Wetlands and People's Well-being: Basic Needs, Food Security and Medicinal Properties

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Abstract Demonstrating links between wetlands and health is a useful way of encouraging policymakers to act before the 'Water for Life' decade ends in 2015. This chapter describes the contributions wetlands make to people's well-being, such as food security through high water quality, protein or edible and medicinal plants. Earning cash income through trade in harvested wetland resources (such as fish, shell-fish or fibrous plants) can also have livelihood benefits. Although some wetlands can have negative effects on public health (such as bilharzia), public appreciation of positive wetland values and their links to public health can motivate local action and policy reform for wetland conservation and resource management. Lessons from innovative cases such as the RUPES programme in Indonesia can inspire new initiatives that put policies into practice for the benefit of local people.

Keywords Food security · Dietary diversity · Medicinal plants · Crop wild relatives · New natural products · Extremophiles

Introduction

It is well known that wetlands provide diverse and valuable goods and services for human well-being (Covich et al. 2004; "well-being" sensu Amatya Sen, see Berenger and Verdier-Chouchane 2007; Horwitz and Finlayson 2011). Despite this, wetland values are widely ignored and wetland destruction and degradation are widespread. The reason for our behaving this way is widely recognized. The direct and indirect values of wetlands are not taken into account, property rights are weak and wetlands can be affected by degradation elsewhere in the watershed (Dudgeon et al. 2006; Turner and Jones 1991). Although wetlands represent a capital asset providing important ecosystem services, these assets are generally not reflected in conventional economic indicators. Instead, wetland goods and services are often considered a "subsidy from nature", just as is the case with forests (Wunder 2007). Integrating economic (Barbier et al. 1997) and socio-ecological approaches (Berkes

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and Folke 1998) in policy and practice for continued provision of those wetland goods and services is therefore essential. Valuation estimates can be controversial (Balmford et al. 2002). In addition, non-market values, such as cultural or religious values of ecosystems are extremely difficult to determine (Adamowicz et al. 1998). Values can also be location specific, such as the high value placed on *Juncus kraussii* culms in southern Africa (Cunningham and Terry 2006) compared to Australia, where this species also occurs.

Despite controversies and gaps, valuation studies commonly indicate the great economic importance of wetlands. What is needed is more effective communication by scientists to policymakers on the importance of wetlands to people's well-being. Links between direct and indirect drivers of wetland change and opportunities provide guidance on how these link to human well-being (Fig. 1).

