where potential negative consequences are foreseeable, this is no reason to avoid actions that seek to achieve these MDGs; rather the argument is that these consequences need to be considered en route as part of the process.

Consideration of the tradeoffs among different wetland ecosystem services and the need for cooperation across sectors will be critical in designing actions in support of the Millennium Development Goals. For example, it is not uncommon for strategies aiming to increase food production and reduce poverty to propose the conversion of marshes to agriculture, conversion of mangroves to aquaculture, and significant increases in the use of fertilizers to increase crop production. This approach, however, will reduce habitat area (and hence the magnitude of services provided by the original habitat), increase the input of water pollutants, remove the natural water filtering service provided by wetlands, and remove ecosystem services provided by mangroves, such as stormsurge protection, timber and charcoal supply and fish habitat, on which local residents in particular rely. This will make the development goal of improved water and sanitation more difficult to achieve and may in fact increase poverty for some groups. In contrast, a development strategy that aims to safeguard the full range of benefits provided by wetlands might better achieve the set of development goals while minimizing future harm to the wetlands.

The role of deliberation in managing tradeoffs

Ecosystem services are mostly public goods by nature, meaning that society as a whole is better off if those services are maintained, even if there are limited numbers of people who privately and exclusively benefit from them. This raises ethical and normative concerns, the issue of social rights and wrongs and the role of dialogue in a public arena to understand their management and fully appreciate the impacts of alternative choices. The heterogeneity of power structures, unequal social positions, and differential strengths in political bargaining processes often prevent rational decision making, leading to marginalization and creation of silent sufferers of imposed choices. In principle, wherever common goals are necessary, they should be worked out in a manner and process wherein each individual is fairly represented. Deliberation therefore plays an important role in managing tradeoffs. When the process of deliberation requires citizens to go beyond private self interest, there is an increased likelihood of achieving social equity and political legitimacy of outcomes (Elster 1997). It is not surprising that value-laden tradeoffs and cost-benefit analyses often fail the test of social equity.

A variety of approaches have been designed and employed to increase deliberation and participation. They range from consultation as an information-gathering exercise to full engagement with decision-making responsibilities (Arnstein 1969). Stakeholder engagement is one of the commonly used techniques. Often small focused groups are also used to derive deliberative solutions. A mix of two approaches, for example social multicriteria analysis and mediated modelling (Kallis et al. 2006; Stagl 2007), has also been suggested.

Though appealing, deliberation is far from being a simple concept and strategy. Stakeholders can be difficult to engage in a process of deliberation (Arzt 2005), especially when they have prior expectations from existing institutions and/or power within existing decision processes that they wish to protect. The 'sustainable livelihoods' approach outlined in Box 4.5 above should help in this regard.

Beyond this, wetland managers and health service providers need to be realistic about the social nature of politics, aware that outcomes from different consultation processes will not be the same. Opinion makers may often lead dialogue in specific directions, and consensus has even been used as a tool to silence specific groups. Seeking to explain, explore and respect (not remove) "dissensus" might be just as valuable in some contexts as aiming for consensus may be in others (Spash 2007).

Engaging with other sectors

A sector is a level of society that shares a common set of goals, represented by a specific language and agreed methodologies and behaviours. In this sense, the *wetland sector* will be different to the *health sector*, the *private sector* will be different to the *public sector*, and the levels of government are represented by different sectors, too (local government vs national government sectors). Sectors tend to develop responsibilities hierarchically, with resources distributed and power relationships established accordingly, and to develop their own languages and patterns of behaviour around what they perceive as their core business. Sectors might overlap for some of their business; for example, water, sanitation, and hygiene are often referred to as a single sector, and that sector can overlap with others, such as occupation, energy, and nutrition. To address that part of the global disease burden associated with water, sanitation and hygiene, these other sectors must be engaged to act as well, including both at policy level and on their specific activities. These sectors manage both determinants of health (e.g., operating dams) as well as their direct effects (e.g., safe water and sanitation in workplaces), but differ in other spheres of activity and emphasis. Another example is the water resources and the wetland sectors, each with different responsibilities but with areas of overlap.

Most of the located, site-based, on-the-ground action-oriented practices already operate across sectors, where interaction with local interests is easier; this should of course be encouraged and supported through governance structures and policies. Herein lies the problem.

Calls for *cross-sectoral action*, like those in this report, really refer to the need to overcome the boundaries that are created (and often defended) between sectors in governance systems, and they will necessitate reciprocity, mutual understanding, and respect. The imperative for wetland policy-makers will be to engage with the health sector in this way, albeit under the assumption that that engagement will be returned. Identifying the areas of commonality and overlap represents a potentially powerful pursuit, like the co-benefits of healthy ecosystems and healthy people, between sectors as disparate in some governments as wetlands and public health. This agenda is elaborated below.

6.3 Enabling responses and interventions – the policy level

This section presents a synthesis of some proposed policy interventions from previous and recent international investigations that are relevant for enhancing wetland ecosystem services and human health. In most cases, the policy interventions are non-specific and non-targeted. Their application can be broad provided that the context is taken into account and the particularities are specified. The responses range from promoting cross-sectoral governance and institutional structures, to promoting rationalized incentive structures, to social and behavioural responses that include capacity building, communication, and empowerment, to technological solutions such as enhancing multi-functionality of ecosystems and other cognitive responses. Finally, the strategic development of appropriate mechanisms that will enable health costs to be included satisfactorily into wetland management are recommended (Figure 6.2).

Institutions and governance

As discussed above, there is considerable potential to build on existing frameworks for social processes that focus on the deliberative, collective, often multi-stakeholder approaches to achieve both ecosystem management and public health objectives. There is a growing consensus that these objectives can only be met by developing governance processes that include adaptive management, social learning, and cross-sectoral engagement in institutional agendas. This is consistent with the view that place-based settings for social learning and action can transcend boundaries between sectors, disciplines, communities and cultures (see the Adelaide Statement on Health in all Policies 2010).

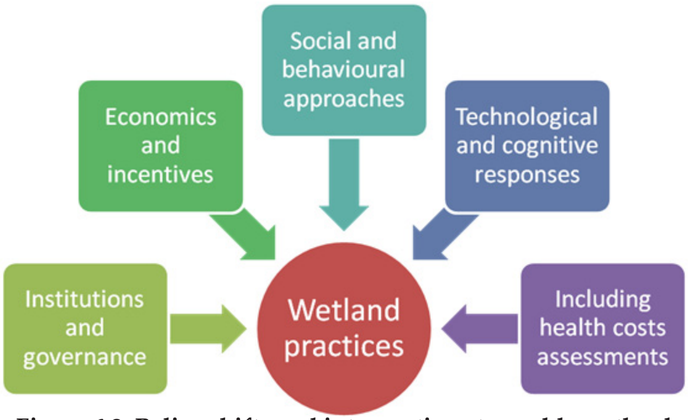


Figure 6.2: Policy shifts and interventions to enable wetland practices to accommodate notions of ecosystem services and human health

If watershed management is to both enhance ecosystem services and also improve environmental and social determinants of health, the challenge will be to create institutional and governance frameworks for water that build trust and social cohesion and reduce inequalities. While each of Ostrom's (1990) design principles for long-enduring natural resource management organizations has relevance in this regard, Falkenmark and Folke (2002) summarise governance imperatives in this way:

- securing social acceptance of measures that are considered necessary and limiting the earlier degrees of freedom;
- arranging for resolution of disputes between stakeholders with incompatible interests;
- attending to existing nestedness between both catchments and subcatchments on the one hand and between ecosystems on the other.

Table 6.1: Ways in which wetland management might contribute towards the achievement of the MDG

Millennium Development Goals	How will intervening in disruption to wetland ecosystem services to improve human health help address the MDGs?	Systemic consequences: where will addressing MDGs need to be alert to the relationship between human health and wetland health?
1. Eradicate extreme poverty and hunger	Food security of the poor often depends directly on healthy ecosystems & the diversity of goods and ecological services they provide. Diverse wetland ecosystems are self-sustaining & provide more nutritious food than, & the essential genetic material for, aquaculture and horticulture. Sustainable livelihoods seek to ensure that the core requirements of food & water are provided to those dependent on the provisioning of wetland ecosystems.	The challenge for irrigated agriculture in this century is to improve equity, reduce environmental damage, increase ecosystem services, & enhance water & land productivity in existing & new irrigated systems. Improving productivity must not come at the expense of other ecosystem services. If it does, the human health consequences of ecosystem disruption will be invoked in full or in part.
2. Achieve universal primary education	Wetland management must address the disruptions to ecosystem services that result in water-related diseases. Water-related diseases such as diarrheal infections cost about 443 million school days each year, diminish learning potential & reduce the coping capacity of local populations for current predicaments & future ecosystem changes.	Primary education will need to include literacies for health, water & energy at least (a fundamental necessity for urban dwellers who have become more alienated from their surroundings than at any stage in human history). Such literacies will enhance the understandings of the interdependencies between human health & wetland ecosystem services. Education services can tend to resist increases attention to such literacies at the expense of other education imperatives.
3. Promote gender equality & empower women	Addressing degradation in wetlands, such as water contamination & deforestation, will contribute to the health of women & girls, who bear the brunt of collecting water & fuelwood & are more vulnerable members of populations to water-borne diseases.	Improved wetland management must involve women & girls in a meaningful way, perhaps by recognizing that women can play greater roles in wetland management than they currently do. "Wetland managers", as a profession, tend to be men. Decision-making structures for water resource management, wetland management, & agriculture are also gendered in many parts of the world. Both may operate as barriers to achieving this Goal.
4. Reduce child mortality	Wetland management will become an essential operational requirement to reduce exposures to waterborne diseases, such as diarrhea & cholera. Prevalence of these diseases is a result of disruption to regulatory services due to overextraction & inappropriate practices.	Interventions at appropriate water treatment facilities (often through aid provision) will usually be technological & infrastructural in the short term to address immediate needs. However the medium- to long-term goal should be to manage wetland ecosystems to ensure that they can provide suitable water purification services.

5. Improve maternal health	Addressing disruptions to wetland ecosystem services will always include an examination of water quality. Provision of clean water reduces the incidence of diseases that undermine maternal health & contribute to maternal morbidity and mortality.	Treating water with chlorine to prevent waterborne microbial diseases produces trihalomethane as a byproduct and these compounds may have adverse birth outcomes. Improving the quality of source water & distribution infrastructure may reduce disinfection loads and the likelihood of these maternal exposures.
6. Combat major diseases	Up to 20% of the total disease burden in developing countries may be associated with environmental risk factors. Preventative environmental health measures are as important & at times more cost-effective than health treatment. Managing wetlands to enhance ecosystem services with the aim of reducing the likelihood of human exposures to pollutants & infectious diseases is preventive, attending to upstream environmental determinants of health. New biodiversity-derived medicines hold promise for fighting major diseases.	Increasing population sizes from successful preventive measures may increase pressure on local water & wetland resources. Wetland management must act in concert with water resource management to deal with these consequences, for instance by increasing awareness & understanding & embedding ecosystem services in prevention strategies. This management will need to be integrated with regional population policies, education & awareness.
7. Ensure environmental sustainability	Current trends in environmental degradation must be reversed in order to sustain the health & productivity of the world's ecosystems. Wetlands, & the biodiversity they support, encompass many of the key ecosystems of the world, & many of the most productive ones. Wetland management must apply directly to this Goal.	Development strategies that aim to safeguard the full range of benefits provided by wetlands might better achieve the goals while minimising harm to wetlands. This will require recognizing & understanding the ecosystem service tradeoffs.
8. Develop a global partnership for development	Poor countries & regions are forced to exploit their natural resources, like wetland ecosystems, to generate revenue & make huge debt repayments. Unfair globalization practices export their harmful side-effects to countries that often do not have effective governance regimes.	Global trade, tourism & migrations of species (particularly waterbirds) are all transcontinental. Meaningful wetland management acknowledges that pests & pathogens capable of decreasing ecosystem services & having consequences for the health of local human communities can be distributed by inappropriate human activities. This requires appropriate recognition in global partnerships for development.

-- see also Molden 2007 and WWDR 2006

These imperatives are reflected by the World Water Development Report (2006) in its chapter dealing with 'Promoting and Protecting Human Health'; in particular, it recommended that governance make the multiple uses and multiple users of water the starting point of planning, developing and managing water resources at the river basin level. It also recommended the promotion of the principle of subsidiarity in the governance of water resources (the principle of subsidiarity holds that "a larger and greater body should not exercise functions which can be carried out efficiently by one smaller and lesser, but rather the former should support the latter and help to coordinate its activity with the activities of the whole community" (Mele 2004).

The Millennium Ecosystem Assessment re-iterated the importance of developing institutional frameworks that promote a shift from highly sectoral resource management approaches to more integrated approaches, requiring collaboration across sectors within government interagency coordination to bring coherence to international negotiations and national policy development. The Adelaide Statement on Health in all Policies highlighted "the need for a new contract between all sectors to advance human development, sustainability and equity, as well as improve health outcomes. This requires a new form of governance where there is joined-up leadership within governments, across all sectors and between levels of government" (see also Kickbusch 2008).