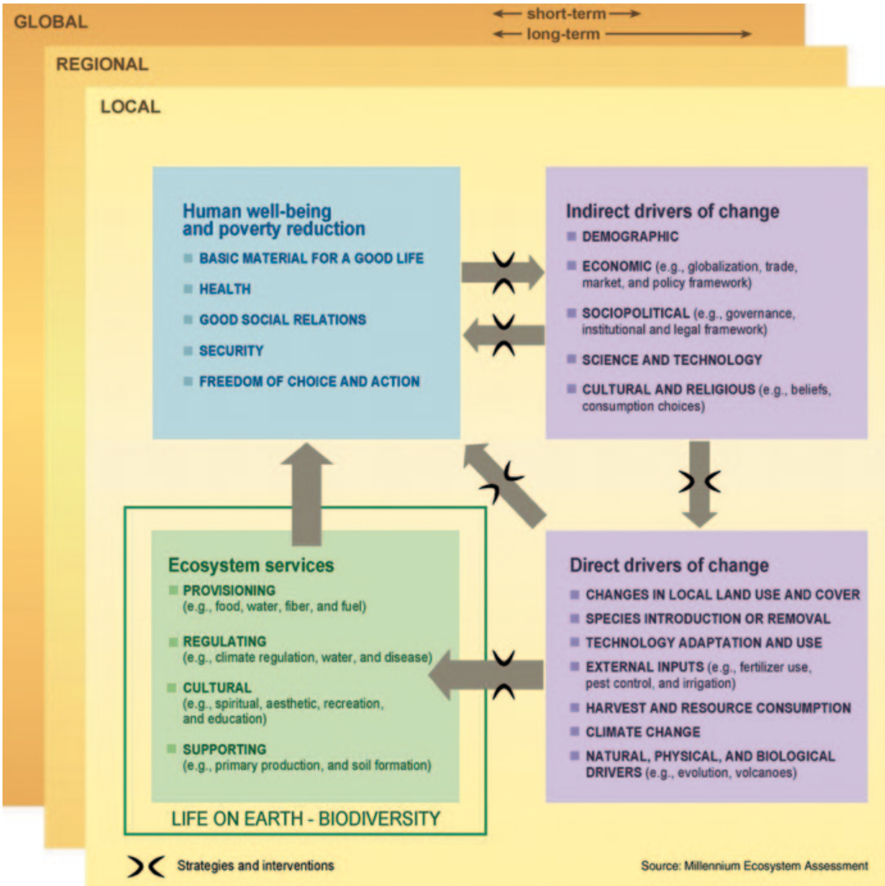

Fig. 1 Links between ecosystem services, drivers of change, human well-being and poverty reduction. (from Millennium Ecosystem Assessment 2005)

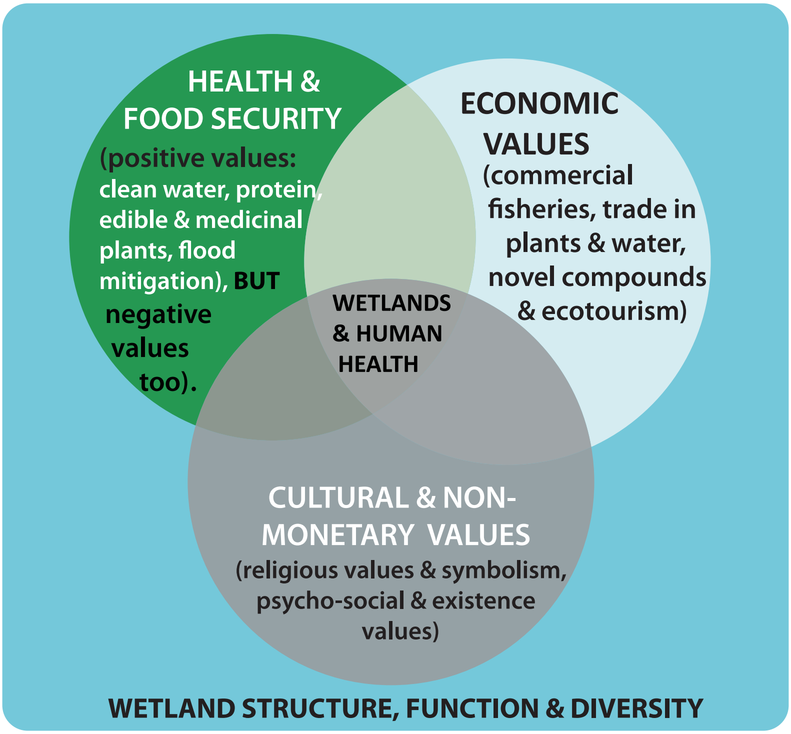

Fig. 2 Links between wetlands and our health and well-being

This chapter describes the contributions wetlands make to people's well-being (Fig. 2). These range from wetland ecosystem services (such as clean water), economic productivity and poverty alleviation (wetlands and fisheries) to food security (such as the genetic diversity of wild relatives of rice (*Oryza*), one the world's major crops, or new natural products from wetland associated fungi, bacteria, animals and medicinal plants). In addition, some wetlands have "insurance" value, reducing our vulnerability to extreme events such as floods while others, such as peatlands, play an important role in carbon sequestration.