An interesting theme here is the parallel recognition by the environment sector and the health sector of the need to integrate both ecosystem management goals and those of public health within other sectors and within broader development planning frameworks. There are also broadly based calls for increased transparency and accountability of government and private-sector performance in decisions that affect ecosystems and human health, including through greater involvement of concerned stakeholders in decision-making.

Integrated, adaptive management approaches (rather than single issue, command-and-control regulatory approaches) are fundamental in achieving social and economic development goals as we are working for the sustainability of aquatic ecosystems to meet the water resource needs of future generations. To be effective, such approaches must consider the linkages and interactions between hydrological entities that cross multiple "boundaries," be they geographic, political, or administrative. Ecosystem-based management approaches also provide a basis for cooperation in addressing common water resources management issues, rather than allowing such issues to become potential sources of conflict between countries or regions.

Economics and incentives

Human behaviour and incentive systems have been central to the provision of wetland ecosystem services. Based on the values people hold for wetlands, important repercussions for ecosystem services could result just by making the link between the economy and environment more explicit. While valuation does serve the important task of capturing the value of ecosystem services in concrete economic terms, individual and institutional behaviours continue to degrade these services as long as markets fail to emerge for most of them (Cornes & Sandler 1996). Experience has shown that well-designed market-based instruments can achieve environmental goals at less cost than conventional "command and control" approaches, while creating positive incentives for continual innovation and improvement (Stavins 2000). Increased emphasis on financing mechanisms within conservation and development sectors is a part of the policy shift that recognizes the success of markets in inducing changes in individual and institutional behaviour in a cost effective manner.

Of late, there is a growing focus on the use of the economic contributions from ecosystem services to design incentive systems wherein external beneficiaries can make direct, contractual and conditional payments to local landholders for adopting practices that ensure continued provision of these services (Wunder 2005). The mechanism, termed 'Payments for Ecosystem Services' (PES), has been one of the important developments linking the valuation of ecosystem services to incentive systems that promote sustainable use of those services (see Box 6.1). Though their application to date has been focused on carbon sequestration, watershed management, and biodiversity conservation, they are significantly valuable for addressing wetland loss and degradation through stakeholder-led management and sustainable financing. Most of the services that have been considered for PES schemes usually emanate at a landscape scale, and in this instance as ecosystem services provided by watersheds and wetlands.

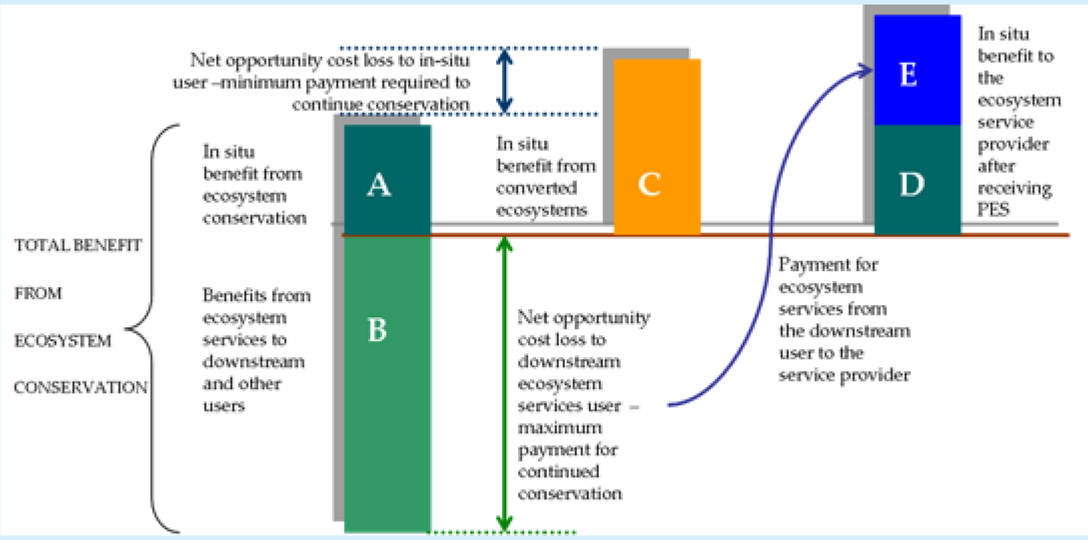
The payments, as water markets and water-pricing develop, will need to occur along with improved allocation of rights to freshwater resources in order to align incentives with conservation needs (Finlayson et al. 2005), with the elimination of subsidies that promote excessive use of ecosystem services (and, where possible, transfer of these subsidies to the payments for non-marketed ecosystem services) (Millennium Ecosystem Assessment 2005).

Other economic instruments and market mechanisms with the potential to enhance the management of ecosystem services include taxes or user fees for activities with "external" costs (tradeoffs not accounted for in the market), creation of markets, including through cap-and-trade systems, and mechanisms to enable consumer preferences to be expressed through markets (Millennium Ecosystem Assessment 2005).

A particular challenge for investing in wetland ecosystem services exists for poor communities in developing countries, often entangled in the poverty trap: to meet short-term livelihood needs, they are forced to exploit their environment unsustainably, eroding critical life support services such as fisheries, timber resources, soil fertility and freshwater provision, and entrenching poor living conditions. One approach in this context is that of 'biorights' – a financing mechanism that links poverty alleviation and environmental conservation (van Eijk & Kumar 2009). In return

Box 6.1: Payment for Ecosystem Services (PES)

PES has attracted increasing interest as a mechanism for translating external, non-market environmental values into real financial incentives (Engel et al. 2008). Recently, there have been increasing attempts to define rigid characteristics for PES, including the following definition proposed by Wunder (2005): "PES is a voluntary transaction where a well-defined environmental service (or a land use likely to secure the service) is being 'bought' by a (minimum one) service buyer from a (minimum one) service provider, if and only if the service provider secures service provision (conditionality)".



The logic of PES is shown in the figure above. The overall economic benefit arising from the conservation of a particular ecosystem is presented by the bar on the extreme left. Recognizing spatial heterogeneity in accrual of benefits, it is assumed that in situ users derive an income stream A, whereas the downstream and other beneficiaries derive an income stream B. For example, in the case of a wetland ecosystem, the in situ benefits could be availability of drinking water supply, fisheries, and economically important vegetation. The flood mitigation, sediment retention and other regulatory services would translate into an income stream to ex situ users. The in situ user is faced with an alternate income stream C which could be derived through ecosystem conversion, say filling up the wetland for agriculture and residential purposes. Thus, despite the overall economic benefit from the converted ecosystem being less than an unconverted one, an ex situ user faces an opportunity cost in terms of lost benefits. This is represented by the difference in the income stream bars A and C. To a rational in situ user, a payment of this difference in income streams constitutes a minimum incentive to maintain the ecosystem. A rational downstream user, who derives an income stream B, can pay a maximum amount equivalent to the income stream at stake through conversion to an alternate use. This induces the ex situ user and an ecosystem service buyer to enter into a contract for continued provisioning of the services by providing a payment, which ranges between the minimum and maximum range (represented by bar E), to the in situ user or ecosystem services provider. The total income stream to the ecosystem services provider (bar D plus E) is thus more than that of a converted ecosystem, making conservation viable. The system thus internalizes what would otherwise be an externality (Pagiola & Platais 2007).

Apart from being a mechanism for achieving ecological objectives, PES could also form the basis of public-private partnerships within the environment sector (Box 6.2). PES has been applied in a wide range of circumstances – Ravnborg et al. (2007) identify 167 PES cases based on hydrological services, biodiversity conservation, carbon sequestration, and landscape beauty. Landel-Mills & Porras (2002) in their global review mention 287 cases of application of PES. However, Wunder (2008) emphasizes that there are no more than a couple of dozen cases that satisfy all the five criteria suggested in the definition. The range of ecosystem services vary from specific services to bundled-up situations, wherein a particular service renders more than one ecosystem service.

Box 6.2: Public-private partnerships for water quality

In 1992 the Société des Eaux Minérales d'Evian joined with the French government to found an organization to protect the catchment area of the natural spring, experimenting with more environmentally-friendly farming practices, expanding the nearby sewers, and ensuring regulatory compliance by livestock holdings. The Société now supports two thirds of the conservation costs in the catchment. Similarly, Vittel pays US$ 230/ha to farmers to support sustainable agricultural practices within the catchments of its water sources; this is cheaper than constructing filtration units (Smith et al. 2006; Perrot-Maître 2006). The Los Negros scheme in Bolivia focuses on watershed and biodiversity protection whereby the Pampagranade Municipality pays Santa Rosa farmers for forest and páramo conservation (Asquith et al. 2008). The central government of China initiated the Sloping Land Conversion Program focusing on watershed protection in which the central government pays rural households for cropland retirement and afforestation (Bennett 2008).

for provision of microcredits, local communities are involved in ecosystem protection and restoration, and with the successful delivery of services, these microcredits are converted into definitive payments. Applications of biorights have been fairly successful in mangrove restoration in Java, tsunami affected areas in Aceh, and waterbird conservation in Inner Niger Delta, Mali.

While such approaches are promising, recent developments in institutional economics have challenged the long-held perception of markets as the optimal resource allocation mechanism, and instead they place markets within a multitude of institutional arrangements encompassing cooperative arrangements and hierarchies that guide decision making and resource allocation (North 1990; Williamson 1985; Stiglitz 1986). Thus, market-based financial systems are increasingly seen as just part of a range of options available to the decision maker and policy planner.

A key opportunity therefore lies in engaging with economic sectors that influence risk distribution within society. The role of wetlands as natural infrastructure buffering against the impacts of uncertainity imposed by climate change and anthropogenic pressures needs to be better communicated and included into risk mitigation strategies as they are adopted. Similarly, financial arrangements should be required to transfer a segment of benefits derived by economic sectors through the functioning of healthy ecosystems into the ecosystems' long-term conservation and management.

Social and behavioural approaches

Wetland managers will recognize that different approaches (involving different instruments and forms of engagement) are available to plan or implement an intervention. Choosing the most appropriate process in some instances will be at least as important as the desired outcome of the intervention. For instance, plans aimed at improving water sanitation will require developing appropriate participation of parents, particularly women, in local communities in the planning and implementation phases. Again most, if not all, interventions will involve the water resource itself.

Falkenmark and Folke (2002) emphasise the importance of social learning, and therefore the roles of participation, empowerment, communication, and education in water-related matters, directing attention away from seeing these matters as merely technical issues. Ivey et al. (2004) propose five questions that will help elucidate a community's capacity to deal with such matters as, specifically, climate-induced water shortages:

- Are community stakeholders aware of the potential impacts of water shortages on human and ecological systems?
- Are local water management agencies perceived by community stakeholders as legitimate?
- Do local water management agencies and related organizations communicate, share information, and coordinate their activities?
- Is there an agency providing leadership to local water management organizations?
- Are members of the public involved in water management decision-making and implementation of activities?

The forces that place populations at risk (such as poverty and high burdens of disease) in many cases also impair the capacity of these populations to prepare for the future. Wetland managers therefore need to be involved in building coping capacity and to recognize that these responses must to operate at community, nation, or regional levels.

There is an increasing realization that the limitations of traditional regulation has led to the introduction of more participatory regulatory approaches, such as demand management and voluntary agreements. These will necessitate education and public involvement and will call for water literacy: public education curricula and awareness campaigns at all levels should vigorously address the issues of the water environment (Falkenmark et al. 2007). In line with the deliberative approaches described above, much more attention should be given to involving various stakeholders in order to make environmental policies better rooted, because an educated and more involved population will be more effective in addressing failures of government and holding institutions to account. Similarly, empowerment of groups particularly dependent on ecosystem services or affected by their degradation, including women, indigenous people, and young people, it is argued, will improve the likelihood of better management of the ecosystems that provide those services (Millennium Ecosystem Assessment 2005).

Technological and other cognitive responses

In order to reduce poverty in rural areas by keeping up with global demand for agricultural products and adapting to changing food preferences and societal demands; to adapt to urbanization and industrialization; and to respond to climate change, Falkenmark et al. (2007) argued that the outdated and outmoded irrigation systems used around the world need to be reconfigured and adapted. The technologies that increase crop yields without any harmful impacts related to water, nutrient, and pesticide use (Millennium Ecosystem Assessment 2005) are the desirable ones for the future.

Establishing programmes to restore ecosystem services was a major recommendation coming from the Millennium Ecosystem Assessment (2005). As pointed out earlier in this report, ecosystem restoration may reduce the incidence of some water-borne diseases, but it can also lead to an increase in the incidence of others. This negative aspect may be countered by improved understanding of the ecological requirements of disease vectors and by incorporating this knowledge into restoration projects, adapting technical approaches accordingly.

The 2nd UN World Water Development Report (WWDR 2006) recommended three interventions of relevance at the policy level, namely the need i) to introduce the use of available tools for estimating costs and benefits of different drinking water and sanitation options initially at the national and subsequently at lower levels of governance; ii) to promote intervention studies that provide scientific information and help strengthen the evidence base on the effectiveness of environmental management methods for control of water-associated vector-borne diseases, and develop an appropriate toolkit for environmental managers; and iii) to refine the correlations between water indicators and the indicators for childhood illness/mortality and nutritional status, the importance of accelerated access to safe water and adequate sanitation, and better Integrated Water Resources Management (IWRM) practices.