Although the different contributions wetlands make to people's well-being are discussed separately below, there are linkages within and between each one. Food security, for example, links to water quality, household income, plant genetic resources and fisheries management. These linkages mean that in many cases, trade-offs between wetland conservation and development need to be carefully assessed and in some instances, compromises reached. Strategies in Bangladesh to reach trade-offs between floodplain conversion for rice production or wetland maintenance for survival and production of floodplain fish populations when both are important in the peoples diet are a good example (Shankar et al. 2004). Similarly, important trade-offs exist between the benefits of development projects such as large dams on one hand, and infectious disease risk (such as schistosomiasis) or sustainable fisheries based on fish whose spawning or migrations are negatively impacted by large dams, on the other. Even recreational uses of wetlands, with the health and tourism benefits they provide may need trade-offs with conservation, such as removal of exotic salmonids from rivers in Chiles and New Zealand (Dudgeon et al. 2006).

Food Security

Food security has three main components, each of which has links to wetland values for food and water. The first is the most obvious, the food availability (through the market and people's own production). The second is having enough buying power or social capital to access food with cash or through barter. The third is that people get sufficient nutrients from the food they eat (Boko et al. 2007). Nutrient intake is also influenced by people's ability to digest and absorb nutrients, which is affected by human health, access to safe drinking water and the diversity and nutritional content of foods. Wetland degradation or loss impacts on all three components that comprise food security. Agricultural production and food security (including access to food) can be compromised with wetland degradation due to the value of wetland resources to peoples diet (for example from fisheries and food plants) and some of the genetic material wetland plants contain. Wild relatives of two important food crops, rice (*Oryza* species) and some cowpeas (*Vigna*) species are indigenous to African and Asian marshes and floodplains.

Starchy staple diets (rice, cassava, maize) are frequently deficient in nicotinic acid, vitamin C, calcium and riboflavin and protein (Cunningham and Shackleton 2004). Harvested wild foods are known to be a valuable source of these nutrients deficient in starchy staple diets, particularly protein from edible fish and shellfish, nicotinic acid from wild edible greens, 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 supplementary food sources. Popular food species are also traded. Examples are water-cress (*Rorippa nasturtium-aquaticum*) in Europe, *Mauritia* fruits and *Euterpe* palm hearts from South America floodplain forests, lotus (*Nelumbo nucifera*) seeds and water-chestnut (*Eleocharis*) tubers in Asia and wild rice (*Zizania aquatica*) and cranberries (*Vaccinium oxycoccos*) collected for food and trade by native Americans in the USA.

Fish are particularly important to people's diet and health in developing countries where they often form the main source of animal protein (Fig. 3). In recent years, the production of fish from inland waters has been dominated by aquaculture, especially growing of carp in China for domestic purposes, with salmon, tilapia, and perch mainly for export (Kura et al. 2004). Inland fisheries are particularly important in developing countries with a large proportion of the recorded catch, with the actual catch possibly several times higher than recorded (Kura et al. 2004). Most of the increase in freshwater fish consumption occurred in Asia and Africa. Historical date for commercial fisheries shows large declines in the twentieth century due to habitat degradation, invasive species, and overharvesting (Revenga et al. 2000).

Fig. 3 Small-scale fish harvesting using traditional methods, often by women and children provides much needed protein—in this case along the middle-Zambezi river, Zambia. (Photo: A B Cunningham)

The Mekong river, for example, sustains one of the world's largest freshwater fisheries, with annual yields of 1 million tonnes of fish, most of which are harvested by small-scale artisanal fisheries (Valbo-Jorgenson and Poulsen 2001). In Cambodia, for example, people get about 60–80% of their total animal protein from the fishery in Tonle Sap and associated floodplains (MEA 2005). Floodplain fisheries are often very productive, although fish production is highly variable due to seasonal floods and longer-term climatic trends (Jul-Larsen et al. 2003) that threaten fisheries such as those around Lake Chad.