Evaluating wetland management interventions by valuing health and well-being outcomes

A critical approach to managing wetlands for both ecosystem services and human health is to develop evaluation processes for interventions that appropriately account for both. Hence, evaluating wetland management interventions should adopt a way of valuing health and well-being outcomes of maintained or restored ecosystem services.

The economic assessment of the costs of health outcomes due to the degradation and disruption of wetland ecosystem services has not been well researched, though theoretical frameworks have been developed. The conventional practice defines health effects broadly into two categories, i.e., mortality and morbidity; in addition to these, there is a growing recognition of the need for application of costs to other health outcomes.

Mortality

Economic approaches to valuing reduced mortality are based on the tradeoffs made by individuals or government policy-makers between changes in the probability of death and other goods having monetary value. An individual's willingness to pay (WTP) for a reduction in the probability of death or willingness to accept compensation for an increase in probability has been proposed as a basis for valuation (Schelling 1968; Bailey 1980). An individual's willingness to pay for changes in the probability of his or her death can be translated into a more convenient figure for evaluating policies that reduce the risk of death through estimation of a value of statistical life or the value of statistical deaths avoided. To cite a numerical example, if the willingness to pay for a 1/10,000 reduction in mortality risk is $200, then the value of statistical life is $200/ (1/10,000), i.e., $ 2 million. It should be carefully understood, though, that this value does not equate with the value of life *per se*, but only for the reduction in risk of mortality. The willingness to pay approach focuses on reduction in probability of death avoided.

An alternate approach to willingness to pay is the human capital approach. It focuses on the output and productivity lost due to the shortening of life of an individual. The approach moves from individual-centered decision-making to societal well-being, as it uses income as an indicator of capital, which in essence is how society perceives the importance of the contribution of an individual.

The monetary value of reduced morbidity

The monetary value of reduced morbidity could be derived either through use of individual preferences-based approaches (willingness to pay or required compensation) or of resource or opportunity costs. A damage function relationship could be developed to derive the real cost of illness in the form of lost productivity and output and an increase in resources devoted to medical care. Despite its relative simplicity in terms of calculation and application, the method does not include evaluation of pain and suffering, which could be captured through the willingness to pay-based approaches. For valuation purposes, the acute effects are usually modeled and estimated as though they are certain to be avoided, whereas the chronic effects are treated using a probabilistic approach used for mortality.

Apart from monetary valuation, the other approaches proposed for assessing the health outcomes of policies is dollars per Quality Adjusted Life Year (QALY). QALYs are converted to dollars generally using a single '$ per QALY' factor and then resulting monetary estimates of benefits can be used in a cost benefit analysis. Alternatively, a set of conversion factors are used related to the particular composition of health effects embedded in QALYs being estimated.

Impacts of wetland policies on human health

A review of the literature on assessment of health outcomes reveals a gap when it comes to wetlands. Many studies are directed toward the impacts of policies related to maintenance of air quality in developed countries (i.e., Krupnick 2004). Attempts to estimate $/QALY due to food-borne illness are presented in Mauskopf and French (1991). Assessments of value of statistical life for the USA have ranged from US$ 5-6 million in different policy contexts, and attempts have also been made to extend the approach to developing countries (Viscusi 1998; Miller 2000). Gyrd-Hansen (2003) estimated a willingness to pay of DKK 88,000 per QALY on the basis of elicited preferences of health status.

Attempts to analyse individual behaviour in response to undesirable health conditions have also been used as basis for assessing economic values related to health outcomes. Harrington et al. (1989) measured the losses due to an outbreak of waterborne giardiasis in Luzerne County, Pennsylvania; the authors concluded that the households spent $ 485-1,540 to avoid contaminated water. Legget & Bocksteal (2000) showed that a change in the concentration of fecal coliforms by 100 colony-forming units of water per 100 mL affected the sale prices of properties by 1.5%, with the dollar amount ranging from $5,000-10,000. Boyle et al. (1999) estimated the demand for water clarity in lakes and observed a loss of value of at least $25,000 per household from a decline in Secchi disc clarity from 3.78 m to 2.41 m. However, the studies do not make direct linkages of ecosystem services with the health conditions – this is an obvious and important area for future research.

Despite the seeming robustness of theoretical frameworks, there are several issues which underpin the successful application of the valuation and assessment approaches to assessing health outcomes. To assert that an individual has a willingness to pay for a reduction in probability of mortality and/or morbidity, it is assumed that the individual can perceive changes in her health status. However, individual behaviour differs significantly between voluntary risk and involuntary risk (Starr 1976). Similarly, there have been debates about philosophical foundations of the concept of value of statistical life. It is contended that if life itself is priceless, a risk of change in status would tend to infinity, and the probability range over which the estimation of the value of statistical life is carried out has been debated. Typically, one would be dealing with lower probabilities of death in most environmental cases, whereas most of the studies tend to use values at the higher end. There are issues related to inter-age variation, latency, and choice of discount rates which also pose significant challenges for method.

Success factors and stumbling blocks in policy reforms

In order for the above responses to be realized, some strategies for their implementation may be useful, looking at what has made past policies either successful or otherwise. Citing a range of sources, the Global Environment Outlook (2007) summarises the wide range of success factors that have been demonstrated as important in better practice policies:

- solid research or science underpinning the policy;
- high level of political will, usually bipartisan and therefore sustained;
- multistakeholder involvement, often through formal or informal partnerships;

- willingness to engage in dialogue with policy opponents;
- robust systems for mediating conflict;
- capable, trained staff engaged in implementation;
- prior systems of monitoring and policy revision agreed, including clauses that mandate periodic revision;
- legislative backing, combined with an active environmental judiciary;
- sustainable financing systems, ring-fenced from corruption;
- evaluation and assessment of policies independent from the rule-making agent, for example, by advisory committees or public auditors;
- minimal delays between policy decisions and implementation; and
- coherence and lack of conflict throughout all government policies.

Conversely, Molden (2007) discusses some reasons why past policy initiatives have fallen short – principal among them are when:

- policy reforms have not taken into account the history, culture, environment, and vested interests that shape the scope for institutional change;
- policy reforms have been based (only) on "blueprint" solutions – solutions that follow a model that may have been successful elsewhere;
- there is a focus on a single type of organization rather than the larger institutional context;
- reforms have ignored the many other factors that affect water use in agriculture – policies and government agencies in other sectors, informal user institutions, and the macroeconomic environment and broader social institutions; and
- any or all of the following are in operation:
    - *inadequate support for reform at required levels;*
    - *inadequate capacity building and incentives for change;*
    - *repeated underestimation of the time, effort, and investment required to change.*

6.4 Wetland-based interventions – the role of the wetland managers

One of the key points made by Corvalan et al. (2005b) was that intervening to reverse the impacts of ecosystem disruptions, while well-intentioned, may not necessarily have a positive effect on human health. They extracted from sections of the Millennium Ecosystem Assessment a sample of recommended responses for ecosystem disruption and demonstrated that in almost every category of ecosystem response, the consequences for health could be either positive or negative. As demonstrated in this report, the reciprocal is also true – that responses specifically designed to address human health might have positive or negative consequences for the maintenance of ecosystem services (Section 3 above). Corvalan et al. (2005b) suggested that these outcomes will depend on how the policy or regulation is framed and what account is taken of contingencies and local circumstances.

There are key questions for wetland managers here: What will be the human health consequences of intervening for wetland management? What are the local particularities of each wetland ecosystem that may have consequences for human health? How do we intervene to improve human health itself? The present report argues that these questions must become part of the full suite of considerations for wetland managers.

Some of the key approaches, tools and instruments likely to be used by the health sector to respond to health effects and health outcomes of disruption to ecosystem services, should be understood and used by wetland managers. Monitoring, surveillance and intervention, burden-of-disease assessments (BDA), health impact assessments (HIA), community health assessments, risk assessments, community and stakeholder engagement (see Box 6.3) are commonly used by public health professionals and in general structure might be similar to their environmental equivalents. Their focus will be different, however, and it will be important for these instruments and approaches to be interpreted for use by wetland managers.

In particular, packages for HIA and BDA designed for those who may not necessarily have training in health-related sciences, specifically for situations where management interventions are proposed for water resources or wetlands, should emerge as a work area from the Wetlands and Human Health agenda. Given the richness of impact assessment instruments in use across social, economic, environmental and health domains, the co-benefits should be obvious for developing instruments that cross over, without a loss of detail and analytical emphasis. Harris-Roxas and Harris (2010) have developed a typology of health impact assessments and recognize four:

i) **Mandated HIA,** which is done to meet a regulatory or statutory requirement;

ii) **Decision support HIA**, which is done voluntarily with the goal of improving decision-making and implementation;

iii) **Advocacy HIA,** "conducted by organizations or groups who are neither proponents or decision-makers, with goal of influencing decision-making and implementation"; and

iv) **Community-led HIA,** where potentially affected communities examine issues or proposals that are of concern for their health consequences.

Seen from these perspectives, a useful three-legged stool model for risk management has been proposed, with each 'leg' being critical to successful wetland management:

i) mitigation of hazard;
ii) regulation of behaviour; and
iii) education for awareness-raising about consequences of behaviour and responses.

Each 'leg' makes an essential contribution to addressing both vulnerability and adaptation, each being a class of response options. Response options refer to the range of human actions, including policies, strategies, and interventions, that address specific issues, needs, opportunities, or problems. In the context of ecosystem management, responses may involve governance, institutional, legal, technical, economic, and financial changes, or changes in behavior and/or attitudes related to knowledge and awareness. Interventions need to be designed at spatial and temporal scales appropriate to the ecosystem disruption and the health outcome of concern; they can focus on local, national, regional, and international scales and within any of these scales, on vulnerable subgroups. Overall factors affecting the choice of responses include the knowledge and understanding of the underlying processes or causes; the capacity to predict, forecast, and warn; the capacity to respond (institutional and otherwise); how the risk might change over time and with ecosystem change; and ethical appropriateness (Corvalan et al. 2005b).

As argued earlier in this report, the health sector will seek to establish the evidentiary basis for disease spread and risk factors for disease, and ideally to evaluate the intervention outcome. The following pathway is pursued: monitoring and surveillance of disease and risk factors; interpretation of data; use of the data in conjunction with environmental and other data to develop models to predict disease occurrence; linking changes in disease rates to specific environmental factors; and intervening to remove the causes of disease or lessen the damage they cause (see Corvalan et al. 2005b). Interventions can be evaluated using a similar process.

Box 6.3: Risk perception, communication, and community engagement

"In order for any research on the health effects of ecological change to affect either official policy or individual behaviour, it is necessary to take into account how risk is perceived. A deliberate and well-informed approach to community risk will maximize the chance of effective changes through policy interventions that enjoy popular support. Any assessment of ecological change and health should be influenced by the risk perceptions of those communities that are most likely to be affected. That is, ecological assessments should involve open and frequent stakeholder participation from the beginning of the process rather than as an afterthought. This approach of community engagement in the process serves the purpose of accessing local knowledge about the effects of ecological factors, ensuring that the assessment addresses issues of greatest concern to those affected and maximizing the probability that any recommended change in policy or behaviour will be adopted. If a source of information is not widely trusted, it is unlikely that recommended changes will be accepted. Community surveys have shown that some groups tend to be regarded as highly trustworthy, while others (such as government agencies) are treated with caution. Healthcare providers (for instance community nurses or doctors) tend to be one of the ''high trust'' groups, underlining again the important role they can play in explaining the significance of healthy ecosystems. Any such consultation should make the best use of the expertise of both stakeholders and researchers. Stakeholders may have expert local knowledge but may have inaccurate ideas of the true nature of risks associated with different factors; researchers should have more exact knowledge of disease processes and relative risks but may inappropriately estimate the applicability of general concepts to local situations. Accurate and accessible reporting of assessment results can remedy inaccurate risk perceptions and can enhance the public's ability to evaluate science/policy issues; the individual's ability to make rational personal choices is enhanced. Stakeholder engagement will make it more likely that the research is credible and is translated into practice. Technically intensive, externally driven interventions may produce rapid results but risks marginalizing local communities. Interventions that engage local communities and transfer expertise are more likely to result in longer term ecologically and socially sustainable improvements."

-- quoted from Corvalan et al. 2005b

One valuable strategy to 'cross over' may lie in using human disease burden data as a bio-indicator to help target and prioritise wetland remediation. Suggestions like this have been made before (i.e., mosquito-borne disease data as a potential bioindicator for ecosystem health; Jardine et al. 2008). Human health data are generally collected more widely and more reliably than are ecosystem health data, and closer collaborations between wetland ecologists and health researchers could therefore help progress the sustainable provision of wetland ecosystem services. In certain circumstances, especially where community livelihoods and wetlands are interdependent and interconnected, health indicators could actually reflect the status of wetlands. There is an opportunity therefore to include health indicators within the suite of indicators used to assess effectiveness of wetland management, particularly in the context of human health. The specific challenge, however, will always be to link an indicator (human disease) with the exact nature of the ecosystem cause in both space and time, and the idea has yet to be evaluated in this regard.