Water Supplies

Fresh water is a basic need for human health. This is widely recognized in national legislation of many countries. This provides an important opportunity for linking local action and public health to wetlands conservation. In the USA, for example, the Clean Water Act has become an important tool enabling Native Americans to leverage wetland conservation and restoration at a catchment level (USEPA 2000). On average, people need 20–50 litres of clean water per person per day for drinking, cooking and personal hygiene, yet over 1 billion people lack access to safe water supplies and 2.6 billion people lack adequate sanitation (MEA 2005). Wetland vegetation plays an important role in improving water quality through extraction of pollutants and pathogens including nitrates, coliform bacteria and faecal streptococci (Ghermandi et al. 2007). In fact this role is so useful that artificial wetlands have been purposely created for this purpose in France for over 20 years (Molle et al. 2005), with the design principles behind riparian wetland construction being developed for stream restoration (D'Arcy et al. 2007). Poor quality water contributes to a range of health problems such as diarrhoea, internal parasites and trachoma. Bad health due to lack of access to safe drinking water and poor sanitation affects the poorest sector of society, with follow-on affects for food security.

Shelter

Building styles and the materials used reflect cultural diversity and preferences for particular species, as well as what is available from vegetation change. In many developing countries, where house construction reflects need rather than restrictive building codes of the developed world, locally harvested plants are the main source of low-cost housing. Although hardwoods from upland forests and woodlands are preferred for support poles, wetlands are a favoured source of thatching material and reeds (Cunningham 1985). In Africa, floodplain grasses and Cyperaceae are commonly used for thatching traditional houses. In southern Africa, the common reed (*Phragmites australis)* was used for wall construction of up to 90% of homes (Cunningham 1985) and in Europe, the same species is used for expensive thatch.

Subsistence Income

For rural people wanting to enter the cash economy, harvesting wild resources (salt, fish, shell-fish, useful plants) is an important option, as local knowledge and skills can be used to harvest products for trade without an initial investment of cash. Complex trade networks commonly characterize this hidden economy. As mentioned earlier, buying power can also help with food security. In many developing countries, these resources also provide a "green social security", as unlike Europe, Australia and North America, there are no government social security payments in times of need. Although income from harvest and trade is small by western standards, its values to households should not be underestimated. Trade in fresh, dried or smoked fish is widespread through Asia, Africa (Abbott et al. 2007) and Latin America. So too, is trade in basketry, including fish traps.

While bamboo and rattans from upland forests and agroforestry systems are a common source of basketry fibres in Asia, plants from wetland and high water-table palm savannas dominate African basketry fibres. The development of commercial craft enterprises since the 1970s has brought much needed income for producers and their families, where it is often used for school costs (Cunningham and Terry 2006). Most southern African basket makers are women from low-income families, living in remote rural areas, and are subsistence farmers who own few (if any) cattle, and have little or no education. For most weavers, cash income is obtained through the sale of home-brewed beer, grain, bread, or thatching grass; casual labour or employment on public works; old age pensions; or money sent by family members who are migrant workers. For many, the only consistent source of cash income is through the production and sale of handicrafts, especially baskets. As a male basket maker in Khwai, Botswana, stated, '*My baskets are my cattle*'. Cultural values can also drive commercial harvest. Each year, several thousand Zulu women harvest mat rush (*Juncus kraussii*) from 20 hectare area of coastal salt-marsh at St Lucia estuary, a Ramsar site in South Africa. These culms are then resold or made into sleeping mats prized for their cultural significance at weddings or crafts for export, with intensive use causing concern about sustainability (Heinsohn and Cunningham 1991).

Traditional Medicines and New Natural Products

Although traditional medicines are dominated by flowering plant use (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 terms of people's health, both sectors need to be considered. 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 anticoagulants brought into health care since heparin was discovered in the early 1900s (Moreal et al. 1996). The 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 and economic values of hirundin is the value of the technology developed from *Thermus aquaticus.* Not only did this win its inventor, Karry Mullis, the Nobel Prize in 1993, but in 1991, the Swiss pharmaceutical company Hoffman-Laroche bought the exclusive world rights to the PCR process for US$ 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 US$ 50–100 million (Lohan and Johnson 2005) and may be more today, given growth in the biotechnology field.