Another valuable strategy is to consider the human health of the communities, especially those having livelihoods dependent on wetland resources, within the context of wetland management plans. Poor health can have severe impacts on the capacity of communities to maintain systems of sustainable resource management and wise use of wetlands. In several societies, the role of women in natural resource management, including of wetlands, for example in collection of water, harvesting of fish and aquatic plants, etc., gives them a particular role in ensuring healthy wetlands. Effective community-led wetland management can therefore be ensured when the people who manage them are themselves healthy. As a response, therefore, the wetland managers could consider integrating health-related services within the wetland communities as part of intervention strategies for

Box 6.4: Response imperatives for Water and sanitation to improve human health

1. Assign the role of water-related public awareness to the agency responsible for integrated water resource management at the country level. *Action: wetland managers need to develop in-house capacities to deliver water-related public awareness.*
2. Institute gender-sensitive systems and policies. *Action: wetland managers should examine their internal operations to ensure gender-sensitivity, including equity in decision making capacities, particularly where inequalities exist in health outcomes.*
3. Raise awareness and understanding of the linkages among water, sanitation, and hygiene and poverty alleviation and sustainable development. *Action: wetland managers should develop their own conceptual models for how these linkages can be articulated in national, regional and local contexts.*
4. Develop in partnership with all relevant actors community-level advocacy and training programs that contribute to improved household hygiene practices for the poor. *Action: wetland managers should participate in such partnerships when approached.*
5. Identify best practices and lessons learned based on existing projects and programs related to provision of safe water and sanitation services focused on children. *Action: wetland managers should identify documentation that demonstrably links management of wetlands to improving ecosystem services and provision of safe water and sanitation relevant for local context.*
6. Create multistakeholder partnership opportunities and alliances at all levels that directly focus on the reduction of child mortality through diseases associated with unsafe water, inadequate sanitation, and poor hygiene. *Action: wetland managers should participate as knowledge providers about diminished ecosystem services that result in proliferation of disease conditions.*
7. Develop national, regional, and global programs related to the provision of safe water and improved sanitation services for urban slums in general, and to meet the needs of children in particular. *Action: wetland managers should contribute local examples of links between management of wetlands and provision of safe water and sanitation, through their national, regional and global networks.*
8. Identify water pollution prevention strategies adapted to local needs to reduce health hazards related to maternal and child mortality. *Action: wetland managers should develop specific communication materials and provide advice on the water quality aspects that require preventive strategies.*

-- based upon WEHAB 2002a, 2002b

Box 6.5: Avian influenza and wetlands: appropriate responses

As well as providing conditions for virus mutation and generation, agricultural practices, particularly those used on wetlands, can enhance the ability of a virus to spread. The role of Asian domestic ducks in the epidemiology of HPAI H5N1 has been closely researched and found to be central not only to the genesis of the virus (Hulse-Post et al. 2005; Sims et al. 2005), but also to its spread and the maintenance of infection in several Asian countries (Shortridge & Melville 2006). Typically this has involved flocks of domestic ducks used for 'cleaning' rice paddies of waste grain and various pests, during which they are exposed to wild ducks using the same wetlands. Detailed research (Gilbert et al. 2006; Songserm et al. 2006) in Thailand has demonstrated a strong association between the HPAI H5N1 virus and abundance of free-grazing ducks. Gilbert et al. (2006) concluded that in Thailand "wetlands used for double-crop rice production, where free-grazing duck feed year round in rice paddies, appear to be a critical factor in HPAI persistence and spread".

Yet there is wide international consensus that attempting to control HPAI through responses such as culling or disturbing wild birds or destroying wetland habitats is both not feasible and diversionary, and thus should not be attempted, not least since it may exacerbate the problem by causing further dispersion of infected birds. Resolution IX.23 (2005) of the Ramsar Convention on Wetlands states the "destruction or substantive modification of wetland habitats with the objective of reducing contact between domesticated and wild birds does not amount to wise use as urged by Article 3.1 of the Convention, and also may exacerbate the problem by causing further dispersion of infected birds". The key to the control of HPAI remains control and prevention in the poultry sector (Greger 2006; GRAIN 2006; Sims 2007), and ornithologists and the conservation community must play their part in this to ensure benefits to all.

One of the central obligations of the Ramsar Convention is that Contracting Parties "shall promote the conservation of wetlands and waterfowl by establishing nature reserves on wetlands", and subsequent decisions of the Conference of Parties have stressed the role of these reserves and associated wetland centres in enhancing public awareness of wetlands and communicating the need for waterbird conservation. Recent events have highlighted the risk that ill-informed media reporting about the spread of HPAI H5N1 may undo decades of building positive public attitudes towards wetland and waterbird conservation. For example, as HPAI H5N1 spread across central Asia and Europe in winter 2005 and spring 2006, visitor numbers at wetland centres in the UK fell markedly, with economic impacts for conservation organizations and changed public attitudes, which encompassed concern and even fear.

Human lives are enriched by birds, contact with and appreciation of which is an important element of the well-being of those who may otherwise have limited opportunities to interact with wildlife. Getting close to birds brings great pleasure. As the late Janet Kear, life-long waterbird conservationist, once said, "just as you can't sneeze with your eyes open, you can't feed a bird from your hand without smiling." It is crucial that we avoid preventable reactions that might encourage people to stay away from wild birds because of unfounded fears and false perceptions of risk. In the long term, this could prove greatly damaging to public support for wetland and waterbird conservation.

Currently, wildlife health problems are being created or exacerbated by activities such as habitat loss or degradation and close contact between domestic and wild animals. Ultimately, to reduce risk of avian influenza and other bird diseases, we need to move to markedly more sustainable systems of agriculture with significantly lower intensity systems of poultry production. These need to be more biosecure, separated from wild waterbirds and their natural wetland habitats, with far fewer opportunities for viral cross-infection and thus pathogenetic amplification (Greger 2006). To deliver such an objective in a world with an ever-burgeoning human population, hungry for animal protein, and with major issues of food-security throughout the developing world, will be a major policy challenge. However, the animal and human health consequences of *not* tackling these issues, in terms of the impact on economies, food security and potential implications of a human influenza pandemic, are quite immense.

-- contributed by Rebecca Lee, David Stroud &Ruth Cromie

wetland restoration. Better targeting and participation in management plan implementation could be achieved through a specific focus on gender and marginalized communities, thereby contributing to the MDGs as stated above.

In many cases we know exactly what needs to be done to improve human health, but the role of wetland managers might not be entirely clear. For instance, WEHAB (2002a, 2002b) produced a list of response imperatives for *Water and sanitation* to improve human health – for each imperative, we have added *an action or a role* that wetland managers should adopt to assist (Box 6.4).

With these suggested actions and roles, policy level responses can be converted to concrete steps or practices as appropriate for wetland managers in general, and specifically developed as guidance material for the Ramsar Convention. While most such interventions have general application, the complexity of response options required for individual diseases must not be underestimated, and that will need to be developed on a case by case basis (as exemplified in Box 6.5) and applied at the local or provincial level with national support.

6.5 Conclusions

Many of the possible response options for addressing ecosystem change and human well-being lie primarily outside the direct control of the wetland sector, or even of the health sector. Instead they are embedded in areas such as sanitation and water supply, education, agriculture, trade, tourism, transport, development, and housing. Intersectoral and cross-sectoral integrated options are therefore needed to reduce the potential health impacts of ecosystem change. In this regard, it is important to identify the principal cross-sectoral partners and responsible stakeholder groups required to achieve appropriate outcomes. These integrated interventions will necessarily address existing social values and cultural norms, existing infrastructure, and the social, economic, and demographic driving forces that result in ecosystem change.

Wetland managers need to be involved in building coping capacity in human communities, and they must recognize that these responses will need to operate at local, national, or regional levels. This is because the forces that place populations at risk (such as poverty and high burdens of disease) in many cases also impair the capacity of these populations to prepare for the future, or, in this instance, to manage their wetland ecosystems appropriately.

Where interventions or responses involve tradeoffs, it is important to understand the consequences of taking any one path in preference to another. Recognizing the potential for tradeoffs is the important first step in this understanding. Undertaking a *process* by which tradeoffs can be negotiated becomes the central concern: representation of marginalised stakeholders, increased transparency of information, and engaging with the core pursuits of other sectors will be key components of such processes.

Managing wetland ecosystem services to improve human health will help achieve the Millennium Development Goals. This can be demonstrated by the close relationship between food production, water use and water extraction, and wetland management.

7. Conclusions and recommendations

This report set out to examine whether it was possible to improve the health and well-being of people in harmony with wetland conservation and wise use objectives. The approach was to identify and propose for implementation actions that could benefit both wetland ecosystems and human health concurrently. In case of any perceived conflict between these objectives, wetland management could proceed by applying as appropriate the guidance on wise use adopted under the Convention, using a people-centered approach.

By using this approach, it is possible to see wetlands as ‘settings' in which the core requirements for human health and well-being, food and water, are sourced and managed. Wetlands can also be viewed as the settings for the prevention of exposures to toxicants, diseases, stressors and other hazards, such as catastrophes. Wetlands are places where people seek their livelihoods and establish their lifestyles; these are the settings for the social determinants of health in many cultures and societies. Water, wetlands, and the cultural, social, economic and political nature of human well-being are linked in this way.

The general principle adopted in the report has been one of seeking co-benefits, where the causes of declining human health linked with wetlands should be addressed by maintaining or enhancing existing ecosystem services that can contribute to the prevention of such declines. For instance, any necessary disease eradication measures in or around wetlands should be undertaken in ways that do not jeopardise the maintenance of the ecological character of the wetlands and their ecosystem services.

To do this, wetland managers must bring information on the scientifically-proven contributions that naturally-functioning wetland ecosystems make to good health and well-being to the attention of national ministries and agencies responsible for health, sanitation, and water supply.

For wetland managers this will require strengthened collaboration and the seeking of new partnerships between the sectors concerned with wetland conservation, water, health, food security and poverty reduction within and between governments, non-government organizations, and the private sector. It will also require countries and their development sectors, including mining, other extractive industries, infrastructure development, water and sanitation, energy, agriculture and aquaculture, transport and others, to take all possible steps to avoid direct or indirect effects of their activities on wetlands that would impact negatively on those ecosystem services of wetlands that support human health and well-being.

Governments are urged to make the interrelationship between wetland ecosystems and human health a key component of national and international policies, plans and strategies, particularly where they concern sanitation and water resources for both domestic and agricultural purposes. This will necessarily include specific wetland targets and indicators that link sustainable wetland management to the targets of the World Summit on Sustainable Development (Johannesburg 2002) for water, energy, health, agriculture and biodiversity, and to all the Millennium Development Goals, most notably 1 ("eradicate extreme poverty and hunger"), 4 ("reduce child mortality"), 5 ("improve maternal health"), and 6 ("combat HIV/AIDS, malaria and other diseases").

Decision-making on co-managing wetlands and human health issues should take into account the current understanding of climate change-induced increases in health and disease risk. It should seek to maintain the capacity of wetlands to adapt to climate change and continue to provide their ecosystem services, since changing climate is expected to continue to increase the risk of human health problems.

Wetland authorities, working with their health sector counterparts and others, should seek to:

i) be vigilant for the emergence or re-emergence of wetland-linked diseases;

ii) act preventively and proactively in relation to such diseases; and

iii) develop scientifically-based responses, taking into account current good practices, where instances of such diseases are identified

Dealing with these relationships will demand an improved collaboration amongst members of the wetland management sector and the human health sector. Wetland managers will find that within the general domain of health and medicine, public health represents the discipline where most of these health issues will resonate. Environmental health professionals will be aware of exposures and ways to prevent them from occurring. Health promotion professionals will have the instruments to look upstream at the environmental and social determinants that underpin adverse health outcomes; these are the determinants at which interventions for prevention are directed.

Building capacity for more integrated approaches to wetland and water management and health will include an acknowledgement of the knowledge that resides in local communities and traditional cultures. Dedicating resources, under an appropriate deliberative process, will be required to build this capacity.

Wetland management should not be done in isolation of other considerations; rather the consequences of decisions and actions should be examined in terms of human health, where the identification of tradeoffs can be incorporated explicitly in decision-making.

An important direction for the future will be to identify ways and means of strengthening collaboration between the World Health Organization and the Ramsar Convention, including on technical issues of common interest, making available the findings of this report to the relevant parts of the human health community.

For the Ramsar Convention a clear mandate arises from this exploration to develop guidance required for on-site wetland managers and regional wetland policy makers to enable them to engage meaningfully with human health issues. The Convention can also advise the WHO and other relevant bodies concerned with human health and ecosystems on ways to help reverse a negative perception of wetlands as places of hazards only. Moreover, there is an opportunity to promote the value of Ramsar Sites that have high positive values for human health, and detailed case studies will be of enormous value in this regard.

The Ramsar Convention can prepare guidance for both wetland managers and the human health sector on processes for identifying appropriate responses to the co-management of wetlands and human health issues, including i) the identification and negation of tradeoffs, ii) the application of health impact assessment and risk assessment approaches, iii) increased transparency of information, representation and participation of marginalized stakeholders, and iv) engagement with the core business of other sectors such as water management. Education providers should consider public health as an important component of a holistic training programme for wetland management.

Finally, the Ramsar Convention has a role to play in encouraging governments, non-governmental organizations, research institutions and others to make available, in appropriate forms, the results of research and demonstration projects on good practice in integrated approaches to wetland ecosystem conservation and wise use and human health, so that demonstrations of the practical value of such good practices can be made available to those directly involved with wetland management.

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