These examples illustrate several points relevant to the confluence between wetlands, the Ramsar Convention on Wetlands, natural products and human health. Firstly, the medicinal qualities of leeches are a good example of the continued value of traditional knowledge to health care today. Secondly, new technologies, such as rapid throughput screening (White 2000) and PCR are changing the face of new natural product development. Thirdly, links between wetland biodiversity and human health need to focus less on the obvious (such as birds, large mammals or plants), than on the "hidden biodiversity" (such as fungi and bacteria). Fourthly, the case of biodiversity prospecting for *Thermus aquaticus* illustrates how controversial this can be, with important policy implications and links to the Convention on

Biodiversity (CBD). Finally, the most likely places for promising leads are wetland species from environments such as hot springs, alpine wetlands, particularly in high diversity montane systems, including the Andes or Himalaya, desert salt-pans, soda lakes, highly alkaline or acid streams and high diversity tropical rivers. Many of these are not listed as internationally important under the Ramsar Convention, although there are exceptions, such as the hot springs and soda lakes of East Africa's Rift Valley (Lake Bogoria and Lake Elementeita). Given that few Ramsar listed wetlands are located on mountains or in deserts, compared to lowlands and along the coast, it may be worth considering the addition of wetlands from other environments to support several goals, including biodiversity conservation.

Traditional Medicines

Worldwide, the skewed 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 and 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 used to treat parasitic diseases, diarrhoea, and for oral hygiene. 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 use CAM (Eisenberg et al. 1998), with use levels increasing significantly over the recent past (Schippmann et al. 2003) (Fig. 4).

Worldwide it is estimated that of 422,000 flowering plants, 12.5 % (52,000) are used medicinally with 8 % (4160 species) of these threatened (Schippmann et al. 2003). At a global scale, export of medicinal and aromatic plants to China, India and Germany is huge, with China the largest exporter mainly to Hong Kong, (140,500 t) as well as being the world's major importer (80,550 t) (Lange 1998). Medicinal properties of plants are commonly concentrated in particular plant families, reflect their evolutionary history and ecological adaptations, such as chemical defenses against herbivores, fungi or pathogens. Although seeds from common wetland plants such as cattail (*Typha*), common reed (*Phragmites*) and lotus (*Nelumbo nucifera*) 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 the coastal systems better represented by Ramsar listed wetlands. Nepal, for example exports between 7000 and 27,000 t of medicinal plants a year, most of them to India, worth between US$ 7–30 million/year (Olsen 2005). Many of these

Fig. 4 A traditional medicines market in Xi'an, China, where, many plants and animals, including species from wetlands, continue to contribute to health care. (Photo: A B Cunningham)

are montane medicinal plants, including threatened species, the Ranunculaceae (*Aconitum*), Papaveraceae (*Meconopsis*), Scrophulariaceae (*Picrorhiza*) and Valerianceae (*Nardostachys*). 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*).

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, 7500 factories produce thousands of Ayurvedic and Unani formulae (Bode 2006). In China, clinical trials for 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 formalised and branding less sophisticated, yet the scale of the trade is deceptively 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). In common with China, India and Nepal, relatively few medicinal species in African and Madagascar trade are from wetlands. Notable exceptions are a massive trade in endemic *Drosera madagascariensis* (Drosearaceae) from Madagascar to Europe (Paper et al. 2005), and in southern Africa where several species from montane marshes and seepages, such as *Allepidea amatymbica* (Apiaceae) are used for coughs and *Gunnera perpensa* (Gunneracae) which is used in herbal preparations prior to childbirth. Many wild species supplying medicinal plant markets are declining in their availability, with important implications for primary health care (Cunningham 1993).

New Natural Products

New natural products discovery have been radically changed due to the availability of molecular biology, PCR technology (thanks for *Thermus aquaticus* and innovative research) and genomic sciences (Drews 2000). In many ways, the biotechnology industry has become a major tool of the industry. Although the focus of this chapter is 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 south-western Australia's unique flora. One of the active ingredients used to treat *Phytophthora*, known as oocydin A, which has application in agriculture and forestry and conservation restoration was developed from *Rhyncholacis penicillata* (Podostemaceae), a plant from rivers in South-west Venezuela associated with an endophytes *Serratia marcescens* which produced 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 5000–10,000 new antibiotics discovered from bacteria and fungi since the 1950s and 1960s when well known drugs such as tetracycline were discovered (Challis and 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 and Daisy 2003). The most promising wetlands to search for endophytes with commercial potential are high diversity systems of tropical lowlands, montane and boreal systems rather than mono-dominant wetlands. Recent studies in Canadian wetlands are a good example of this (Kuhajek et al. 2003). Implementation of the Convention on Biological Diversity's policies on access and benefit sharing are important to recognize as the search for new natural products continues. These have been outlined recently in the Nagoya Protocol (Secretariat of the Convention on Biological Diversity 2012).

In addition to *Thermus aquaticus*, as the best known extremophile, there is great interest in other extremophiles. Wetland examples are the green algae *Dunaliella acidophila*, which survives at pH 0 and *Gloeochrysis* which lives on stones in acidic (pH 2) streams running out of active volcanoes in Patagonia, Argentina (Goss 2000; Baffico et al. 2004). The industrial applications of natural products from these extremeophiles include waste treatment, liposomes for drug delivery and cosmetics, and the food industry. This can have both positive outcomes (such as waste treatment) and negative outcomes for wetlands and human health (such as their use in protein-degrading additives in detergents, made possible due to their ability to with stand high temperatures).

Conclusion

In many parts of the world, indigenous and local peoples have existed in harmony with wetlands for centuries. In urban-industrial societies this is often not the case, resulting in adverse impacts not only on both wetlands and people's well-being. Understanding the links between ecosystem services and human health, as detailed by Horwitz and Finlayson (2011) is a crucial entry point for improvements in policy and practice for wetland conservation and restoration. Maintaining or restoring wetland goods and services cannot be achieved by working in isolation, but has to be achieved on the basis of entire watersheds. Achieving this is complex, even on a national scale, but can be done. A recent process that could be followed is the adaptive co-management system developed for a Ramsar listed wetland in the lower Helgeå River catchment, Sweden (Olsson et al. 2004). As wetland goods and services become scarcer, interest in the idea of paying others, such as communities on forested land, to provide ecosystem services on a sustained basis, is also growing (Katoomba Group 2007; Wunder 2007; Horwitz and Finlayson 2011). Worldwide, payment for ecosystem services (PES) is at an early stage, so as would be expected, fewer projects were identified in this recent inventory where money had exchanged hands. In Asia, PES schemes relevant to Ramsar are also growing. The first example is watershed management projects under RUPES (Rewarding the Upland Poor for Environmental Service) in Philippines, Nepal, Indonesia (Swallow et al. 2005). The second case is at a much larger scale, costing 3.65 billion yuan (c. US$ 2.4 billion) between 1999 and 2001. Planned to reduce soil erosion from steep slopes in catchments, the "Grain for Green" programme in China has involved nearly 15 million ha of cropland and 40–60 million rural households (by 2010) (Ushida et al. 2005).

Wetland restoration using ecological engineering is also being implemented in many parts of the world (Alexander and McInnes 2012). Since the wake-up call from hurricane Katrina, good science is also being applied to re-establish ecosystem services and reconnect the Mississippi river to the deltaic plain (Covich et al. 2004). The 'Water for Life' decade ends in 2015. Now is the time to effectively communicate links between wetlands and health to get policymakers to act.

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